

## **Instructional Effectiveness: A Real-time Feedback Approach using Statistical Process Control (SPC)**

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### **Abstract**

Are students satisfied with their courses? Students are typically requested to assess the course and instruction at the end of the semester. Course evaluations report student ratings of instruction in order to provide feedback to the instructor and administration. Although this feedback may provide long-term insight into instructional effectiveness, it cannot be used to provide real-time information to the instructor.

There are assessment techniques that provide real-time course assessment, but none that monitor assessment trends over time based on some standards. Statistical Process Control is a method used to monitor quality characteristics and determine the capability of the process over time. In a classroom, SPC can allow the instructor to monitor multiple predetermined course attributes associated with class lectures such as course organization, efficient use of class, or instructor enthusiasm. The instructor can use this feedback to monitor their effectiveness and make improvements before the course is over. The paper presents an overview of the SPC process and a case study that explores the application of SPC within an engineering course.

### **Introduction**

In recent years, much focus has been placed on course and student assessment, but instructional assessment has not received the attention it deserves. Many tenure-track professors in the United States are evaluated heavily on their research contributions to the university, but for other universities, quality instruction is a top priority.

What is quality instruction? ASCE ExCEED Teaching workshops define “good teaching” based on the ExCEED (Excellence in Civil Engineering Education) Teaching Model<sup>1</sup>. The six main focus areas of the teaching model include; structured organization, engaging presentation, enthusiasm, positive rapport with students, frequent assessment of student learning, and appropriate use of technology. Seymour and Hewitt<sup>2</sup> were able to quantify what students considered “bad teaching” by interviewing several math, science, and engineering students. The list included such things as inadequate preparation, preoccupation with research, inability to communicate, presenting material at too high of a level, and not understanding how students learn. We will focus on the aspects of “good teaching”.

How do we assess teaching performance? Estes and Ressler<sup>3</sup> present a comprehensive list of tools used to assess the teaching performance of a Civil Engineering faculty member at the United States Military Academy (USMA). The list of tools include:

1. Student Ratings
2. Student Performance
3. Course Assessment
4. Time Survey
5. Peer/Mentor Assessment
6. Classroom Assessment Techniques
7. Self-Assessment (Faculty Training)

The Civil Engineering Department at the USMA uses an extensive list of tools to assess the teaching performance of a faculty member. Although, I do not believe that many institutions use such an extensive list to evaluate faculty. Some use a subset of the tools mentioned above, but many universities base the instructional assessment on a standardized set of questions. The Office of Educational Assessment<sup>4</sup> at the University of Washington has the Instructional Assessment System (IAS) which provides a standardized method to collect and report student ratings of instruction. An example assessment form is shown in Appendix A. As with many assessment tools, the assessment form is administered at the end of the semester. The anonymous evaluations are collected and sent to the IAS for processing and reporting. The reports are usually returned to the instructor 2-3 weeks after the semester commences. The instructor reviews and assimilates the results and then files the report until the next course offering which could be next semester, next year, or even years from now. This is not an efficient method to provide real time feedback so that one can monitor and improve the quality of instruction.

Midterm evaluations are a useful method to collect instructional assessment that can be applied real-time to the current class. Angelo and Cross<sup>5</sup> provide several student assessment methods that can be also applied real-time. An instructor could use “The Minute Paper” to determine important qualities in the lecture or the “The Muddiest Point” to find out the bad points of the lecture. These techniques are useful in providing immediate feedback, but none that monitor assessment trends over time based on some standards.

### **Statistical Process Control (SPC)**

Statistical Process Control is a method to monitor, control, and improve process performance over time by studying variation. A process can be comprised of machines, methods, people, and other resources that transform some input into an output that has one or more quality characteristics. Processes consist of multiple variables or attributes that may play a significant role in reducing the variability in each of the quality characteristics. Some of the process factors or variables are controllable, whereas other factors are uncontrollable (nuisance variables). The process for an industrial plant takes raw materials and creates a finished product. A process can be represented by the model shown in Figure 1.

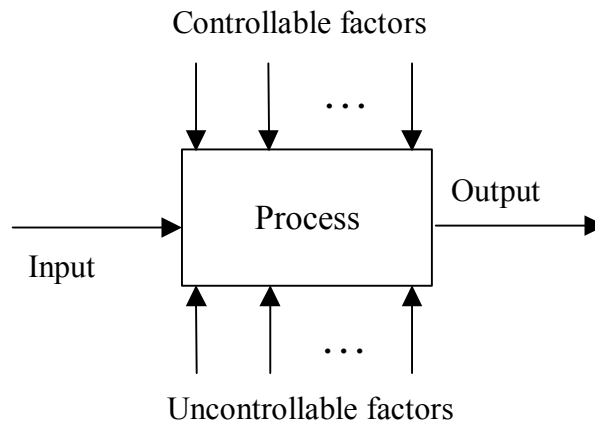


Figure 1: A Process Model

The principal tool of SPC is the control chart. A control chart is a graphical display of the quality characteristic (process value) that has been measured or computed from a sample over time. Figure 2 shows a sample control chart which shows the process values plotted over time. The key features of the control chart are the center line (CL), upper control limit (UCL) and lower control limit (LCL). The blue center line represents the expected value or average value of the quality characteristic. The red upper and lower control limits are chosen so that if the process is stable, a large percentage of the points will fall within the limits. These limits are most commonly placed at three standard deviations from the centerline. For further discussion of the selection of control limits, see Montgomery<sup>6</sup>.

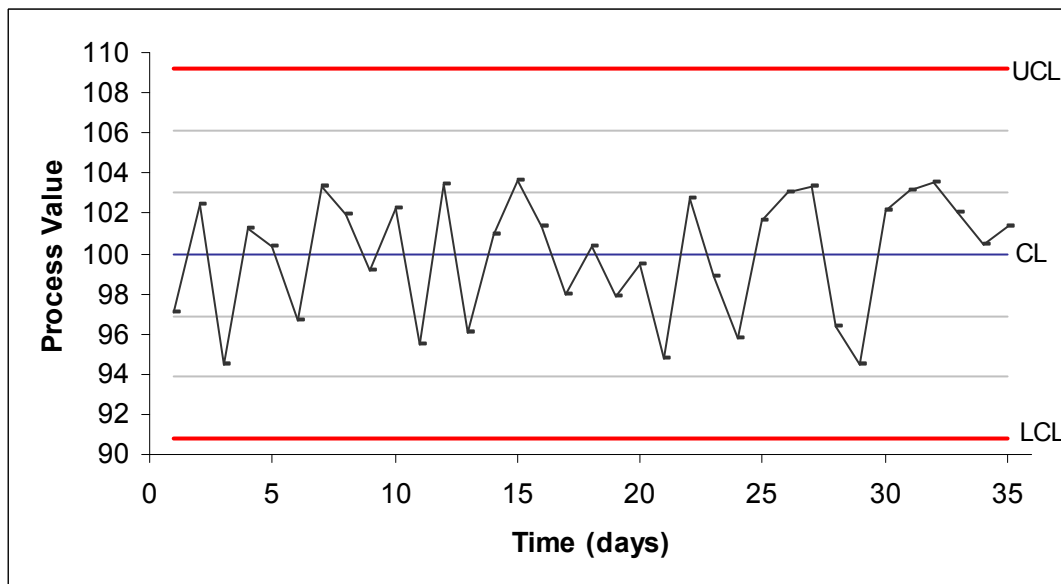


Figure 2: A Control Chart

If all of the points fall within the limits, the process is assumed to be in control, otherwise, the process is out of control. If this occurs, one should take corrective action on the process to determine the root cause of the problem.

There are other scenarios where the process is considered out of control. The Western Electric Handbook suggests a set of control chart decision rules for detecting out of control situations. The rules state;

1. One point plots outside the three standard deviation control limits (UCL, LCL);
2. Two out of three consecutive points plot beyond two standard deviations (warning limits);
3. Four out of five consecutive points plot beyond one standard deviation;
4. Eight consecutive points plot on one side of the center line.

These rules apply to one side of the center line at a time. The rules can help prevent potential trending problems from occurring.

There are many interpretations on the implementation of SPC. Montgomery<sup>6</sup>, Grant and Leavenworth<sup>7</sup>, and Smith<sup>8</sup> each provide a thorough discussion of steps and guidelines required. The following steps provide a high level methodology to implement SPC in a process. The implementation steps are;

1. Identify the process to control
2. Determine quality characteristic to monitor
3. Choose the appropriate control chart based on
  - a. Type of data
  - b. Sample size
  - c. Frequency
4. Perform process improvement using SPC tools
5. Implement continuous quality improvement on process

The guidelines are applicable to any type of process, such as manufacturing, service, or even the course instructional process.

### **Implementing SPC in Classroom**

In a classroom, SPC can be used to monitor and improve the instructional process as well as provide feedback on a real-time basis. The implementation of SPC in the classroom will follow the methodology presented above. Since the process to monitor has already been identified, we will begin with second step in the methodology.

When determining the quality characteristics to monitor in a process, one should consult the process expert. I felt that the standardized form used to assess my performance the last two course offerings was a good place to start. The form has over 30 assessment questions for the students to evaluate. It was my decision to focus on the areas (questions) that received the lowest scores from the previous course evaluations. The standardized form along with input from my constituents (students) would provide the necessary input to determining the initial quality

characteristics. The finalized quality characteristics can be seen in the course assessment form in Figure 3. The general categories are; professor, material, and course.

<b>NAME:</b>	<b>DATE:</b>
<b>Q1. Professor</b>	
Q1.1 Use of Class Time	1 2 3 4 5 6 7 8 9 10
Q1.2 Explanations of Material	1 2 3 4 5 6 7 8 9 10
Q1.3 Use of Examples/Illustrations	1 2 3 4 5 6 7 8 9 10
Q1.4 Effectiveness in Teaching subject	1 2 3 4 5 6 7 8 9 10
<b>Q2. Material</b>	
Q2.1 Supplemental Material (Handouts)	1 2 3 4 5 6 7 8 9 10
Q2.2 References	1 2 3 4 5 6 7 8 9 10
Q2.3 Sequence of Material	1 2 3 4 5 6 7 8 9 10
Q2.4 Pace of Material	1 2 3 4 5 6 7 8 9 10
<b>Q3. Course</b>	
Q3.1 Clarity of Student requirements	1 2 3 4 5 6 7 8 9 10
Q3.2 Amount you learned	1 2 3 4 5 6 7 8 9 10
Q3.3 Reasonableness of assigned work	1 2 3 4 5 6 7 8 9 10

Figure 3: Course Assessment Form

The form was given to each student at the end of each lecture beginning the second week of the class and ending on the midterm. The forms were then collected and stored in an Excel spreadsheet for analysis. To protect student identity the students choose fictitious names that would be used the entire semester. This would ensure students that they could provide honest assessment without any concern about their course grade. The assessment forms were not distributed during exam sessions. The instructor can use this feedback to monitor their effectiveness and make improvements before the course is over.

### Assessment Analysis

The student assessment data collected provided several uses. It provided daily feedback to the instructor, demonstrated several SPC concepts in the classroom, and was used by students for midterm SPC projects. An example of how the data is stored in excel for one class session is depicted in Figure 4.

<b>DATE</b>	<b>NAME</b>	<b>Q1.1</b>	<b>Q1.2</b>	<b>Q1.3</b>	<b>Q1.4</b>	<b>Q2.1</b>	<b>Q2.2</b>	<b>Q2.3</b>	<b>Q2.4</b>	<b>Q3.1</b>	<b>Q3.2</b>	<b>Q3.3</b>
3-Feb	NEO	9	9	8	10	10	9	10	6	7	8	9
3-Feb	Wolfman	7	8	7	8	9	7	8	7	8	7	7
3-Feb	Leo T.	8	8	9	8	10	6	9	9	9	9	9
3-Feb	Action Jackson	4	6	7	6	7	5	6	5	6	5	6
3-Feb	Scooby Doo	7	8	9	8	9	5	7	8	7	7	10
3-Feb	Popeye	7	7	8	7	8	6	7	6	7	7	8
3-Feb	John Smith	8	9	7	9	10	7	8	9	7	9	9
.	.	.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.	.	.

Figure 4: Sample Score data

The data were first used to monitor daily assessment. SPC control charts were created and monitored to determine if classroom instruction was “in-control”. The quality characteristics previously selected were monitored daily. An X-bar/S chart was created based on the sample size and type of data. A control chart was created for each of the questions and monitored for any “out of control” points on the chart based on the Western Electric rules. A sample X-bar/S chart for question Q2.3 is displayed in Figure 5.

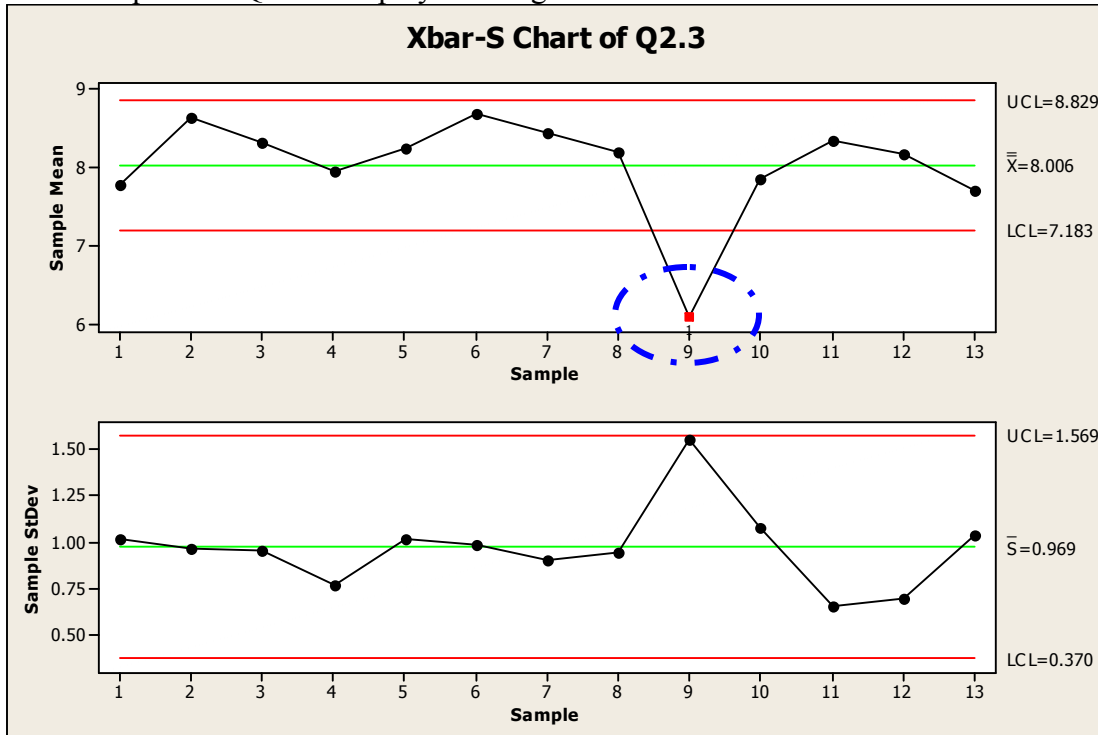


Figure 5: Xbar/S Chart of Question 2.3

It appears that sample nine is below the LCL making the point out of control. The point was investigated using other SPC tools to determine root cause of the point. Q2.3 refers to sequencing of the material. Investigation determined the sample nine was 24Feb occurred on a Monday. It also was determined that on that Monday, Annual Review Reports were due. It appears that the extra workload may have prevented the instructor from preparing a well sequenced lecture. In the future, better planning is required to prevent this from occurring once again. On other SPC control charts there were similar instances, but not all were below the LCL. Some points were plotted above the UCL, but is that a bad thing? Points plotted above UCL are due to high ratings by the student for that day. Again, investigation was performed to determine what the instructor did to receive such high ratings. In most instances, high scores were due to interactive lessons.

The Cause-and-Effect (Fishbone) diagram was utilized to determine potential causes for out of control scores on the control chart. Fishbone diagrams are very useful when determining the root cause of a problem. Another SPC tool, the Pareto chart was also used to rank the common problems in the classroom. The students liked the application of tools learned in class to a hands-on project that they were able relate to.

The students were required to apply the SPC concepts learned in class to a midterm project. The project required that students analyze 8 weeks worth of assessment data. Each student would analyze another randomly selected student's scores. Students were expected to use many of the SPC tools to analyze the data. The students applied several of the SPC tools such as Histograms, Pareto diagrams, Check sheets, Fishbone diagrams, Box Plots, and Control charts. The students also calculated descriptive statistics for the data. The midterm project was well received among the students.

## Conclusion

There are many assessment techniques available to the instructor, some more effective than others. SPC, more specifically, control charts are an assessment tool that provides real-time feedback to the instructor. The instructor is able to make adjustments daily, weekly, or halfway through the semester or quarter. The frequency of adjustments depends on the severity of the problem and the ease of implementation. One of the most important results of SPC is that data is available to make objective decisions. The data can provide insight to potential trends whether they are good or bad. It can also be compared to your end of semester assessments. Hopefully, the instructor will use data to improve on instructional effectiveness.

## Bibliography

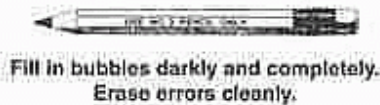
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Appendix A  
Office of Educational Assessment at the University of Washington: Form A

**I**nstructional  
**A**ssessment  
**S**ystem



FORM  
**A**

Instructor \_\_\_\_\_ Course \_\_\_\_\_ Section \_\_\_\_\_ Date \_\_\_\_\_

Completion of this questionnaire is voluntary. You are free to leave some or all questions unanswered.

		Excel- lent	Very Good	Good	Fair	Poor	Very Poor		
1. The course as a whole was:	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	■	
2. The course content was:	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	■	
3. The instructor's contribution to the course was:	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	■	
4. The instructor's effectiveness in teaching the subject matter was:	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	■	
5. Course organization was:	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	■	
6. Clarity of instructor's voice was:	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	■	
7. Explanations by instructor were:	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	■	
8. Instructor's ability to present alternative explanations when needed was:	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	■	
9. Instructor's use of examples and illustrations was:	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	■	
10. Quality of questions or problems raised by instructor was:	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	■	
11. Student confidence in instructor's knowledge was:	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	■	
12. Instructor's enthusiasm was:	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	■	
13. Encouragement given students to express themselves was:	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	■	
14. Answers to student questions were:	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	■	
15. Availability of extra help when needed was:	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	■	
16. Use of class time was:	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	■	
17. Instructor's interest in whether students learned was:	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	■	
18. Amount you learned in the course was:	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	■	
19. Relevance and usefulness of course content were:	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	■	
20. Evaluative and grading techniques (tests, papers, projects, etc.) were:	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	■	
21. Reasonableness of assigned work was:	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	■	
22. Clarity of student responsibilities and requirements was:	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	■	
<b>Relative to other college courses you have taken:</b>									
23. Do you expect your grade in this course to be:		Much Higher			Average		Much Lower		
24. The intellectual challenge presented was:	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	■	
25. The amount of effort you put into this course was:	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	■	
26. The amount of effort to succeed in this course was:	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	■	
27. Your involvement in this course (doing assignments, attending classes, etc.) was:	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	■	
28. On average, how many hours per week have you spent on this course, including attending classes, doing readings, reviewing notes, writing papers and any other course related work?	<input type="radio"/> Under 2 <input type="radio"/> 2 - 3 <input type="radio"/> 4 - 5	<input type="radio"/> 6 - 7 <input type="radio"/> 8 - 9 <input type="radio"/> 10 - 11	<input type="radio"/> 12 - 13 <input type="radio"/> 14 - 15 <input type="radio"/> 16 - 17	<input type="radio"/> 18 - 19 <input type="radio"/> 20 - 21 <input type="radio"/> 22 or more	■	■	■	■	■
29. From the total average hours above, how many do you consider were valuable in advancing your education?	<input type="radio"/> Under 2 <input type="radio"/> 2 - 3 <input type="radio"/> 4 - 5	<input type="radio"/> 6 - 7 <input type="radio"/> 8 - 9 <input type="radio"/> 10 - 11	<input type="radio"/> 12 - 13 <input type="radio"/> 14 - 15 <input type="radio"/> 16 - 17	<input type="radio"/> 18 - 19 <input type="radio"/> 20 - 21 <input type="radio"/> 22 or more	■	■	■	■	■
30. What grade do you expect in this course?	<input type="radio"/> A (3.9-4.0) <input type="radio"/> A- (3.5-3.8) <input type="radio"/> B+ (3.2-3.4)	<input type="radio"/> B (2.9-3.1) <input type="radio"/> B- (2.5-2.8) <input type="radio"/> C+ (2.2-2.4)	<input type="radio"/> C (1.9-2.1) <input type="radio"/> C- (1.5-1.8) <input type="radio"/> D+ (1.2-1.4)	<input type="radio"/> D (0.9-1.1) <input type="radio"/> D- (0.7-0.8) <input type="radio"/> E (0.0)	<input type="radio"/> Pass <input type="radio"/> Credit <input type="radio"/> No Credit	■	■	■	■
31. In regard to your academic program, is this course best described as:	<input type="radio"/> In your major? <input type="radio"/> In your minor?	<input type="radio"/> A distribution requirement? <input type="radio"/> A program requirement?	<input type="radio"/> An elective? <input type="radio"/> Other?	■	■	■	■	■	