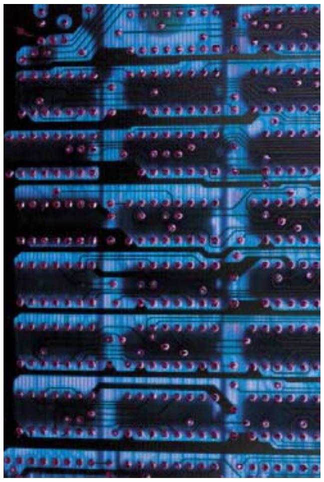

Vertical Integration of Engineering Education

2004 – 2006 Comprehensive Report

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Table of Contents

1. Executive Summary

The Vertical Integration of Engineering Education (VIE) curriculum of two experimental instructional and laboratory classes over a two semester period provided several advantages to the students in experimental classes. There is, however, not enough longitudinal data to demonstrate the impact the VIE curriculum had on student retention, or success in future engineering endeavors. Data collected on the 2004-2005 cohort of 13 students indicated that the students believed they had a better conceptual understanding for the material and better curricular experiences when compared with students in the traditional curriculum. Survey measurements show that VIE students and students in the traditional curriculum had few differences in grades, retention, the laboratory or with interaction among their class, group or instructors.

When asked in a focus group about their experience, the following four themes emerged about their VIE experiences.

- Continuity in the course structure promoted student learning.
- Intense course structure promoted a deep understanding of the material.
- Small class structure promoted accountability, interaction, and flexibility.
- Course structure may promote opportunities after completion of the classes.

One recurring finding was that the students in the experimental VIE classes believed that they had a richer more rewarding experience than they would have had in the traditional curriculum, despite the lack of support for these claims. All qualitative indications about the VIE curriculum show that this is an educationally purposive approach that promotes student growth through greater student engagement, smaller class sizes, clearer communication with the faculty, intense learning, and a tailored curriculum. This has not been supported quantitatively, but this lack of support may be due to a short time period for the study. Only a longitudinal study will determine the longer term impact of the VIE project.

2. Background

During the Fall 2004 and Spring 2005, the Departments of Electrical and Computer Engineering and Mechanical Engineering developed new and reformulated curricula in computer, electrical, and mechanical engineering with the goal of fundamentally changing the way faculty teach and have a greater impact on student learning of material. Essentially the program sought to integrate curriculum, research and teaching, interdisciplinary information, and the community. More specifically, the activities on the planning grant defined a "learning stream" model for this VIE curriculum.

The National Science Foundation funded a planning grant to field test the VIE concepts. During Fall 2004 and Spring 2005, the VIE program curriculum consisted of two courses in the Computer Engineering (CprE) major (CprE 281x and CprE 381x) that were each six-hour courses. The classes served as the initial core courses for the Computer Engineering major and replaced the standard three four-hour courses (CprE 210, CprE 211, and CprE 305) that an engineering student would normally take over three semesters. Project personnel theorized that through an accelerated process students in the VIE curriculum will have a richer experience where they can more readily draw connections among engineering concepts.

Evaluation consisted mainly of comparisons between the standard courses and the experimental courses. Other evaluation activity included qualitative interviewing with the students involved with the VIE curriculum. In Fall 2004, 18 students completed the CprE 281x course while 144 students completed the CprE 210 course. In Spring 2005, 13 students (that were previously enrolled in the CprE 281x course) completed the 381x course and 99 students completed the CprE 211 (64) and CprE 305 (35) courses.

The VIE program curriculum project did not receive additional funding to fully implement the courses in the electrical and mechanical engineering departments and plans were made to cancel the courses in the computer engineering department. The program clearly had an impact on the students in the 2004-2005 cohort, because students requested the curriculum to continue. As a result, 23 students enrolled in a second cohort of the VIE curriculum for the 2005-2006 academic school year.

On the following pages, evaluation questions are explored to demonstrate the results from the curricular assessment study. The report focuses on the 2004-2005 cohort (detailed in sections 4 – 7), but does include one study of the 2005-2006 cohort (section 8).

3. Method

The process for evaluating and assessing the VIE program utilized a mixed methodology that triangulated understanding for how the program impacted student learning. Methods included surveys, group interviews, existing student data, and document analysis. Regular reporting during the project period provided formative feedback to the organizers. This final report provides a more summative report on what happened during the 2004-2005 VIE project period. Further reporting and results occurred with the second VIE class in Fall 2005.

The NSF proposal listed the following five research questions:

- To what extent is student development enhanced by embedding the VIE model of discovery-based learning into the curriculum?
- To what extent are instructors' knowledge and teaching ability enhanced?
- To what extent are faculty better interconnected across departments and programs?
- To what extent are lessons learned from previous learning community experiences transferable to VIE implementation?
- To what extent is research guided by VIE experience?

RISE adapted these questions through the development of an evaluation plan matrix (located on the next page in Table 3.1) that guided the evaluation. Questions from this matrix are used as the major headers for the report on the 2004-2005 cohort in sections 4 – 7 of this report).

Table 3.1: Evaluation Plan Matrix

Research Question from Proposal	Operational Evaluation Questions	Evaluation Strategy/Measures
To what extent is student development enhanced by embedding the VIE model of discovery-based learning into the curriculum?	What differences, if any, can be noted in academic performance of students in the VIE curriculum vs. the traditional curriculum? What attitudes do students in the VIE model hold regarding their experiences? What attitudes do students in the traditional curriculum hold regarding their experiences? What do student reflections from students in the VIE reveal about their learning? What effects does the "community of teams" (grad, undergrad, K-12) have on the learning experience of students in the VIE classes?	- Comparison of quiz and test scores between matched pairs of the experimental group (281x and 381x) and a control group (students in 210, 211, and 305 courses). - Attitudinal surveys of students at key points during the semester. - Plus/Delta formative evaluation - Analysis of stream writings (SWH) - Focus group interviews of students in the VIE classes
To what extent are instructors' knowledge and teaching ability enhanced?	In what ways have VIE instructors adapted or changed their previous teaching approaches? New methods? New content?	- Interviews of instructors - Plus/Delta formative evaluation
To what extent are faculty better interconnected across departments and programs?	How are connections among and between faculty different or the same in the VIE model? How are course structures (assignments, content, etc.) different or the same between the VIE curriculum and the traditional curriculum?	- Interviews of instructors - Focus group/reflective dialogue with research team at end of each semester - Document analysis of course syllabi
To what extent are lessons learned from previous learning community experiences transferable to VIE implementation?	How are the intended outcomes of the learning communities (LC) connected to the experiences of students in the VIE model? Are the outcomes experienced by VIE students similar to those documented for LC students?	- Document analysis of learning community annual reports - Attitudinal surveys of students at key points during the semester - Focus group interviews of students in the VIE classes
To what extent is research guided by VIE experience?	To what extent are lessons from the VIE model applicable to other courses? How have other courses changed or been modified as a result of the VIE implementation?	- Focus group/reflective dialogue with research team at end of each semester - Document analysis of course syllabi

4. Academic Performance

There is very little support for the hypothesis that students involved in the VIE curriculum performed academically better or were retained at a greater rate than their cohort in the CprE courses.

Comparison of course grades

Table 4.1 shows that students in CprE 281x did statistically perform better than their counterparts in CprE 210, however these students did not maintain statistical significantly better or worse grades in Spring 2005 when compared to students in CprE 211 and CprE 305. In addition, semester and cumulative GPAs were reviewed and there were no significant findings.

Table 4.1: Comparison of Average Course GPAs

	281x		210		Mean Cmp 281x-210 [1]	
	avg	n	avg	n	sig?	p
CPRE	3.17	17	2.69	64	**Yes**	**0.026**
EE	3.33	1	2.06	34		
COMSCI			2.96	19		
PCS			1.53	25		
OTHER			3.00	2		
TOTAL	3.18	18	2.38	144	**Yes**	**0.000**

Average Course GPA for Spring '05

	381x		211		Mean Cmp 381x-211 [2]		305		Mean Cmp 381x-305 [3]	
	avg	n	avg	n	sig?	p	avg	n	sig?	p
CPRE	3.15	13	3.16	46	No	0.990	2.75	33	No	0.291
EE			2.98	16			2.00	1		
COMSCI			3.33	2						
TOTAL	3.15	13	3.12	64	No	0.917	2.72	35	No	0.258

Notes:
1 This is a mean comparison, (e.g., t-test) between the 281x course and the 210 course.
2 This is a mean comparison between the 381x course the 211 course.
3 This is a mean comparison between the 381x course the 305 course.Table

Student Retention

Table 4.2 shows that retention as an Iowa State University student, as an Engineering Major, or as a CprE major among the courses was essentially the same.

Table 4.2. Student Retention as ISU Students, Engineering Majors, or CprE Major

Retention to Fall '05

As Student[4]		Retention as Eng Major[5]		Retention as CPrE Major[6]	
Fall '04		Fall '04		Fall '04	
CPrE 210	91%	CPrE 210	75%	CPrE 210	73%
CPrE 281x	95%	CPrE 281x	78%	CPrE 281x	76%
Spring '05		Spring '05		Spring '05	
CPreE211	97%	CPreE211	89%	CPreE211	91%
CPrE305	100%	CPrE305	100%	CPrE305	100%
CPrE381x	100%	CPrE381x	86%	CPrE381x	86%

Notes:
[4] Student retention included all students that either graduated or enrolled in courses in Fall 2005.
[5] Engineering retention includes those students that identified as an engineering major in the semester the course was offered and Fall 2005.

[6] CprE retention includes those students that identified as a CprE major in the semester the course was offered and Fall 2005.

5. Conceptual Understanding and Course Evaluation

What attitudes do VIE students hold regarding their experiences? What attitudes do students in the traditional curriculum hold regarding their experiences?

Conceptual Understanding

Attitudes about skills gained demonstrate that students in the VIE curriculum believe they have greater proficiency with the course concepts. Table 5.1 (on the following page) shows that students in the VIE curriculum significantly improved their understanding, when compared to the control students, on course concepts related to arithmetic circuits and finite state machines, programmable logic devices, computer architecture, and assembly language programming. In the Spring semester VIE students indicated significant gains in basic concepts of microcontrollers/ microprocessors. Spring results are detailed in Table 5.2.

It should be noted that although VIE students indicated greater conceptual gains, these areas included only 5 of the 20 conceptual areas covered in the VIE curriculum or in the three standard courses (CprE 210, 211, and 305). Additionally, the VIE students did not perform academically any better than the control students in the specific CprE classes identified for this studies, generally in their major, or for the semester.

Table 5.1: Conceptual Comparison of VIE students with Traditional Students, Fall 2004

FALL 2004	Control Classes (210, 211, 305)			VIE Classes (281x, 381x)			Group Differences	
	Pre	Post	*p*	Pre	Post	*p*	Pre *p*	Post *p*
Number systems and data representation	2.72	4.17	**0.000**	2.93	4.20	0.008	0.614	0.900
Boolean algebra and logic minimization	2.14	4.31	**0.000**	2.29	4.60	**0.000**	0.732	0.380
Combinational design	1.70	3.81	**0.000**	1.93	4.30	**0.000**	0.544	0.175
Sequential logic design	1.60	3.64	**0.000**	2.00	4.30	**0.000**	0.345	0.081
Arithmetic circuits and finite state machines	1.60	3.63	**0.000**	1.71	4.50	**0.000**	0.747	**0.015**
Programmable logic devices	1.83	3.19	**0.000**	1.71	4.20	**0.000**	0.760	**0.001**
Computer aided schematic capture systems	1.92	3.69	**0.000**	1.93	3.70	**0.003**	0.989	0.991
Simulation tools, and hardware description languages	1.86	3.49	**0.000**	1.86	3.90	**0.000**	0.993	0.171
Design of simple digital systems	1.78	3.50	**0.000**	1.43	3.90	**0.000**	0.274	0.251
Computer organization and design	2.01	3.03	**0.000**	2.00	3.50	**0.000**	0.965	0.114
Computer architecture	2.12	2.80	**0.002**	2.00	3.50	**0.000**	0.681	**0.027**
Assembly language programming	1.75	2.25	0.021	1.71	3.20	**0.001**	0.916	**0.003**
Memory systems	1.71	2.88	**0.000**	1.57	3.40	**0.000**	0.618	0.082

Note: Scale was a 6-point scale where 0 was "unfamiliar" and 6 was "proficient." Significant differences are noted by **bold *p*** values. Significance was calculated using a Bonferroni adjustment at the α = .05 level = .05/13 = .0038.

Table 5.2: Conceptual Comparison of VIE students with Traditional Students, Spring 2005

SPRING 2005	Control Classes (210, 211, 305)			VIE Classes (281x, 381x)			Group Differences	
	Pre	Post	*p*	Pre	Post	*p*	Pre *p*	Post *p*
Microprocessor instruction sets	1.52	3.39	**0.000**	3.77	4.42	0.069	0.000	0.023
Architecture of the Power PC/MIPS processor	1.40	2.97	**0.000**	3.00	3.58	0.009	0.000	0.072
Programming in C and Motorola PPC/MIPS assembly language	2.56	3.97	**0.000**	3.69	4.08	0.139	0.004	0.740
How C is converted to assembly code	1.96	3.58	**0.000**	3.23	4.08	**0.001**	0.004	0.223
Basic concepts of microcontrollers/ microprocessors	1.92	3.19	**0.000**	3.69	4.33	**0.003**	0.000	**0.003**
Basic computing concepts such as interrupts, ISRs, and I/O subsystems	2.04	2.55	0.036	2.75	3.75	**0.014**	0.131	0.013
Basic hardware and software debugging	3.04	3.74	0.055	4.23	4.17	0.169	0.002	0.243

Note: Scale was a 6-point scale where 0 was "unfamiliar" and 6 was "proficient." Significant differences are noted by **bold *p*** values. Significance was calculated using a Bonferroni adjustment at the $\alpha = .05$ level = .05/7 = .007.

Curriculum Course Evaluation

VIE students had higher overall ratings for the curriculum than the students in the traditional courses (CprE 211, 305). Specifically the VIE students believed there was a clear connection between lecture concepts in the current course and previous courses, they understood the course objectives, and felt the course was a foundation for their major. VIE students had a lower rating, although not significant, than the students in the traditional courses for whether they feel the course will benefit them as an engineer.

Table 5.3: Curriculum

2004-2005 Cohort	Control Classes (CprE 211, 305)		VIE Class (CprE 281x)		*Group Differences*
	Mean	St. Dev.	Mean	St. Dev.	*p*
There was a clear connection between concepts in previous CprE classes and this class.	5.00	0.76	3.63	1.01	**0.0006**
There is a clear connection between lecture concepts and lab activities.	3.63	1.01	4.38	1.30	0.2813
The challenge of the course will benefit me in the future as an engineer.	4.38	1.30	3.84	1.30	0.2813
The course objectives were clear to me.	3.84	1.30	5.50	0.53	**0.0022**
This course provided a foundation for my major.	5.00	0.76	3.63	1.01	**0.0006**

Note: Scale was a 6-point scale where 0 was “Completely Disagree” and 6 was “Completely Agree.” Significant differences are noted by **bold *p*** values. Significance was calculated using a Bonferroni adjustment at the α = .05 level = 5/.05 = .01.

For questions regarding laboratory experiences, the VIE students had a significantly higher rating to demonstrate that they believed there was continuity among the lab assignments. There was not a difference in responses concerning whether the labs were relevant to the real world, whether the labs forced student to consider more advanced issues or whether the labs helped with developing a final lab project.

Table 5.4 Laboratory experiences

2004-2005 Cohort	Control Classes (CprE 211, 305)		VIE Class (CprE 281x)		*Group Differences*
	Mean	St. Dev.	Mean	St. Dev.	*p*
There was continuity among the lab assignments.	5.50	0.53	3.98	1.31	**0.0022**
The labs were relevant to the real world.	3.98	1.31	4.38	0.92	0.1595
Lab exercises forced me to consider more advanced issues.	4.38	0.92	3.69	1.29	0.1595
The labs helped me to develop the skills for the final lab project	3.69	1.29	5.13	0.99	0.0167

Note: Scale was a 6-point scale where 0 was "Completely Disagree" and 6 was "Completely Agree." Significant differences are noted by **bold *p*** values. Significance was calculated using a Bonferroni adjustment at the $\alpha = .05$ level = 4/.05 = .0125.

There were no statistical differences between the VIE students and the students in the traditional courses concerning group interaction. It should be noted, however that students in all of the classes agreed that they had group team spirit and had a lot interaction with the faculty members and/or teaching assistants.

Table 5.5: Group interaction

2004-2005 Cohort	Control Classes (CprE 211, 305)		VIE Class (CprE 281x)		*Group Differences*
	Mean	St. Dev.	Mean	St. Dev.	*p*
My experiences emphasized working with others.	3.90	1.34	5.25	0.46	0.0592
I felt team spirit within my group.	5.25	0.46	4.73	0.73	0.0592
I had a lot interaction with the faculty member(s) and/or teaching assistants	4.73	0.73	4.75	0.89	0.4071
I felt accountable to my peers.	4.75	0.89	4.41	1.10	0.4071
I felt accountable to the faculty member(s) and teaching assistants.	4.41	1.10	4.25	0.89	0.6753

Note: Scale was a 6-point scale where 0 was "Completely Disagree" and 6 was "Completely Agree." Significant differences are noted by **bold *p*** values. Significance was calculated using a Bonferroni adjustment at the $\alpha = .05$ level = 5/.05 = .01.

6. Attitudes about the courses

Evaluation questions: What do student reflections from students in the VIE reveal about their learning?

Students in the VIE curriculum were interviewed and findings supported the learning stream goals. The following themes emerged from the responses from the students:

- Continuity in the course structure promoted student learning
- Intense course structure promoted a deep understanding of the material
- Small class structure promoted accountability, interaction, and flexibility
- Course structure may promote opportunities after completion of the classes

Theme 1. Continuity in the course structure promotes student learning

Students believe that their learning experience is enhanced by continuity in the structure of the course. Continuous flow of material and lab projects permitted students to have the knowledge needed to begin spring course material or as one student said they could, "pick right up instead of backtracking." Faculty involvement from the fall to the spring semester provided students with an understanding of teaching methods and expectations as well as an opportunity for a connection with the faculty members. Maintenance of the same students in both the 281x and 381x courses, provides students with connections to other students that promotes opportunities for small group learning. One student commented that in a class of 80 students (e.g., the 210 and 211 courses), they may know five students, but in a class of 15 students they know all the other students.

Laboratory exercises that are cumulative and connected provide opportunities for learning. Cumulative labs over both semesters were described as very "big" and require great understanding for the project. Because they were continuous, one student indicated that he learned more by building a project from start to end, than if the lab exercises were disconnected and unrelated to one another. Another student supported this by indicating the advantage of working at his own pace.

Theme 2. Intense course structure promotes a deep understanding of the material

Because students are enrolled in the course and labs for eight hours per semester, they are deeply immersed in the course material and believe that they have a greater understanding for the concepts. One student indicated that he was able to understand and experiment with the concepts because of the depth of the instruction and labs. Students agreed that they felt the challenge of the course and the heavy requirements for learning this material will benefit them in the future as engineers because they believe they will have better ability to recall the information taught.

Theme 3. Small class structure promotes accountability, interaction, and flexibility

Students believe that the small class structure promotes interaction with other students and faculty. This leads to more accountability to instructors and peers, while allowing flexibility based on unforeseeable developments in learning and instruction. Students have a close connection with the two faculty members and have open communication with them about class expectations. As noted earlier, the students have close interaction with one another, so they feel comfortable asking each other for help. Also, the small class structure, combined with the relationships developed among faculty and students, permit the faculty instruction to be flexible to the learning styles and pace of the students.

Theme 4. Course structure promotes and strengthens opportunities after completion of the classes

Students felt that there will be benefits of the course structure after completion of the academic year because of the connection between the students to other students, students to the faculty, and the intense learning that took place. Students indicated the relationships formed with other students will be beneficial in their senior year when they need additional feedback on their senior projects. Students felt that their candidacy for an internship or job after graduation were strengthened because they knew recommendation letters from faculty would be informed by active involvement with them, and that they were better prepared than their peers in other courses. One exemplary quote that concisely summarizes the theme was that that the course helped them to “know what it means to be an engineer.”

6. Faculty Interaction and Curricula Similarities

Evaluation questions: How are connections among and between faculty different or the same with the VIE curriculum? How are course structures (assignments, content, etc.) different or the same between the VIE curriculum and the traditional curriculum?

The connections among faculty did not change due to the implementation of the VIE curriculum. The VIE curriculum was identified as a field test for the Fall ’04 and Spring ’05 semesters with specific focus on the creation of CprE 281x and 381x courses. With additional funding, the VIE curriculum was going to be applied to courses from other departments (e.g., Mechanical Engineering and Electrical Engineering) with the anticipated affect of encouraging greater connections among and between faculty. Additional funding was not received and learning streams were not fully implemented, which explains why connections among and between the faculty were essentially the same.

The only similarities between the traditional curriculum (210, 211, and 305) and the VIE curriculum (281x and 381x) was the inclusion and application of the same course concepts. The approach to the VIE classes was very different from the traditional curriculum in the following fundamental ways: the size of the class was smaller, the concepts were taught in a different order, there was greater flexibility for faculty to adapt the order of the concepts to meet student needs, students immediately applied the concepts in the laboratory, laboratory work was cumulative, and more work was required of the students given the condensed nature of the class.

The number of students in the VIE classes promoted accountability among the students, accountability of the students to the faculty and graduate assistants, and allowed the faculty to have greater connection to the students. One faculty member believes that students were more accountable to the faculty because, “the teacher recognizes the students who are absent.”

Concepts that were covered in the traditional three course curriculum were reordered in a logical way to promote understanding. Engineering majors from non-CprE programs did not need all three of the traditional curriculum courses so there was not a need to maintain three separate courses. For those CprE majors that take the three traditional courses, they often are not able to fully understand what they have learned until they take CprE 305. The reordering of concepts includes concepts from CprE 305 in the first semester and the second semester to promote understanding.

The faculty were given greater flexibility to adapt the curriculum to the needs of the students. When students had difficulty on a topic, the faculty members adapt the curriculum to ensure the students had the time needed to grasp the concepts before moving on to another topic. Additionally, this flexibility promoted accountability from the class to the teacher and vice versa.

After learning the concepts, students applied them in the laboratory. One faculty member called this a "Learn and Apply" method that allowed students to practice the concepts through application. Additionally, the laboratory assignments were cumulative, or they built on one another and lasted throughout the semester. The laboratory activities in the traditional curriculum are individual assignments that change each week.

The most notable difference between the traditional and VIE curricula was the shortened intense nature of the VIE classes. This cause the students to do more work that also caused the students to place higher value on the courses. The faculty believe the intense nature of the class has deepened learning causing the students to feel more confident about the material.

7. Application of Project to Other Curricula

Evaluation question: To what extent are lessons from the VIE model applicable to other courses?

Some key VIE concepts are applicable to other courses, yet there exists an implementation barrier based on funding. The concepts related to course teaching on problem-based design, maintaining continuity among courses, and a close relationship between lab activities and lecture are excellent models for other courses. Further study should be conducted to determine the feasibility of implementing these concepts in courses.

The learning stream concepts concerning a small student-to-faculty ratio, curricular flexibility, and the involvement of senior/experienced faculty may be expensive to implement and may require additional funding. The College of Engineering received a planning grant to study the VIE model, but did not receive additional support to further implement the VIE concepts. A further feasibility study may be conducted to determine whether these VIE concepts could be implemented without increased support.

In a survey of faculty involved with the implementation of the VIE program, they agreed that smaller class sizes would be difficult to accomplish without additional funding, but believed components of the VIE curriculum could be pursued with the larger class sizes of the traditional (CprE 210, 211, 305) courses. They specifically believed that the traditional courses could be further adapted to present the information in a logical way, which will promote concept understanding. They believed that the courses should allow more flexibility in the presentation of concepts and that classroom learning should be directly applied to projects in the laboratory. One faculty member supported his beliefs when he said, “The 281/381 sequence takes more resources, but not that much.”

8. Fall 2005 VIE - The Project Continues

After notification that additional funding was not received to fully implement the VIE program, plans for continuing the CprE 281/381 sequence were cancelled. Unexpectedly, students made a special request to Dr. Arun Somani, the chair of the electrical and computer engineering department, to continue the VIE program. Subsequently 23 students enrolled in the reopened 281x class that was taught by Dr. Somani. This section of the report details differences between those students enrolled in the CprE 281x class and students enrolled in CprE 210, CprE 211, and CprE 305 based on a survey that was administered at the end of the Fall 2005 semester.

Method and Results

A survey of students in each of the previously mentioned classes was administered at the end of the Fall 2005 semester. The survey considered content knowledge, views of the curriculum, the laboratory experience, and group interaction. All students in the four classes (CprE 210, 211, 281x, and 305) were given an opportunity to complete the survey. Given the size of the CprE 210 course, they were emailed a link to an on-line survey. A researcher visited the other classes and administered the survey in person.

Table 8.1 details that there were a total of 176 respondents. This included acceptable samples of the CprE 210, 211, and 305 classes, and all of the CprE 281x class.

Table 8.1 Respondents

Class	Sample	Population	Response Rate
CprE 210	89	272	33%
CprE 211	26	111	23%
CprE 305	38	95	40%
CprE 281X	23	23	100%
Total	176	501	35%

Content Knowledge

Although students were surveyed in all the standard courses, only the students in the CprE 210 course could be compared to the CprE 281x students because they both started with the same conceptual understanding for the material, which is very little considering they had not started core courses for the computer engineering major. Table 8.2 shows student reported conceptual understanding for the concepts that were covered in CprE 210 and 281x . It should be noted that students in both classes report significant increases in the knowledge areas after completing the course, but there are few significant differences between the classes.

Table 8.2: Conceptual comparison of VIE students with traditional students, Fall 2005

FALL 2005	Control Classes (CprE 210)			VIE Class (CprE 281x)			Class Differences	
	Pre	Post	*p*	Pre	Post	*p*	Pre *p*	Post *p*
Number systems and data representation	3.19	4.33	**0.000**	2.96	4.74	**0.000**	0.474	0.071
Boolean algebra and logic minimization	2.33	4.36	**0.000**	1.87	4.57	**0.000**	0.071	0.534
Combinational design	1.67	3.94	**0.000**	1.35	4.39	**0.000**	0.072	0.011
Sequential logic design	1.58	3.83	**0.000**	1.43	4.26	**0.000**	0.267	0.024
Arithmetic circuits and finite state machines	1.58	3.75	**0.000**	1.23	4.14	**0.000**	0.028	0.004
Programmable logic devices	1.69	3.69	**0.000**	1.18	4.18	**0.000**	**0.002**	0.043
Computer aided schematic capture systems	1.75	4.03	**0.000**	1.35	4.04	**0.000**	0.028	0.571
Simulation tools, and hardware description languages	1.67	4.08	**0.000**	1.22	4.61	**0.000**	0.008	0.004
Design of simple digital systems	1.72	4.03	**0.000**	1.35	4.48	**0.000**	0.042	0.012
Computer organization and design	2.08	3.53	**0.000**	1.59	3.95	**0.000**	0.058	0.009
Computer architecture	2.28	3.31	**0.000**	1.55	3.68	**0.000**	0.011	0.017
Assembly language programming	1.69	2.50	**0.001**	1.22	4.09	**0.000**	0.006	**0.000**
Memory systems	1.75	2.81	**0.000**	1.36	3.45	**0.000**	0.036	**0.001**

Note: Scale was a 6-point scale where 0 was "unfamiliar" and 6 was "proficient." Significant differences are noted by **bold *p*** values. Significance was calculated using a Bonferroni adjustment at the α = .05 level = 13/.05 = .0038.

Curriculum

VIE students had higher overall ratings for the curriculum than the students in the traditional courses (CprE 210, 211, 305). Specifically the VIE students had higher agreement that there was a clear connection between lecture concepts, the course will benefit them as an engineer, they understood the course objectives, and felt the course was a foundation for their major. There was not a significant difference between the control and VIE groups concerning a clear connection between the current course and previous CprE courses; is important to note that many of the students completing the survey were in either CprE 210 or CprE 281x, two foundational courses, which may have been their first computer engineering course.

Table 8.3: Curriculum

Fall 2005	Control Classes (CprE 210, 211, 305)		VIE Class (CprE 281x)		*Group Differences*
	Mean	St. Dev.	Mean	St. Dev.	*p*
There was a clear connection between concepts in previous CprE classes and this class.	4.04	1.29	3.96	1.30	0.7730
There is a clear connection between lecture concepts and lab activities.	4.57	1.28	5.52	0.79	**0.0000**
The challenge of the course will benefit me in the future as an engineer.	4.49	1.33	5.74	0.45	**0.0000**
The course objectives were clear to me.	4.40	1.18	5.43	0.79	**0.0000**
This course provided a foundation for my major.	4.17	1.45	5.61	0.78	**0.0000**

Note: Scale was a 6-point scale where 0 was “Completely Disagree” and 6 was “Completely Agree.” Significant differences are noted by **bold *p*** values. Significance was calculated using a Bonferroni adjustment at the α = .05 level = 5/.05 = .01.

Students in the VIE curriculum felt they had continuity among their lab assignments and that the labs were relevant to the real world. These findings support the design of the VIE courses to show continuity and be relevant to the students.

Table 8.4 Laboratory experiences

Fall 2005	Control Classes (CprE 210, 211, 305)		VIE Class (CprE 281x)		*Group Differences*
	Mean	St. Dev.	Mean	St. Dev.	*p*
There was continuity among the lab assignments.	4.77	1.07	5.39	0.84	**0.0085**
The labs were relevant to the real world.	4.40	1.16	5.09	0.73	**0.0004**
Lab exercises forced me to consider more advanced issues.	4.46	1.18	5.04	0.93	0.0247
The labs helped me to develop the skills for the final lab project	4.68	1.17	5.26	0.75	0.0226

Note: Scale was a 6-point scale where 0 was “Completely Disagree” and 6 was “Completely Agree.” Significant differences are noted by **bold *p*** values. Significance was calculated using a Bonferroni adjustment at the α = .05 level = 4/.05 = .0125.

The survey section concerning group interaction shows overwhelming support for the differences between the VIE course and the standard courses. VIE students feel that the course emphasizes working with others, fosters team spirit, involves students with the faculty, and established accountability among students and faculty.

Table 8.5: Group interaction

Fall 2005	Control Classes (CprE 210, 211, 305)		VIE Class (CprE 281x)		*Group Differences*
	Mean	St. Dev.	Mean	St. Dev.	*p*
My experiences emphasized working with others.	3.26	1.65	5.04	1.22	**0.0000**
I felt team spirit within my group.	3.31	1.58	5.04	1.02	**0.0000**
I had a lot interaction with the faculty member(s) and/or teaching assistants	3.24	1.48	4.73	0.88	**0.0000**
I felt accountable to my peers.	3.57	1.51	5.00	1.21	**0.0000**
I felt accountable to the faculty member(s) and teaching assistants.	3.60	1.48	5.14	0.71	**0.0000**

Note: Scale was a 6-point scale where 0 was "Completely Disagree" and 6 was "Completely Agree." Significant differences are noted by **bold *p*** values. Significance was calculated using a Bonferroni adjustment at the $\alpha = .05$ level = 5/.05 = .01.

Appendix A: Fall 2004 ECE Core Course Curriculum - Pre-Survey

Survey Summary

The survey of students in CprE 210 and 281x served to document student's understanding of concepts covered in both courses at the start of the 2004 Fall Semester. It also is a tool to provide formative feedback to the course instructors about student needs, and to demonstrate the differences between students in the CprE 210 and the 281x courses. Because the VIE project has received sponsorship to implement a new engineering curriculum, this pre-test creates a baseline in which to compare the results from later testing.

There were no differences between students in the CprE 210 and 281x courses on their reported knowledge of course topics. They were asked to assume it was the beginning of the semester and to identify on a six-point scale (1 – unfamiliar, 6 – could teach the topic) their knowledge of course topics such as memory systems and sequential logic. Since there was not a statistical difference between the courses, if there are differences in the post-test, it may be due to the new VIE curriculum. Among both courses, students indicated the greatest understanding of number systems and data representation (2.73 points on a 6-point scale) and the lowest understanding of arithmetic circuits and finite state machines (1.62 points on a 6-point scale).

Students were asked to identify the way that they prefer to learn and ranked "apply concepts in the laboratory" as their most preferred way to learn, followed closely by "lecture from professor." At the bottom of the rankings was "presentation by students," but this had a bi-modal distribution, meaning that it was ranked low by most, but 21 students (20%) ranked this as their number one way to learn in class.

Most students (58%) indicated that they were most interested in "computers in general" when asked about their engineering interests. The fewest students (18%) indicated that they were interested in VLSI design. Students in 281x showed significantly more interest in embedded systems (α=0.022), VLSI design (α=0.008), and computers in general (α=0.010).

There were a series of open-ended questions that asked students why they chose to take the course, what goals they have for the course, how the course will prepare them as engineers, and what additional comments the students wanted to make about the course. Eighty-eight percent of the students in CprE 210 indicated that they are taking the course because it is required. Many students indicated that they were interested in taking the course to understand digital design (17%) or to gain a background in the field (16%).

When asked about goals, about a third of the total students (32%) reported that they wanted to get a good grade.

Method

Web forms were distributed to students in CprE 210 and 281x. Anonymous responses were forwarded to the Research Institute for Studies in Education (RISE) for evaluation. Of 174 possible students enrolled in CprE 210 and 281x, 105 (60%) completed the web form. This included 90 (58%) of the 156 students enrolled in CprE 210 and 15 (79%) of the 19 students enrolled in CprE 281x.

Results

1. Answer as if it were the beginning of the semester. Select the boxes that best describes your knowledge of… (1=Unfamiliar, 2=Basic Understanding, 3=Understand and Experiment, 4=Apply Concepts, 5=Proficient, 6=Could Teach This)

	mean (s.d., number)
Number systems and data representation	2.73 (1.24, 105)
Boolean algebra and logic minimization	2.14 (1.27, 105)
Combinational design	1.71 (1.16, 104)
Sequential logic design	1.67 (1.16, 105)
Arithmetic circuits and finite state machines	1.62 (1.05, 104)
Programmable logic devices	1.78 (1.13, 104)
Computer aided schematic capture systems	1.94 (1.17, 103)
Simulation tools, and hardware description language	1.89 (1.16, 105)
Design of simple digital systems	1.69 (1.07, 104)
Computer organization and design	2.06 (1.10, 105)
Computer architecture	2.11 (1.14, 105)
Assembly language programming	1.71 (1.13, 105)
Memory systems	1.70 (1.02, 105)

Comparison of 210 and 281x courses on the first question.

	Course 210 (avg, sd, n)	Course 281x (avg, sd, n)	Alpha level α (significance)
Number systems and data representation	2.67 (1.21, 89)	3.00 (1.41, 15)	0.35 (No)
Boolean algebra and logic minimization	2.09 (1.22, 89)	2.27 (1.44, 15)	0.64 (No)
Combinational design	1.66 (1.14, 88)	1.93 (1.28, 15)	0.40 (No)
Sequential logic design	1.61 (1.10, 89)	1.93 (1.44, 15)	0.31 (No)
Arithmetic circuits and finite state machines	1.61 (1.03, 88)	1.67 (1.23, 15)	0.86 (No)
Programmable logic devices	1.80 (1.13, 88)	1.67 (1.23, 15)	0.69 (No)
Computer aided schematic capture systems	1.94 (1.14, 87)	1.87 (1.41, 15)	0.82 (No)
Simulation tools, and hardware description language	1.88 (1.15, 89)	1.87 (1.25, 15)	0.98 (No)
Design of simple digital systems	1.74 (1.08, 88)	1.40 (1.06, 15)	0.26 (No)
Computer organization and design	2.03 (1.13, 89)	2.13 (0.92, 15)	0.75 (No)
Computer architecture	2.13 (1.17, 89)	1.93 (0.96, 15)	0.53 (No)
Assembly language programming	1.72 (1.13, 89)	1.67 (1.23, 15)	0.87 (No)
Memory systems	1.73 (1.04, 89)	1.53 (0.92, 15)	0.49 (No)

There were no significant differences in the means between the two courses using a one-way analysis of variance. There also were no significant results in Chi-Square frequency comparisons.

2. Rank the following learning activities in the order that you prefer to learn. (1-highest, 6-lowest)

Rank		1 (n)	2 (n)	3 (n)	4 (n)	5 (n)	6 (n)	Total (n)
1	D. Applying concepts in laboratory	26	18	22	18	9	7	100
2	B. Lecture from Professor	26	20	18	14	14	9	101
3	C. Cooperative group work	9	27	19	21	18	4	98
4	E. Discussion of concepts with classmates	7	17	20	27	25	5	101
5	A. Reading the textbook	13	12	17	11	24	21	98
6	F. Presentation by students	21	7	6	11	11	51	107

7. What are your interests? (Select all that apply).

Rank	I am interested in …	Course 210 % (n)	Course 281x % (n)	Total % (n)
1	… computer in general	58% (53)	93% (14)	64% (67)
2	… computer network design	49% (44)	53% (8)	50% (52)
2	… security	49% (44)	53% (8)	50% (52)
2	… software systems	52% (47)	33% (5)	50% (52)
5	… general electrical engineering	33% (30)	33% (5)	33% (35)
6	… embedded systems	24% (22)	53% (8)	29% (30)
7	… VLSI design	18% (15)	47% (7)	21% (22)

Following were significant differences identified in the means between CprE 210 and 281s using an one-way ANOVA (Analysis of Variance).

Embedded systems: Sig. = 0.022*, (281x students showed more interest)
VLSI design: Sig. = 0.008**, (281x students showed more interest)
Computer in general: Sig. = 0.010**, (281x students showed more interest)

3. Why did you choose to take this course? (open-ended question). (The following represent themes among the responses).

	Course 210 % (n)	Course 281x % (n)	Total % (n)
The course is required	88% (79)	-	75% (79)
I have interest or motivation	18% (16)	33% (5)	19% (21)
Interesting course design	2% (2)	53% (8)	10.0% (10)
Advised to by my advisor	-	7% (1)	1.0% (1)
More practical	-	7% (1)	1.0% (1)
281x to late announced	2% (2)	-	2.0% (2)
281x no time/don't fit schedule	2% (2)	-	2.0% (2)

The following are all of the open-ended responses for CprE 210 except for those who responded with a response like “because it was required.”

Course 210
Required course but I am also interested
Required Course for my major and seemed interesting
Because it is required for my major, but it also sounded fairly interesting.
Required - but I do find it useful.
It was required of my major. Assumed it would help me in my future classes
It was required but also a good idea to have a basic understanding of these concepts.
It was a required class to take and I enjoy dealing with computers.
It is one of the core classes that I am required to take for computer engineering, plus I was interested in learning various concepts about computer systems and other computer related topics
It is interesting and I need it for my Major which is Computer Science
It's part of my curriculum. But, mostly I was really interested in learning the subject.
Interest in computers, requirement for ECPE major
Interest/Motivation
Because I like computer so much and would like to know how people actually made them.
Understand how basic computer design is done.
I thought it would help me to become a better engineer
have an interest in the field and it's applications to the field of supercomputing
I chose to take this class to gain a better understanding of logic and computer systems.
I have worked with Logic systems as an intern during two summers so it is very appealing to me.
Course design
281X was 6 credits and combined with the other courses I am currently taking, I would have 18 credits of tech.
I didn't if I wanted to take further Computer Science classes.
Announcing 281x too late
It is a required class. Announcing a new class three weeks before the being of the semester is just stupid.
It was required. The department did not notify me of 281x early enough for me to seriously consider taking it.
No time for 281x
Required Course and the experimental one didn't fit my schedule
It is required for my CprE majors and I didn't think I’d have time for the new experimental class

All the open-ended responses for CprE 281x
A fellow classmate told me that Cpre 210 moves really slow and I wanted a faster learning environment.
Because it was a new class, and it gave me the opportunity to open up my schedule more for other classes later on. Also because the student to teacher ratio was much smaller than the alternative.
Completed many goals at once.
I choose this course because I thought it would be a good opportunity to experience a different type of class structure. I thought it would be more of working in groups with a professor to understand concepts rather then listening to a professor talk.
I wanted to accelerate my four year plan. I also thought it would be better to be in a class with only 19 other students.
I wanted to get more classes out of the way faster. And I thought the teacher to student ratio would be beneficial.
I wanted to partake in something that was specialized in computer engineering, in hopes to learn something better, more efficiently, than otherwise through the curriculum.
I was interested in a smaller class size and accelerated curriculum.
I chose to take this class because of an interest in computer hardware and how circuits function.
It looked interesting, and it was an accelerated course
It sounded interesting and a good way to learn the class in a smaller group setting
more hands on
My major is electrical engineering, but I want to have as diverse a background as possible. Courses in materials, computer and electrical engineering are all very interesting to me.
One of the CprE advisors thought it would be a great opportunity for me.

4. What goals do you have for this course? This is an open-ended question where more than one answer was possible.

	Course 210 % (n)	Course 281x % (n)	Total % (n)
Get a good grade	34% (31)	13% (2)	32% (34)
Learn about circuits	16% (14)	13% (2)	15% (16)
Understand everything	16% (14)	7% (1)	14% (15)
Foundation for further courses	8% (7)	27% (4)	11% (12)
Learn about digital design	13% (12)	-	11% (12)
Gain a basic understanding of computers	9% (8)	27% (4)	10% (11)
Pass exams	9% (8)	-	9% (9)
Learn as much as possible	4% (4)	20.0% (3)	8% (8)
Learn about hardware	7% (6)	7% (1)	7% (7)
Learn about programming	5% (5)	-	5% (5)
Learn about basic logic	2% (2)	-	2% (2)
Get ahead of my peers	-	7% (1)	1% (1)

5. How will this course prepare you as an engineer? (open-ended question, more than one answer possible)

	Course 210 % (n)	Course 281x % (n)	Total % (n)
Understand digital design	19% (17)	7.1% (1)	17% (18)
Basic knowledge of the field	12% (13)	28.8% (4)	16% (17)
Understand computer in general	12% (11)	28.8% (4)	14% (15)
Problem solving skills/ understand logic	10% (9)	14.3% (2)	10% (11)
Understand circuits	8% (7)	7.1% (1)	8% (8)
Laboratory prepares for real world	7% (6)	14.3% (2)	8% (8)
Preparation for further courses	5% (5)	-	5% (5)
Understand hardware	5% (5)	-	4% (5)
Don’t know	4% (4)	-	4% (4)
Learn nothing	3% (3)	-	3% (3)
Learning teamwork	-	7.1% (1)	1.0% (1)
I do not plan to be an engineer	11% (10)	-	10% (10)

6. What additional topics would you like to learn about in this course? (open question, more than one answer possible)

210 – Open-Ended responses

Additional Topics that CprE 210 students would like to learn about.
a more complete discussion of the actual hardware and tools used (FPGA's, etc.)
assembly programming. applicable repair skills would be nice although this may not be the right class to teach that in.
Assembly would be neat.
Assembly would be pretty sweet - is that a part of the class to come?
Future methods of digital design.
How computers can interpret light as a form of code. Although engineers haven't yet made a marketable computer that can do this, it would be interesting to see how one might start.
how the net working is related to this digital world.
I wish they wouldn’t assume that we had prior knowledge of circuits. the most I knew was what a capacitor was, and had no idea how a circuit board was set up/run
I would learn more about IC chips.
I would like to learn more about PLC control type systems as I have worked with and the ladder logic programming that the company I worked for uses to run these large PLC cabinets.
I would like to learn more verilog.
memory modules and applications(in depth)
Networking systems.
program more in VHDL
real world design of computer hardware.
Some detail about how digital design is applied in real industries.
some more of computer architecture/design
Storage elements, encoders/decoders, more about Verilog
The design and working of computer components that we use everyday.
What I think would be interesting is if they actually made a class where we made our own circuit and got to program it with what we wanted it to do. so maybe something like that
Would like to have more exposure to the materials covered in lab, such as the operation of software design tools

281x – Open-Ended responses

Additional Topics that CprE 281x students would like to learn about.
Do hands on building of processors and hardware devices
Embedded chips and discussion on main boards for computers. I would also like to understand the various devices that are located on a main board of a computer.
I would like to learn about some more theoretical designs that are skimmed over.
Integration of software and hardware
More history of how computers came to be.
More on circuits.
More on hardware, but not completely sure of everything we're learning.
Optical processing!

8. What additional comments do you have regarding this course? (open-ended question with more than one possible answer)

	Course 210 % (n)	Course 281x % (n)	Total % (n)
Good course/good professors	16% (14)	40% (6)	19% (20)
Critical comments	21% (19)	27% (4)	22% (23)

Select additional comments from CprE 210 Students
Boolean algebra is far more interesting than hardware to me. I suppose that's why I'm Com S rather than CprE.
Course really good. The professors should understand that what they can think of in a few seconds will take me a lot longer. I only begun to understand this material and they have been studying it for many years. More reasonable tests by length.
I am still uncertain as to which specific area I would like to go into within computer engineering so I would like to learn a variety of topics so I may be able to determine which I like or dislike
It's a good course so far, except the tests are way too long
Make the tests easier.
Maybe give more examples in the lecture and lower the speed of the class just a little bit. Also, the test should only cover the material that we have been t4aught.
more correlation between lecture and lab. does not explain how to write verilog at all and expects us to use verilog to complete labs that have increasing difficulty and complexity
more lecture cover over topics presented. some lectures only give few minutes over detailed topics thus giving very little explanation for the topic
more time on recitation so we can do more exercise
Need to stop being taught it is so basic it hurts at times
needs a higher English standard for TA's and Professor
Nothing in this class is group oriented - Which means all thinking and algorithm development is our own, but in the same sense, we are being limited to our own thinking - I'd like to see a middle ground.
Recitation is too far away (Industrial Ed.)
Sometimes Dr. Chu is difficult to understand.
The grading may be slightly too harsh for the level of the course.
the lectures seem to go extensively over some things that may not need that much time then the homework seems difficult in comparison.677
the test was too long for the amount of time given to work on it
this class is too fast paced, but obviously needed for my major (relevant)
Unfair for students that Chu is a lot harder. Better 3 courses than students learn more and achieve better, not all essential material covered. Majority of students take this class as 3in1bargain deal (only to get a lot of credits)
What is difficult about this course is that you get a lot of information dumped on you each day and if you are new to the information it is sometimes hard to grasp and understand by the time the test time comes around. We should have more lecture then two days a week but not for two hours
I like it so far. The faculty to student ratio is awesome. One question: We do everything in pairs (homework, labs), why not tests?
It is hard to sit through a class that is 2 hours long and pay as much attention as I would like to.

Appendix B: Fall 2004 ECE Course Curriculum Plus/Delta

Survey Summary

On November 10, 2004 a Plus Delta (+/Δ) exercise was conducted with the CprE 281x class to provide formative feedback to the class instructors and to determine whether changes need to occur in the experimental course. Overall the students feel the laboratory exercises have contributed most to their learning, but are concerned about the length of the two-hour lectures.

During the facilitated +/Δ exercise, students felt the activities that are going well included the labs (n=13), the lab partners (n=8), and the teaching assistants (n=5). Activities that they felt should be changed included the length of a two hour lecture (n=11), the amount of preparation needed for homework (n=7), instructions for labs (n=6), and the schedule for labs (n=6). (Complete results follow in subsequent sections).

During the written +/Δ exercise, students indicated positive experiences mostly in regards to labs including the use of lab partners, and the application of the class material to the labs. Class activities that they felt should change include shortening the length of the class (n=13), clarifying the homework assignments (n=6), releasing the requirement to complete homework with a partner (n=5), making lab times more flexible (n=5), and better coordination among the professors (n=5).

Students indicated that the purpose of the class was to learn about digital logic (n=5 of 14), to improve on the CprE 210, 211, 305 series of classes (n=3), or to learn about computer design (n=2). Respondents demonstrated that they understood both the purpose of class according to the class description, or the purpose of the class as an experimental curriculum.

There was not a consensus on what was the most important concept learned so far. Students reported responses such as, “the application of Boolean logic to circuits/networks” and the use of “binary to express everything.”

The most challenging activity in the class was laboratory (n=4 of 14), homework (n=3) or learning new material (n=2). One student indicated that the most challenging activity in the class was “learning the new material and applying it in labs.”

The most rewarding activity in the class was laboratory exercises (n=5 of 13). Four students also reported rewarding activities that appeared to be lab related including the student who wrote, (the most rewarding activity was) “the day I realized I was able to talk to a computer in basically just 1s and 0s.”

The most surprising thing about the class was the depth or detail of the class material (n=3 of 9). One student wrote that they were surprised by “the amount of detail involved with chip design & logic.”

The most common response to what students wish the class had done was to better line up the labs with the class material and the homework (n=4 of 8). One student wrote that they wish the class would discuss “the material more before lab rather than after.”

Most students (n=4 of 12) understand the class material best when the classroom concepts are applied in the lab. One student wrote that they learn it best when they attend a lecture, “perform an immediate lab over it, and have (a) homework assignment right after the lab all on the same topic.

Students did not agree on what they need (n = 7). Two wrote that they need “a holiday” while others wrote comments like “more explanation” or to understand the concepts more.”

When given the opportunity to say anything, students indicated that they enjoy the class (n=2 of 6), while others indicated the class was complicated because of the amount of information and the volume of material taught in a two-hour lecture (n=2).

Method

A +/Δ exercise serves to provide rudimentary diagnostics on the class to determine what is going well and what needs to be changed. It is a free-form exercise that allows students to write and/or engage in a conversation about classroom activities. A classic +/Δ exercise has two parallel columns with a + at the top of the column for those activities that are going well, and Δ at the top of the column where students write about activities that need to be changed. The exercise completed for the 281x included the classic +/Δ exercise as well as a series of nine fill-in-the-blank open-ended sentences.

Students were grouped by their lab partners and asked to first complete the nine open-ended questions. They were then instructed to complete a classic +/Δ exercise on the backside of the page. After the first two exercises, a facilitated +/Δ conversation took place with the RISE researchers.

Facilitated +/Δ Conversation

+ (things to encourage)	n	Δ (things to change)	n
Lab in general	13	Two hour lecture too long	11
Lab partners	8	Homework preparation	7
TA's	5	Lab instructions	6
One day without class	4	Lab schedule	6
Pace of the class	2	Homework with a partner	5
Tests	2	Coordination between professors	5
		Too much information in one lecture	4
		Classroom participation	3
		More visual examples	2
		More sample test/problems	2
		Tests without partner	1
		More integrated lecture	1
		Spread lectures out	1
		New mice in computer lab	1

Written +/Δ Exercise

Students were asked to discuss those class related activities that have been positive experiences (+) and those that need to be changed (Δ).

+ (Things to encourage)	n
Lab partners	4
No class on Friday	3
Chen	3
Working with partners	3
Lab with a partner is a good thing	2
Having two labs.	2
Labs	2
2 Person labs are good	1
Labs in groups	1
Lab activities	1
Lab exercises - application pace	1
Lab go along with material very well, I do the most learning there.	1
Lab helps us learn the topic and remember (very important)	1
Lab is going well to help learn the material	1
Lab is where we learn	1
Lab work	1
Labs work well to commit what we have learned and learn more.	1
The detail and application in the lab	1
No class on one day	1
Fast pace	1
Pace of the class	1
TAs are helpful	1
The multiple TAs are very helpful.	1
Test fairness	1
Tests	1
Group work	1
Partners	1

Δ (Things to change)	n
Don't require homework with a partner	1
Having a homework partner does not always work	1
Homework can be done by self	1
Individual homework assignments	1
Partner homework	1
Evening lab is hard to be motivated	1
More flexible lab times	2
More flexible lab times (had to drop two clubs and miss out on intramurals)	1
No Thursday night lab (too many exams on Thursday)	1
Tuesday /Thursday lab has a lot of conflicts with other class exams, club meetings, campus events	1
2 different professors teaching more integrated	1
Have professors coordinate with each other (know what the other has taught).	1
Having two different professors is a little confusing	1
More coordination between professors	1
Professors more coordinated know what the other has covert	1
2 hour class is hard	1
2 hour lecture at once 3 x 1.5 hour lectures	1
2 hour lecture make it hard to concentrate on heavy material the whole time	1
Break up 2 hour lecture	1
Class for two hours is hard to stay focus	1
It would be better to have more shorter lectures	1
Shorter class times by 15-30 minutes or have a 3rd class with all 1 hr, if 2 hours long, nice break	1
Shorter lecture time	1
Shorter lectures	2
Two hour lectures are tough to sit through	1
Better lab instructions	2
Discussing lab after lab	1
Discussing lab after the fact	1
Material in lab covered in class better, TA are getting asked a lot of questions (this is important)	1
Material in labs should be covered better, TA's are getting a lot of questions (this is important though)	1
More visual presentation	1
Need more visual examples in class (to help explain how to do some concepts)	1
Go over homework material	1
Go over homework material before assigning homework	1

Δ (Things to change)	n
Homework clarification & relevance	1
Homework needs to be more clear and with lecture on same schedule	1
Homework relevant to lectures and clarification	1
Homework should be relevant to lecture/labs, covered and clarified before posting	1
Organize homework so it is more of what we learn in class	1
Amount of information per hour of class	2
One topic at a time	1
Too much information too fast	1
Classroom participation	1
More classroom participation	1
More classroom participation, specific questions to be answered by us (Dr. Tyagi more so than Dr. Somani)	1
More sample tests/problem	1
Need sample tests or practice problems	1
Everything else is partner, why not tests?	1
More integrated lectures	1
New mice in computer lab	1
Spread lectures out: MTRF maybe	1

Written Fill-In-the-Blank Responses

1. The purpose of this class is … (Total n=14)

Response	n
CPR E 210, 211, 305	1
to get rid of an overlap in the 3 classes	1
to make the classes 210, 211, and 305 flow more completely and to connect the contents more efficiently	1
to learn	1
to learn more about computer engineering	1
educate me about the principles of computer hardware, digital logic and how hardware and software relate	1
learn about computer architecture and digital design	1
learn software and hardware integration	1
learn the basic of computer design	1
to introduce us to digital logic, systems	1
to learn about digital logic & chip design at very accelerated pace	1
to learn about how a computer works and what goes on inside the machine and how to design the different parts and the machine code for it	1
to learn about logic and assembly programming	1
to learn circuit design, the coding, and background that goes along with it	1

2. The most important concept I have learned so far is … (Total n=14)

Response	n
circuitry design and implementation	1
designing logic circuits	1
digital logic, transistor logic, counters, flipflops, MIPS, PC	1
everything can be done with gates and binary	1
how computers work down to the transistor level	1
how integrated systems work	1
how to design something with different gates, to output what I want it to, given certain inputs	1
implementing digital logic	1
MIPS assembly	2
programming in assembly to see how the computer actually controls its internal structures	1
software/hardware interface	1
the application of Boolean logic to circuits/networks	1
the use of binary to express everything	1

3. The most challenging activity in this class was … (Total n=14)

Response	n
Learning	1
trying to understand the concepts and logic of making things work	1
learning the new material and applying it in labs days in a row	1
lab	2
doing the homework when the lectures aren't caught up to the same point	1
homework over uncovered material	1
some of the homework and labs	1
flipflops	1
learning new programming language	1
organizing thoughts into assembly code and data locations	1
the ILLA adder	1
the labs where we had to build devices to manipulate a lot of data (16,32,64 bit)	1
working a recursive program in MIPS assembly, despite having functional C-Code and the output gates	1

4. The most rewarding activity in this class was … (Total n=13)

Response	n
lab	3
the labs and understanding how everything works	1
the labs, working with lab partner	1
A few of the most rewarding activities have included designing a 32-bit ALU, an LCP decoder, and more rewards a bit shifter.	1
completing any of the labs, especially early	1
creating an actual adder program we could control via switches	1
designing hardware like the register file and ALU	1
designing the circuits in MaxPlus 2 + implementing that onto the circuit boards	1
lab using gates, not Verilog	1
learning how to connect binary to hex, decimal etc.	1
the day I realized I was able to talk to a computer in basically just in I's + O's	1

5. The most surprising thing about this class was … (Total n=9)

Response	n
how in depth we go for just being a 200 class	1
how much information there was	1
two doctors teaching a group of 20 sophomores	1
no quizzes, 1 homework a week	1
how difficult problems usually make sample measures, once a concept or relationship is realized	1
how easily the concepts seem to flow together and make sense	1
programming in C, MIPS, PC	1
the amount of detail involved with chip design & logic	1
we get hands on experiences	1

6. What I wish we would have done is … (Total n=8)

Response	n
discussing the material more before lab rather than after	1
do homework exercises in class instead of lectures all the time	1
kept the lectures more in pace with the homework and had slightly shorter class times. 2 hours is too long, maybe an hour and a half	1
learn more about why these are done, for each lab, why it does what it does	1
make this less than an 8 hour a week class	1
used a simulation program like electronic workbench to better understand gates and Boolean algebra	1
build circuitry	1
Learn more about computer architecture and how things go together. What is the hardware used to connect and synchronize pieces?	1

7. I understand the class material best when we … (Total n=12)

Response	n
Apply it in Lab	4
go over it again in lab	1
do hands on learning lab work	1
I work with it hands on	1
get lectured on it, perform a immediate lab over it, and have homework assignment right after the lab all on the same topic	1
it is folded in to lectures and it is explained well	1
go over it first	1
have visuals, and take time, interact	1
see diagrams	1

8. What I need now is … (Total n=7)

Response	n
a holiday	2
more clarity on homework materials	1
more classes like this with a great teacher/student ratio	1
more explanation of things	1
sample tests + sample problems for the test	1
understanding the concepts more	1

9. Something I would like to say is … (Total n=6)

Response	n
I enjoy this class	1
I enjoy this class and look forward to next semester.	1
the pace is pretty hardcore, but why do the tests cover not much	1
the tests don't reflect very well on the class	1
this class has a lot of information in it and sometimes its hard to retain it all in a 2 hour period	1
I'm proud to be an American	1

Appendix C: Spring 2005 VIE Focus Group and Plus/Delta Exercise

Executive Summary

Students in CprE 381x participated in a focus group and a Plus/Delta written exercise where they provided feedback on course experiences. Overall the students feel the program promotes student-to-student interaction, faculty-to-student interaction, continuity of class material, and encourages a deep understanding of the course concepts. All students involved in the evaluation exercise would take the sequence of courses again if given the opportunity. Despite student support of the program, they believe that the course structure may not be suitable for all students because it is intense and time-consuming. The following sections contain a description of the method, analysis of the themes presented in the focus groups, course advocacy, formative suggestions for course changes, and the results of the Plus/Delta survey exercise.

Method

The Research Institute for Studies in Education (RISE) conducted two focus groups with those students who attended class on 2/10/2005 by splitting them into two groups of 5 students. A series of 10 questions were asked about the course, their experiences, and how they would change the course. The focus group script is included at the end of this report. Each focus group was conducted by a RISE evaluator and was accompanied by a note taker, who took written notes during the session. After a 45-minute focus group, students were asked to complete a Plus/Delta form that asked about what course concepts they would encourage or change, and their personal study activities they would encourage or change.

Themes

This report is summarized into prominent themes that emerged through the analysis of focus group notes. A theme is included if it was identified in both classes. Themes are presented in order of meaning to the students and frequency of mention in both focus groups.

Theme 1. Continuity in the course structure promotes student learning

Students believe that their learning experience is enhanced by continuity in the structure of the course. Continuous flow of material and lab projects permitted students to have the knowledge needed to begin spring course material or as one student said they could, "pick right up instead of backtracking." Faculty involvement from the fall to the spring semester provided students with an understanding of teaching methods and expectations as well as an opportunity for a connection with the faculty members. Maintenance of the same students in both the 281x and 381x courses, provides students with connections to other students that promotes opportunities for small group learning. One student commented that in a class of 80 students (e.g., the 210 and 211 courses), they may know five students, but in a class of 15 students they know all the other students.

Laboratory exercises that are cumulative and connected provide opportunities for learning. Cumulative labs over both semesters were described as very "big" and require great understanding for the project. Because they were continuous, one student indicated that he learned more by building a project from start to end, than if the lab exercises were disconnected and unrelated to one another. Another student supported this by indicating the advantage of working at his own pace.

Theme 2. Intense course structure promotes a deep understanding of the material

Because students are enrolled in the course and labs for eight hours per semester, they are deeply immersed in the course material and believe that they have a greater understanding for the concepts. One student indicated that he was able to understand and experiment with the concepts because of the depth of the instruction and labs. Students agreed that they felt the challenge of the course and the heavy requirements for learning this material will benefit them in the future as engineers because they believe they will have better ability to recall the information taught.

Theme 3. Small class structure promotes accountability, interaction, and flexibility

Students believe that the small class structure promotes interaction with other students and faculty. This leads to more accountability to instructors and peers, while allowing flexibility based on unforeseeable developments in learning and instruction. Students have a close connection with the two faculty members and have open communication with them about class expectations. As noted earlier, the students have close interaction with one another, so they feel comfortable asking each other for help. Also, the small class structure, combined with the relationships developed among faculty and students, permit the faculty instruction to be flexible to the learning styles and pace of the students.

Theme 4. Course structure promotes and strengthens opportunities after completion of the classes

Students felt that there will be benefits of the course structure after completion of the academic year because of the connection between the students to other students, students to the faculty, and the intense learning that took place. Students indicated the relationships formed with other students will be beneficial in their senior year when they need additional feedback on their senior projects. Students felt that their candidacy for an internship or job after graduation were strengthened because they knew recommendation letters from faculty would be informed by active involvement with them, and that they were better prepared than their peers in other courses. One exemplary quote that concisely summarizes the theme was that that the course helped them to “know what it means to be an engineer.”

Course Advocacy and Suggestions for Future

When asked if they would take the course again if given the opportunity, students unanimously said that they would because it was a special opportunity that gave great benefits to learn foundational course material. A common response was that they were, “glad I took it, (and I am) not disappointed” and the course has helped me to “know the meaning of hard work.” Some students enjoyed the fast pace of the learning, while others liked the ability to complete the required courses in one year while satisfying 16 credits in two semesters.

When asked if they would recommend it for others they were not sure whether the course could be replicated for all students, and felt that the requirements of the course may be too intense for all students in the CprE program. It is not a course for students who carry 17 or 18 credits, because the course takes a lot of time. Although they admit that the small class atmosphere is a wonderful experience, they are concerned that it is not replicable. They were not sure whether the growth of the program, through similar types of small classes, would provide the same type of experience that they are having with two prominent faculty members in the department, including the department chair.

Student Suggestions for Change

Several suggestions for change were forwarded from students in each of the focus groups. They are summarized here with support from the conversations the group had about the suggestions.

Consistent with the results found in the plus/delta exercise in the fall semester, students feel that the two-hour lecture is too long. The faculty instructors should consider cutting down the time for lectures to one hour and twenty minutes.

The schedule for the course should be arranged in the semester previous to the semester of the course. By waiting to schedule the course, the lecture times were not favorable for students. Students indicated that they were dedicated to the course, and that they would schedule their other courses after scheduling the 281x/381x course.

Students would like practice exams before administration of the graded exam. They were concerned that some of the questions were unsolvable on the exams, and they were told to study only 1/3 of the information that was on the test.

Students in both focus groups indicated that they would like greater access to the laboratory space. One student suggested a novel idea, which was to provide lab hours in place of office hours. He indicated that he was not concerned about the class material or homework, but would like more assistance with the labs.
In regards to the labs, one student suggested that a class lecture be placed between the labs. This will provide the opportunity for students to ask questions to the faculty instructors about the lab activities. To assist with learning this material, the department may consider adding this course to the supplemental instruction (SI) program.

The 281x/381x sequence is intense, and time consuming. Students suggest that when planning this for the future, that students avoid taking Computer Science 228, and Physics 222 at the same time as the 281x/381x courses.

Students suggested that they give progress reports on lab progress, because each team works at a different pace. This creates another mechanism for communication of progress and provides an opportunity for students to help each other with the lab projects.

Plus/Delta Results

The following results are the student responses from the Plus/Delta survey administered after the focus group. The student feedback generally supports the results summarized from the focus group.

1. In terms of helping you learn- what's working in the course/with the instructor?

ID	Response
101	small class, instructor actually knows the material, lot of lab work, lab work ties in with lecture
102	good teaching style, instructor knows what he's talking about
103	Talking about the labs - everyday; before during and after projects to keep us on task and to help us with problems.
104	The instructor's personality with the students and passion about teaching allows up to get a better understanding of the material. The amount of info learned is good.
105	I like the practical examples given in class. i.e. One time we learned about the current state of embedded systems, another time we saw how marketing plays a role in design.
106	It is great getting the focus of our two professors and TA's so they can help us with our problems when we need it. They really tailor to our needs.
107	Good teaching philosophy works well with the pace of class and material type.
108	Labs are good sources of learning.
109	Labs more personal time to ask questions with professor and other students.
110	Lectures are very good. The smaller class size allows more attention to each student.

2. What aspects of the course/instructor need to be changed?

ID	Response
101	8:00am - not working
102	Sometimes unsure what is asked. Review assignment questions and test questions more before assigning, then to make sure they actually make sense and nothing contradictory is asked or emerges.
103	The homework being related to labs is helpful, but requiring design of components too early before really ready to make them is not helpful, since designs seem to need redoing during implementation of work, make practice tests.
104	The need for practice exams to be presented and tests to be proofed before they are given, the labs to be thoroughly completed ahead of time. The instructors could be more open to office hours. No 8 am lectures for technical courses, no 2 hour lectures, 3- 1.5 hour lectures good. Split up the labs between lectures.
105	(We need) more reading assignments, (and) more relations to the real world. Maybe include what businesses are doing in the fields we are learning about.
106	When finishing a project, I would like to see an ideal working project to compare my own with.
107	
108	A little more structure in the support department.
109	Just better scheduling times, but it's a first time class so I understand. Instead of office hours, maybe "lab hours' on Saturday or something
110	Need a little more organization and structure. I realize this is the first trial for this course.

3. In terms of helping you learn - what are you doing as a student that's working?

ID	Response
101	Working on labs and project on my own time.
102	Going to class, completing labs.
103	Making time coordinate with my partner; many specifics of time to say "I will be here at X time ready to work." (though we need this more)… It is helping me that I've committed to class attendance despite time/sleep needs.
104	Spending countless hours in the lab allows me to learn the material better as well as seeking clarification with the lab TA's to give us instant on what's to be learned.
105	Labs.
106	Working with other students.
107	Focusing very heavily on this course and spending the required time out of class on labs.
108	Putting in extra hours of lab work.
109	Working closely with other students and professor.
110	Spending a lot of time in the labs making sure I got things right. Working with a partner and other groups for help and advice.

4. What are you doing as a student that needs changing?

ID	Response
101	Nothing
102	Could possibly read the text material.
103	I need to put more time specifically into my group's lab times and to spend more time reading/reviewing material.
104	Preparation for tests need to change as well as a general attitude towards the course work ahead of me.
105	More reading from text, better understanding of verilog.
106	More reading from the text.
107	Make more time for homework.
108	Ask for help more often.
109	Not procrastinate homework and other classes. Delegate time more effectively.
110	Probably should read the book a little more.

Focus Group Script

1. What do you think you are getting out of participating in the 281x/381x sequence?

2. How is the sequence similar to other courses you have taken?

3. How is the sequence different from other courses you have taken?

4. What aspects of the course structure have positively affected your learning experience?

5. Do you view the 281x and 381x courses as different courses or as a continuous course? Explain.

6. Would you take this sequence of courses again, if given the opportunity?

7. Would you recommend this sequence of courses to other students in your program?
Why?

8. If you were teaching this sequence of courses, what would you do differently?

9. What has this sequence of courses meant to you?

10. What else would you like to share with me about the 281x/381x sequence?

Plus/Delta Feedback Technique

Teacher/Course – What's working	Teacher/Course – What needs changing?
Example: Providing practical examples of the theoretical approaches has been beneficial – 5 How class is structured in general – 4	Example: Web CT → few group members, late postings by group – 2 Abstracts – difficult to keep to 200 words, taking points off – 2
You as the Student – What's working?	You as the Student – What needs changing?
Example: Reading material and abstracting helps me learn – 7 My interaction with my learning group is positive – 4	Example: I need to invest more time in preparation – 2 I need to engage more actively in class discussions – 4

Appendix D: Spring 2005 Post-Class Report on CprE 211

Executive Summary

Students in the Introduction to Microcontrollers (CprE 211) course in Spring 2005 indicated through a survey administered near the end of the semester that they were able to understand and experiment with most of the concepts included in the course, agree that the curriculum contributed to their learning, greatly agree that the labs contributed to their experience, and somewhat agree that group interaction contributed to their learning experiences. More than 50% of the students indicated interest in software systems, general computers, and security. Most students indicated that they believe they will retain an understanding for assembly design or programming.

For purposes of revising a paper originally authored by A. Striegel and D. Rover, titled “Evolution of an Introduction to Embedded Systems Course,” the evaluation supports the following beliefs students have about the class:

- There is a clear connection between lecture concepts and lab activities.
- The challenge of the course will benefit students in the future as engineers.
- The course provided a foundation for the Computer Engineering major.
- There was continuity among the lab assignments.
- The labs were relevant to the real world.
- Lab exercises forced students to consider more advanced issues.
- The labs helped students to develop the skills for the final lab project.
- My experiences emphasized working with others.
- Students felt accountable to peers.
- Students felt accountable to the faculty member(s) and teaching assistants.

Method

A post-class survey was administered on Tuesday March 5, 2005 at the beginning of the class lecture to a class of 31 students in attendance. A two-page survey was distributed that asked about their understanding of course concepts and whether they agree with statements that reflect goals of the course. They were asked to indicate their interests regarding computer engineering, whether they would recommend the course to others, and what they believe they will retain from the course.

One purpose for this survey was to test statements made in the Striegel and Rover article. Questions concerning curriculum, laboratory work, and group work were based on statements made in the original manuscript and an evaluation for the CprE 281x/381x courses that required 211 student input. If two-thirds (66.6%) of the student respondents supported a statement, then it was considered “sufficiently supported” and may be appropriate for inclusion as a statement in the revised manuscript.

Results

This results section summarizes the responses to the surveys that are supported by numerical results shown in the tables in the following Results Tables section. Most responses to the open-ended questions centered on comments related to the instructor and not to the course, which is not relevant to this report. A question concerning what students will retain from the course is the only open-ended question summarized in this section.

Concept Understanding. Students indicated the best understanding for programming in C and Motorola PPC assembly language (mean = 3.97 of 6 maximum)[1], and basic hardware and software debugging (mean = 3.74). They indicated the lowest understanding, on average, on basic computing concepts such as interrupts, ISRs, and I/O subsystems.

Curriculum Structure. Students indicated that the class did clearly connect lecture concepts and lab activities (71% indicated a degree of agreement, mean = 4.23 of 6 maximum)[2], and that the challenge of the course will benefit them as an engineer (81% agreement, mean = 4.19). There was not sufficient agreement[3] to support the statements that there was a clear connection between concepts of digital logic in the previous class and digital systems in this class (61% agreement, mean = 3.48), and that the course objectives were clear to the students (65% agreement, mean = 3.84). For the 25 students who identified computer engineering as their major, they agreed that the course provided a foundation for their major (84% agreement, mean = 4.40). Those who did not indicate they were computer engineering majors did not agree that the course provided a foundation for their major (33% agreement, mean = 2.83).

Laboratory Work. Students supported all of the statements concerning the class activities in the lab. There was unanimous agreement that there was continuity among the lab assignments (100% agreement, mean = 4.87 of 6 maximum)[4] and that the labs helped them to develop the skills for the final lab project (100% agreement, mean = 4.77). They also agreed that the labs were relevant to the real world (94% agreement, mean = 4.68) and that lab exercises forced them to consider more advanced issues (87% agreement, mean = 4.61).

Group Work. Students had experiences that emphasized working with others in groups (80% indicated a degree of agreement, mean = 4.26 of 6 maximum)[5]. While in the groups students felt they were accountable to their peers in the groups (97% agreement, mean = 4.39) and to faculty member(s) and/or teaching assistants (73% agreement, mean = 3.87). There was not sufficient agreement to support the statements that students felt team spirit with their group (60% agreement, mean = 3.61), or that they had a lot of interaction with the faculty member(s) and/or teaching assistants (53% agreement, mean = 3.55).

Students indicated that they will retain concepts associated with programming C and Motorola PPC assembly language, and an understanding of the architecture of the Power PC processor. Of the 28 responses, 17 (61%) indicated a response that included assembly comprehension, design, and/or language including the following common response, "I will retain basic knowledge of assembly and the internal workings of the computer."

Results Tables

[1] Based on a 6-point Likert range where 1 = Unfamiliar, 2 = Basic Understanding, 3 = Understand and Experiment, 4 = Apply Concepts, 5 = Proficient, and 6 = Could Teach This.
[2] Based on a 6-point Likert range of 6 where 1 = Completely Disagree, 2 = Disagree, 3 = Somewhat Disagree, 4 = Somewhat Agree, 5 = Agree, and 6 = Completely Agree.
[3] Sufficient agreement was determined if greater than 2/3 of the class respondents (66.6%) were in agreement with the statement.
[4] Based on a 6-point Likert range where 1 = Completely Disagree, 2 = Disagree, 3 = Somewhat Disagree, 4 = Somewhat Agree, 5 = Agree, and 6 = Completely Agree.
[5] Based on a 6-point Likert range where 1 = Completely Disagree, 2 = Disagree, 3 = Somewhat Disagree, 4 = Somewhat Agree, 5 = Agree, and 6 = Completely Agree.

The responses include aggregated Likert-type responses and responses to the open-ended questions. For questions about Curriculum, Laboratory, and Groups sections, a percent agreement was included based on those that indicated some level of agreement with the statement (noted by those with a response of a "4" or greater on the 6-point Likert range).

CONCEPTS

QUESTION	Mean	Response Frequencies [a]					
		1	2	3	4	5	6
Microprocessor instruction sets	3.39	0	9	8	8	5	1
Architecture of the Power PC processor	2.97	0	13	11	3	3	1
Programming in C and Motorola PPC assembly language	3.97	0	2	9	10	8	2
How C is converted to assembly code	3.58	0	3	13	10	4	1
Basic concepts of microcontrollers	3.19	0	9	12	5	5	0
Basic computing concepts such as interrupts, ISRs, and I/O subsystems	2.55	2	17	6	5	1	0
Basic hardware and software debugging	3.74	0	4	9	10	7	1

[a] Key: 1 = Unfamiliar, 2 = Basic Understanding, 3 = Understand & Experiment, 4 = Apply Concepts, 5 = Proficient, 6 = Could Teach This.

2a. In regard to this course to what extent do you agree with the following statements?

CURRICULUM

Question	Mean	Percent Agreement [a]	Response Frequencies [b]					
			1	2	3	4	5	6
There was a clear connection between concepts of digital logic in the previous class and digital systems in this class.	3.48	61%	1	6	5	15	4	0
There is a clear connection between lecture concepts and lab activities.	4.23	71%	0	2	7	8	10	4
The challenge of the course will benefit me in the future as an engineer.	4.19	81%	1	2	3	11	12	2
The course objectives were clear to me.	3.84	65%	0	5	6	10	9	1
For CprE majors (*n* = 25)								
This course provided a foundation for my major.	4.40	84%	0	1	3	8	11	2
For non-CprE majors or those who did not indicate a major (*n* = 6)								
This course provided a foundation for my major.	2.83	33%	1	1	2	2	0	0

[a] Agreement indicates those respondents that selected 4 or greater on the 6-point Likert-range.
[b] Key: 1 = Completely Disagree, 2 = Disagree, 3 = Somewhat Disagree, 4 = Somewhat Agree, 5 = Agree, 6 = Completely Agree.
A bolded row indicates that the statement was sufficiently supported.

2b. In regard to this course to what extent do you agree with the following statements?

LABS

Question	Mean	Percent Agreement [a]	Response Frequencies [b]					
			1	2	3	4	5	6
There was continuity among the lab assignments.	4.87	100%	0	0	0	10	15	6
The labs were relevant to the real world.	4.68	94%	1	0	1	9	15	5
Lab exercises forced me to consider more advanced issues.	4.61	87%	0	0	4	9	13	5
The labs helped me to develop the skills for the final lab project	4.77	100%	0	0	0	8	16	6

[a] Agreement indicates those respondents that selected 4 or greater on the 6-point Likert range.
[b] Key: 1 = Completely Disagree, 2 = Disagree, 3 = Somewhat Disagree, 4 = Somewhat Agree, 5 = Agree, 6 = Completely Agree.
A bolded row indicates that the statement was sufficiently supported.

2c. In regard to this course to what extent do you agree with the following statements?

GROUPS

Question	Mean	Percent Agreement [a]	Response Frequencies [b]					
			1	2	3	4	5	6
My experiences emphasized working with others.	4.26	80%	0	1	5	9	11	4
I felt team spirit within my group.	3.61	60%	0	6	6	11	4	3
I had a lot of interaction with the faculty member(s) and/or teaching assistants	3.55	53%	1	3	10	10	3	3
I felt accountable to my peers.	4.39	97%	0	1	0	15	10	4
I felt accountable to the faculty member(s) and teaching assistants.	3.87	73%	0	2	6	15	4	3

[a] Agreement indicates those respondents that selected 4 or greater on the 6-point Likert range.
[b] Key: 1 = Completely Disagree, 2 = Disagree, 3 = Somewhat Disagree, 4 = Somewhat Agree, 5 = Agree, 6 = Completely Agree.
A bolded row indicates that the statement was sufficiently supported.

2d. What comments do you have about any of the previous statements? (a reference to the Likert-type questions.)

ID	Response
101	Lab descriptions were at times difficult to understand. Lecture was sometimes over informative and confusing.
103	Lab work was difficult to complete on time given many of the computers in lab had errors in their operation
105	Clear description on what to read each day instead of half a dozen links to long web pages.
106	Maybe give more time to explain examples, homework, and related information. Going a little slower speed would be nice.
108	We have not done a final lab project.
114	I work alone
115	The lectures need to follow the lab a little more closely
117	na
120	Hardly any concepts carried over from 210. Instructor is impossible for me to understand, which caused many problems. Because of this, I was forced to rely on notes that weren't entirely clear to understand as well.
122	This course needs to focus more on assembly than C programming as well as more of the architecture and basic computing concepts.
123	Labs are too overwhelming.
124	If you have specific questions email me: (email address omitted).

126	The Lab TA did next to nothing… I would like to see the TA's be more active in lab.
127	In groups of 2, I felt teamwork was very successful. Larger than that it seemed less productive.
128	Labs did not provide enough potential modularity for all members of a group to be involved simultaneously.
129	Programming in C and Assembly ->C->4, ASM->2, You snuck assembly in there "foundation for my major" ~ "final lab from previous labs" -> I can't know these answers yet, merely assumptions
131	I don't see the relevance between some of the concepts in lecture and the questions in lab. Also, it didn't help that I could only see my lab TA (office hrs) due to my schedule.

3. What are your interests? (Select all that apply.) (*n* = 31)

Interest Area	#
a. Embedded systems	15
b. VLSI design	5
c. Computer network design	13
d. Software systems	17
e. Compilers	4
f. General computer	16
g. Security	17
h. General electrical engineering	11
i. Computer architecture	13
j. Reconfigurable computing with FPGAs	15

4a. Would you recommend this course to others?

Answer	#
YES	15
NO	11
UNDECIDED OR ?	4
NO RESPONSE	1

4b. Please explain your response.

ID	Y/N/?	Response
101	N	I would recommend an equivalent, but the increased difficulty of this course because the instructor could not speak good English and there was no textbook to supplement the teaching. However, If there was no equivalent, then I would encourage them that they can make it through it with much extra effort.
102	N	I think it is a fast paced class that can be hard to grasp certain concepts in so little time.
103	Y	This course provides a necessary foundation for future CprE coursework/material
104	N	As an EE with a distaste for programming I wouldn't recommend the class to anyone.
105	Y	It isn't too bad, just a different programming language.
106	Y	If they are interested in programming, this will be a great course to take.
107	Y	It is a very interesting and challenging course. The first one that gave me a sense of becoming an engineer.
108	Y	For a CprE it builds a good base for the rest of their education.
111	N	No book, notes are difficult to understand, they are notes
112	N	Got very little out of this class. Hard to follow and understand what was going on.
113	Y	Learning the concepts and applications of microcontrollers can be interesting and help to understand general computer operations while continuing to develop computer language skills.
115	N	Way too hard. Not comparable to 210.
116	Y	It will be necessary if anyone wants to do embedded systems.
117	Y	you learn what the PC is doing at an assembly level. If anything is pulled from the course, problem solving and working as a team is big.
118	?	Only if they wanted to learn assembly.
119	Y	I've seen friends in the alternative completely stressed over it. Lab was fun.
120	N	It is very difficult to understand the instructor, therefore tough to do well, or learn anything.
121	N	I wish this course had a textbook.
122	?	A textbook is needed. I did learn the basics about assembly, but I could have learned the same by looking on web sites myself.
123	?	It depends on how much interest/ knowledge the student has. Anyone who is somewhat interested with no background - NO Even someone who is very interested without any previous skills would have difficulty.
124	Y	Well I see the people in 381x and they struggle a lot but they get 305 done a semester early/benefit
125	Y	I have learned a lot in this course, although it has been a lot of work to keep up with everything that we are supposed to know. Sometimes things aren't explained or covered well enough, but in the end the topics are very interesting.
127	Y	Good understanding of connection between software and hardware
128	Y	It covers a number of topics that provide a basis for other computer engineering courses.
129	N	It is a difficult course, but it is also required, so I can't really recommend it to others to take out of interest. It is a required and specialized course, so either you have to take it, or you take three other classes to meet the prerequisites. I know it’s an elective for EE's, but I've had a bad experience with my lab partner who was an EE and dropped the course out of

		desperation.
130	Y	Built a great foundation and provides experience to practical knowledge
131	N	I didn't understand much of what the professor said, and I also didn't like the way lecture was set up… just PowerPoint slides and that laser pointer.

5. What do you think you will retain from this course?

ID	Response
101	Concept of embedded circuits programming. Working in groups. Some assembly.
102	PPC programming in C
103	Knowledge of the PPC architecture
104	C programming and assembly programming knowledge.
105	Proprietary uses and concepts related to the PowerPC
106	Programming assembly.
107	Using C+ assembly to write instructions for embedded systems.
108	concepts of assembly and computer architecture.
111	Not sure.
112	Conversion of C to Motorola PPC assembly.
113	Assembly language/ C skills, interrupt/I/O techniques.
115	C, assembly. Better idea of general embedded systems.
116	General information on assembly.
117	Retain basic assembly language, and process of I/O.
118	how to do basic assembly and C coding
119	Assembly conversion bit wise logic
120	Knowledge of assembly level programming. Understanding PPC architecture.
121	Most programming concepts.
122	How to read assembly.
123	A memory of feeling like the information wasn't presented in a helpful way, and having to painfully struggle through it.
124	Assembly design.
125	A better understanding of assembly computer hardware architecture, processor design.
126	I will retain basic knowledge of assembly and the internal workings of the computer.
127	The understanding of how high-level languages work on the lower level
128	General understanding of assembly programming.
129	Basic assembly. Learning to do things in a modular fashion. Learning to understand foreigners.
130	Microprocessor architecture
131	A little bit of the assembly programming, and the skills to solve the problems presented in lab.

6. What additional comments do you have regarding this course?

ID	Response
101	If there is anything the professor can do to mellow out his accent it would make lecture much less fatiguing! A textbook would help so we can learn from areas other than lecture, which is difficult!
103	Homework helps greatly to create a connection between lecture and lab work.
104	I am glad they removed from the requirements in the new catalog for EEs.
105	Maybe a recitation or non-lab non-lecture time would benefit people.
106	The teacher is doing a great job helping and encouraging students.
111	Understanding the lecturer isn't the problem. Knowing how to go about the course is.
112	Disliked.
114	This class could be something great but it falls short. I'm transferring so good luck!
115	Too hard. Bring more points from labs to attendance points. (Too exam/lab heavy).
116	Fairly tough course.
117	Hard to understand lecturer.
118	SI or extra help sessions would be a significant help in this class.
119	A book would be necessary. A shorter lecture (MWF instead of TR) would help immensely.
120	Could be a very good course if it was better taught and easier to understand.
121	I wish this course had a textbook.
122	Need textbook! And stop testing us on concepts that we just learned a week ago and haven't tried in lab yet.
123	Lectures - although pertaining to lab, are not helpful so I feel utterly unprepared and lost every week during lab.
124	It is easy.
125	Sometimes it is hard to find information in the lectures in the on-line notes. A book would be nice.
126	This course needs to follow a book of some sort. The lecturer has very poor English and is hard to understand.
129	The instructor is slightly difficult to understand, but I can't hold that against him. I am the arrogant and uncompromising American.
131	This course, along with one other CprE class and the computer science courses forced me to drop CprE. I just didn't like it anymore.

Appendix E: Spring 2005 Post-Class Report on CprE 305

A post-class survey was administered on Tuesday April 11, 2005 at the beginning of the class lecture to a class of 18 students in attendance. Students were handed a two-page survey that asked about their understanding of course concepts and whether they agree with statements that reflect goals of the course. They also were asked to indicate their interests regarding computer engineering, whether they would recommend the course to others, and what they believe they will retain from the course.

The following series of tables summarize the responses for the CprE 305 class by aggregating Likert-scale responses and organizing open-ended question responses.

1. Select the boxes that best describe your knowledge of the following course concepts.

CONCEPTS

QUESTION	AVG	Unfamiliar	Basic Understanding	Understand and Experiment	Apply Concepts	Proficient	Could Teach This
		1	2	3	4	5	6
Microprocessor instruction sets	3.39	0	5	5	5	2	1
Architecture of the Power PC processor	3.17	0	6	5	5	2	0
Programming in C and Motorola PPC assembly language	3.61	0	2	5	5	4	1
How C is converted to assembly code	3.39	1	5	5	3	1	3
Basic concepts of microcontrollers	3.39	1	3	5	7	1	1
Basic computing concepts such as interrupts, ISRs, and I/O subsystems	2.89	1	7	6	2	1	1
Basic hardware and software debugging	3.28	1	4	3	9	1	0

Bold indicates the modal response

2a. In regard to this course to what extent do you agree with the following statements?

CURRICULUM

Question	AVG	Completely Disagree	Disagree	Somewhat Disagree	Somewhat Agree	Agree	Completely Agree
		1	2	3	4	5	6
There was a clear connection between concepts of digital logic in the previous class and digital systems in this class.	3.89	0	1	5	7	5	0
There is a clear connection between lecture concepts and lab activities.	3.17	2	4	4	5	3	0
The challenge of the course will benefit me in the future as an engineer.	3.61	2	4	0	6	5	1
The course objectives were clear to me.	3.44	1	6	2	4	3	2
This course provided a foundation for my major.	3.56	3	2	2	5	5	1

Bold indicates the modal response

2b. In regard to this course to what extent do you agree with the following statements?

LABS

Question	AVG	Completely Disagree	Disagree	Somewhat Disagree	Somewhat Agree	Agree	Completely Agree
		1	2	3	4	5	6
There was continuity among the lab assignments.	4.50	0	0	2	5	11	0
The labs were relevant to the real world.	3.94	0	3	2	6	7	0
Lab exercises forced me to consider more advanced issues.	4.06	0	2	2	8	5	1
The labs helped me to develop the skills for the final lab project	4.50	1	1	2	2	8	4

Bold indicates the modal response

2b. In regard to this course to what extent do you agree with the following statements?

GROUPS

Question	AVG	Completely Disagree	Disagree	Somewhat Disagree	Somewhat Agree	Agree	Completely Agree
		1	2	3	4	5	6
My experiences emphasized working with others.	4.17	0	2	2	5	9	0
I felt team spirit within my group.	3.72	1	2	1	7	5	1
I had a lot interaction with the faculty member(s) and/or teaching assistants	2.83	2	6	5	3	2	0
I felt accountable to my peers.	3.56	0	3	3	6	5	0
I felt accountable to the faculty member(s) and teaching assistants.	3.39	2	3	3	7	2	1

Bold indicates the modal response

2c. What comments do you have about any of the previous statements? (A Reference to the Likert-scale questions.)

ID	Response
301	
302	I felt the course was extremely unfocused and unorganized. Objectives were not made clear and it was difficult to prepare for exams with no information of what would be covered in them.
303	
304	
305	We didn't have a lot of group work except for the lab project.
306	Labs take too long, for credit given.
307	
308	
309	Need more connection with lab and class and homework.
310	The labs and lectures were not planned together. Homework asked for more advanced material than what was taught. The instructor is completely clueless to what is happening in the class.
311	There was really that much group work to consider. Except the final project, which we're only part way through.
312	The final project is totally different from the other labs, and more time should have been given to complete it, since students have other classes that involve projects and out-of-class work.
313	Most, if not all, of the learning in this course is in Lab. Lecture has not proved to be worthwhile as clear examples are not given. It is much more worthwhile to spend time reading the book, but attendance is mandatory due to pop-quizzes.
314	More examples could be useful for future classes.
315	
316	
317	
318	

3. What are your interests? (Select all that apply.) (n=18)

Interest Area	#
a. Embedded systems	6
b. VLSI design	4
c. Computer network design	12
d. Software systems	12
e. Compilers	3
f. General computer	13
g. Security	7
h. General electrical engineering	1
i. Computer architecture	5

j. Reconfigurable computing with FPGAs	6

4a. Would you recommend this course to others?

Answer	#
YES	10
NO	8
UNDECIDED OR ?	
NO RESPONSE	

4b. Please explain your response.

ID	Y/N/?	Response
301	Y	Very Important foundation for other fields
302	N	Unless you are going into a hardware related field within CprE, I don't feel that the course is useful.
303	N	The professor was not prepared and showed no control over the course. There was a big lack of communication between the professor and TA and Lab TA.
304	N	Worst organization every, teacher doesn't care.
305	Y	It is a good learning step between writing programs and actual internal computer physics.
306	N	Instructor was pretty bad. Labs take too much time for the credit given. Tests were not like labs. Never get any graded material back.
307	Y	It is interesting and useful material.
308	Y	I consider this course essential to building a knowledge base for computer architecture.
309	N	Mostly because of the professor, but the class overall is very disconnected. They do not give a broad enough view of processor design and questions seem way too specific.
310	N	The class could be worthwhile with a different teacher. I could do what Chang does with the slides in front of me. Chang is constantly unprepared for class and merely reads the slides. The test also does not reflect material covered in class.
311	Y	I actually have enjoyed this class and found it to be a giant step in understanding how a computer actually works.
312	N	I feel this is a repetition of 211, and the lab is not designed in a good way, since you must learn verilog in an ad-hoc manner.
313	N	Although lab is worthwhile, this class needs a better professor to teach lecture. The very unorganized homework assignments and even material covered in class makes this course frustrating.
314	Y	
315	Y	The material is kind of dry, but it's a necessary foundation to understanding computers in general.
316	Y	
317	Y	

318	Y	There are important concepts on development of computers

5. What do you think you will retain from this course?

ID	Response
301	Memory hierarchy, pipelining
302	No
303	
304	How much I had Model SIM and verilog.
305	Single and double cycle datapaths.
306	How to study on my own, and learning basic verilog vin model sin.
307	Processor architecture/ data path. Understanding of how pipelining affects imaging programs, cache strategies.
308	Almost all that was if taught if I were to follow a career path in computer architecture and design.
309	How datapaths work, some floating point conversion, and some optimization techniques.
310	Processor design theory and instruction set theory.
311	The general make up of a processor and memory, as well as some MIPS implementation.
312	"Go to Best Buy," The difference between CISC and RISC ISA.
313	Lab work; lab final project - MIPS instructing, data-path, pipe-lining/ cache concepts
314	A basic understanding, I would have to look stuff up to apply it later, but I would know what to look for.
315	Data path design, instruction set architecture.
316	Knowledge about computer architecture.
317	It is required.
318	how to write verilog code.

Appendix F: Spring 2005 Post-Class Report on CprE 381x

A post-class survey was administered on Thursday March 7, 2005 at the beginning of the class lecture to a class of 8 students in attendance. Four surveys were received later for those students that were not in attendance. Students completed a two-page survey that asked about their understanding of course concepts and whether they agree with statements that reflect goals of the course. They also were asked to indicate their interests regarding computer engineering, whether they would recommend the course to others, and what they believe they will retain from the course.

The following series of tables summarize the responses for the CprE 381x class by aggregating Likert-scale responses and organizing open-ended question responses. A companion evaluation included the 211 students. There will be another report that compares both classes.

1. Select the boxes that best describe your knowledge of the following course concepts.

CONCEPTS

QUESTION	AVG	Unfamiliar	Basic Understanding	Understand and Experiment	Apply Concepts	Proficient	Could Teach This
		1	2	3	4	5	6
Microprocessor instruction sets	4.42	1	0	0	4	6	1
Architecture of the Power PC processor	3.58	0	1	5	4	2	0
Programming in C and Motorola PPC assembly language	4.08	0	1	2	4	5	0
How C is converted to assembly code	4.08	0	2	1	4	4	1
Basic concepts of microcontrollers	4.33	0	1	0	6	4	1
Basic computing concepts such as interrupts, ISRs, and I/O subsystems	3.75	0	3	2	3	3	1
Basic hardware and software debugging	4.17	0	1	1	6	3	1

Bold indicates the modal response

2a. In regard to this course to what extent do you agree with the following statements?

CURRICULUM

Question	AVG	Completely Disagree	Disagree	Somewhat Disagree	Somewhat Agree	Agree	Completely Agree
		1	2	3	4	5	6
There was a clear connection between concepts of digital logic in the previous class and digital systems in this class.	4.92	0	0	0	3	7	2
There is a clear connection between lecture concepts and lab activities.	4.50	0	1	0	5	4	2
The challenge of the course will benefit me in the future as an engineer.	5.50	0	0	0	0	6	6
The course objectives were clear to me.	4.50	0	0	2	4	4	2
This course provided a foundation for my major.	5.17	0	0	1	0	7	4

Bold indicates the modal response

2b. In regard to this course to what extent do you agree with the following statements?

LABS

Question	AVG	Completely Disagree	Disagree	Somewhat Disagree	Somewhat Agree	Agree	Completely Agree
		1	2	3	4	5	6
There was continuity among the lab assignments.	5.17	0	0	0	0	10	2
The labs were relevant to the real world.	4.67	0	0	1	3	7	1
Lab exercises forced me to consider more advanced issues.	4.58	0	0	2	2	7	1
The labs helped me to develop the skills for the final lab project	5.25	0	0	0	1	7	4

Bold indicates the modal response

2b. In regard to this course to what extent do you agree with the following statements?

GROUPS

Question	AVG	Completely Disagree	Disagree	Somewhat Disagree	Somewhat Agree	Agree	Completely Agree
		1	2	3	4	5	6
My experiences emphasized working with others.	4.67	0	1	1	1	7	2
I felt team spirit within my group.	4.17	0	1	1	2	5	2
I had a lot interaction with the faculty member(s) and/or teaching assistants	4.83	0	0	0	2	4	5
I felt accountable to my peers.	4.58	0	0	0	2	7	2
I felt accountable to the faculty member(s) and teaching assistants.	4.67	0	0	0	2	6	3

Bold indicates the modal response

2c. What comments do you have about any of the previous statements? (A Reference to the Likert-scale questions.)

ID	Response
201	
202	Labs, homework, and projects were done in pairs, and since my partner has struggled through most of this course, the partnership seemed to hinder more than it helped.
203	
204	
205	
206	The ideas of this style of speed learn class was very good. The material covered for the 211 portion could be more entertaining.
207	I like working with a partner of my choosing.
208	I am not sure why, perhaps it was that we need more labs to strengthen knowledge of interrupt/exception handling, but that is the weakest area by far for me.
209	
210	
211	Labs corresponded well with lectures. It was much better this semester.
212	My lab partner often fell asleep during lab, which frustrated me.

3. What are your interests? (Select all that apply.) (n=12)

Interest Area	#
a. Embedded systems	6
b. VLSI design	5
c. Computer network design	6
d. Software systems	3
e. Compilers	0
f. General computer	9
g. Security	7
h. General electrical engineering	3
i. Computer architecture	8
j. Reconfigurable computing with FPGAs	6

4a. Would you recommend this course to others?

Answer	#
YES	12
NO	0
UNDECIDED OR ?	0
NO RESPONSE	0

4b. Please explain your response.

ID	Y/N/?	Response
201	Y	I have enjoyed this class.
202	Y	Time isn't wasted from overlap between class as in CprE 210, 211 305. Fast-paced course keeps you interested and coming to class.
203	Y	An important experience for computer engineering.
204	Y	I would recommend it if it is not taken with too many other technical courses so that the workload is not unhealthy.
205	Y	It is a very informative class and introduces you to a lot of things but I found myself getting lost and now don't understand much of what is going on.
206	Y	The ability to speed through a somewhat easy 210, then jump into 305 and go through the gut wrenching 211 gets you through it faster.
207	Y	Only if you are willing to put in the time. Class was enjoyable and laid-back, but required a lot of work.
208	Y	I think it is extremely valuable asset.
209	Y	If you have the time to devote to it and are very motivated.
210	Y	The most effective part of the learning came through labs and projects. I liked the flow between the two classes.
211	Y	Challenging, but good overall.
212	Y	I have recommended this course to fellow students.

5. What do you think you will retain from this course?

ID	Response
201	Assembly
202	
203	Digital design elements.
204	Understanding of microprocessors, ideas from interrupt/exception handling.
205	I think I will retain some coding I have learned and my knowledge of a processor.
206	The familiarity with the teachers and relevant materials are good.
207	Butter understanding of working in a team and the requirements of a project.
208	Computer Engineering fundamentals and processor design.
209	The basics of how a processor works (the data path) of pipeline and single cycle. The very basics of assembly. Not much of exception handling/interrupt handling.
210	Most of the topics, especially architecture design.
211	The subject matter…
212	I will a lot of the skills of finding information and applying it.

6. What additional comments do you have regarding this course?

ID	Response
201	
202	PowerPC section this section should have gone much faster than it did.
203	
204	
205	
206	Dr. Somani & Tyagi have invested a lot of time to this class and it has been a pleasure to learn from them.
207	Good course. More correlation between lecture and labs.
208	I think more practice is needed with interrupt/ exception handling. This was the most difficult part of the class, at least for me.
209	It is easy to get behind if you are busy with other things in your life, i.e., involved with various things on campus. Also, with the fast pace of the course it is extremely difficult to catch up.
210	
211	I still think something should be done about CS228
212	None.