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Active-Learning-Based Engineering at a Community College: A Key to Student Success

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Incorporating Active Learning and Standards-based Grading in a Community College Engineering Course: A Path to Student Success

Abstract

This paper describes an introductory engineering course utilizing active learning strategies and standards-based grading. This first-year course for engineering and technology students at a community college emphasizes working in teams to complete hands-on activities using EXCEL and structured programming with MATLAB.

Initial assignments involve using EXCEL to display and analyze data from Ohm's Law and the speed of sound in air. The next assignment requires distance measuring with ultrasound and designing an ultrasonic range-finder. In the remainder of the assignments over the final three-quarters of the semester, MATLAB is used as a structured programming language to first control the movement of a stepper-motor rotor and then to identify different translucent materials from their visible light spectra as measured by a spectrometer. A final project combines the stepper-motor rotor with spectroscopy to automatically identify different oils by their spectra produced with a tungsten lamp.

Oral communication expertise is a very empowering skill-set to possess and being able to work well in a group and to deliver a presentation are highly prized job skills. To further reinforce the learned concepts and to incorporate another valuable skill-set, students are required to deliver over the course of the semester three presentations of their projects.

Standards-based evaluation is used to assess each student's submissions. Standards for each week's submissions are published at the beginning of the semester and reemphasized as needed. As the course has a goal of facilitating learning, and encouraging the mastery of new skills rather than penalizing mistakes, resubmission of assignments that have not reached the required standard is allowed and encouraged.

During the first four years of this course, Supplementary Instruction (SI) with SI Leaders was gradually introduced and is now incorporated into all sections of the course including adjunct instructor offerings.

To document student success, data on student achievement in the course has been collected for twenty-two sections of the course over a span of four and one-half years. Data on course completion rates for this course will be presented and compared to course completion rates for other engineering courses at the community college which do not have SI and to the course completion rates for all courses at the community college. Longitudinal data on student persistence in engineering at the community college and on engineering students transferring to the university will also be presented.

Introduction

This paper describes a first-year, engineering course utilizing active learning[1, 2] at Northern Essex Community College (NECC), one of fifteen public community colleges in Massachusetts. The course, Engineering Essentials and Design, has a minimal prerequisite of the student being ready for college level mathematics and was designed for first-semester engineering students. In practice, up to one-half of the students enrolled in the course have already earned more than 15 college credits.

Engineering Essentials and Design uses hands-on lab activities and the writing of structured programs in MATLAB to engage students and promote active learning in engineering. In the second quarter of the course, the MATLAB programs student teams write are used to control the movement of stepper-motor driven rotors. In the second half of the course, MATLAB programs are written to gather data from visible light spectrometers and to analyze that data to identify different colored filters and then later to identify different oils. The final project involves automatically moving the samples of oil into a sample chamber and correctly identifying pure olive oil.

To assess students' mastery of the subject matter, standards-based assessment[3] has been used throughout the course each time it has been offered. As is typical in a standards-based course, students in Engineering Essentials and Design are given every opportunity to demonstrate that they have achieved mastery of the prescribed standards. In the student-written programs, the general standards are that the MATLAB code not only works correctly and achieves the desired result, but that it is properly structured, adequately commented, and clearly understandable.

The origins of this course and its development over the first three semesters (Fall 2011, Spring 2012, and Fall 2012) have been described in a previously published paper.[4] This new paper looks at the evolution of the course over the subsequent six semesters (Spring 2013, Fall 2013, Spring 2014, Fall 2014, Spring 2015, and Fall 2015).

Since its inception, this 3-credit course (two lecture hours and 2 lab hours) has been scheduled as four consecutive 50-minute periods on a single day or evening in a dedicated classroom/lab in the Technology Center of NECC. During each 200-minute session, needed breaks are taken by individual students at their discretion. Because of the interesting nature of the course, excessive breaks have never been a problem.

Tests have never been used for assessment, although a few short quizzes have been administered occasionally to ascertain the grasp of MATLAB concepts by the entire class. Instead of tests, assessment of student learning has been done through evaluation of weekly student assignments by the instructor. Each assignment has been completed by each team of two or three students in the classroom/lab, shown to the instructor during the session for approval, and then submitted via Blackboard by each individual for grading. Over the length of the course, each student team creates three PowerPoint presentations that are presented in front of the entire class, including a Final Presentation of the last programming project. The Final Presentation is used as an assessment tool instead of a final exam.

Course Content

Each week of the course has hands-on activities to be completed by the students working in teams after a brief presentation of material by the instructor. Most activities of the first three weeks involve using EXCEL for data analysis, curve fitting, and display. In the following weeks, student teams write MATLAB code. The first programs control a stepper-motor-rotor, a stepper-motor driven device which rotates a pointer around a circular dial. Subsequent programs analyze spectroscopic data to identify and discriminate between colored filters and then to identify and discriminate between various cooking oils. The final assignment is to combine stepper-motor position control of curettes of oil with spectroscopic identification of oil type and automatically discriminate between extra virgin olive oil and adulterated olive oil.

All work from each week's activities must be submitted individually via Blackboard in order to receive a grade for that assignment. In addition, a few hard-copy submissions are required. The submission deadline is usually five or six days after the class session. Students are allowed to revise and resubmit work if they receive less than perfect scores on the assignments.

From the first day of the course, students are told that each and every graph, flow chart, and MATLAB program submitted via Blackboard must include a text box with names of members of the team and date on which the submitted item was created.

EXCEL is used during the first three weeks to construct charts and graphs for various sets of data. In the second week, students generate data by taking measurements of current and voltage in simple DC electric circuits involving a single resistor or a single incandescent light bulb. In the third week, EXCEL plus an oscilloscope is used to determine the velocity of sound from a 40k-Hz ultrasound module and then the ultrasound module and an oscilloscope are used in conjunction with EXCEL to design and build an ultrasonic range finder.

In weeks four and five, an introduction to procedural programming, basic building blocks for procedural programming and rules for constructing proper flowcharts for procedural programs are introduced. MATLAB is used as a procedural programming language to develop the script files and functions needed to control the stepper-motor- rotor which can be rotated around a 360^{O} dial. Two position sensors on the dial are used to sense the position of the rotor. Students are given five previously written m-files for them to use in this work. Two of the m-files specify the direction of the rotation, either clockwise or counterclockwise. Another m-file advances the stepper motor by one step. The two remaining m-files read voltage from one of the two photosensors on the dial. As the rotor passes over a sensor, the light falling on the sensor will be reduced and the voltage read from the sensor will increase in value.

During the last six weeks of the course, each student team writes script files and functions in MATLAB that analyze data from a compact spectrometer in the 350-700 nm range and a tungsten lamp. The MATLAB code produced must determine the spectra of various colored filters and identify automatically each colored filter. To interface with the spectrometer and retrieve data from the spectrometer, students are provided with five MEX files which are executable files written in C++, provided by the manufacturer of the spectrometer. In doing the

procedural programming in MATLAB, students learn how to work with large arrays of data, including the important topic of indexing in MATLAB.

A final project, completed by each team, combines positioning with a stepper motor rotor and spectroscopic identification of various oils. Spectroscopic ID of oils in curettes is achieved by mounting curettes on an upside-down rotor and using MATLAB-controlled positioning of the rotor to place the sample curettes between the light source and the spectrometer. Once in position, additional MATLAB code identifies the type of oil. Student teams receive minimal direction but the instructor and the SI leader are ready with support and advice. Instead of a final exam, a final presentation of Auto_Oil_ID is made by each team. The final presentation is done in PowerPoint with students encouraged to include video of their projects in action.

EST104 Schedule of topics for fall 2015

- Week 1-3 EXCEL with applications to Ohm's Law and the Speed of Sound in air; designing an ultrasonic range finder.
- Week 4 Flowcharting and Procedural Programming
- Week 5-8 MATLAB – Programming a Stepper Motor in MATLAB
- Week 9-11 Spectroscopic ID of colored filters using a spectrometer and MATLAB
- Week 12 Spectroscopic ID of oils using visible light, a spectrometer, and MATLAB
- Week 13-14 Combining positioning by stepper-motor rotor with spectroscopic ID of oils using visible light, a spectrometer, and MATLAB
- Week 15 Final Presentations

Students can earn a total of 200 points. As shown below in Table 1 the assignments for the first eight weeks are each worth 10 points. The assignments for weeks 9 through 15 are worth more because of the increasing sophistication of the work.

Week	EXCEL Graphs	Other	WORD Documents	PowerPoint Presentations	MATLAB programs	MATLAB plots	Flowcharts	Points
1	2	2	2					10
2	3							10
3	1		1					10
4							3	10
5				1	6			10
6					6		3	10
7					5			10
8				1	2	2		10
9			1			4		20
10					3	6		20
11					1			20
12					1	1		15
13					1			15
15				1	1	1		30

Table 1 Types of Work Submitted on Blackboard by Week (200 points total)

Supplemental Instruction

During the first two years of this course, Supplementary Instruction (SI) was gradually introduced and, by year three, SI was incorporated into all sections of the course including all DCE offerings.

At NECC, each course designated for SI is assigned an SI Leader, a student who has taken the course before and received a grade of A or A-. The SI Leader is identified before course registration begins and the time and day of the SI sessions are made known to the students before they register for the course.

At NECC, the time for the SI sessions has evolved into either two hours of SI before or after the usual 3.5 hour class session with the instructor. Another SI format is one hour before and one hour of SI after the 3.5 hour class session. Each SI Leader attends each 3.5 hour class session alongside students enrolled in the class. This arrangement is an invaluable help with all of the hands-on activities in EST104. In addition to class time, the SI Leader conducts additional sessions for students outside of regular class time without the instructor present.

Any student from any of the three sections of EST104 that are typically offered each semester may attend any of the SI sessions that are held each week. Since the three sections share a common syllabus and have identical assignments, each SI leader is able to help any student from any section of the course.

Attendance at the SI sessions is optional, but incentive is provided by offering up to 10 points of extra credit for SI attendance. Attendance at the SI sessions is recorded and tabulated with a program called TutorTrac.[5] Weekly summaries of student attendance at each of the three SI sessions are provided to the instructor by the college's Tutor Center.

Because of the activity-based, hands-on nature of EST104 at NECC, these optional SI sessions must take place in the one classroom/lab which has both MATLAB and the required lab equipment: the stepper-motor rotors, control boxes, DAQs, and spectrometers. This classroom/lab is only open to students when the SI Leader is there to supervise.

Supplemental Instruction (SI) has been an added feature of every one of the 18 sections of this course that have been offered beginning with the spring 2013 semester. Financial support from local industry has been essential to this inclusion of SI.

Eliminating the textbook

In the Fall of 2015, the textbook was replaced by course notes and extensive written tutorials, the 60 or so pages of which are printed by the college (with financial support from a local engineering company), placed in loose-leaf binders, and distributed free-of-charge to the students. With money saved by no required textbook, students are encouraged to buy a student edition of MATLAB at about 1/3 of the cost of a textbook. To reinforce the importance of MATLAB in engineering, later courses in Math and Engineering at the college include additional

problems and applications employing MATLAB. For those students unable or unwilling to purchase the student edition of MATLAB, available links to FreeMat and Octave are publicized.

How well does this particular course work at NECC?

In an earlier paper[6], it was described how, after initially looking at grade distributions, the department eventually decided to measure success by a Course Completion Rate (CCR) for all students enrolled in the course and by a Persistence in Engineering rate for those who had completed the course with a grade of C or better.

Course Completion Rate (CCR)

To measure the success of the EST104 course, a Course Completion Rate (CCR), defined as the percentage of Grades (A-C) but not including C-, was used.

In February of 2013 a report[7] about the academic standing of students who had received a letter grade in EST104 was submitted by the Director of Institutional Research at NECC.

Table 2 compares the CCR for the first seven sections of EST104 (fall 2011, spring 2012, and fall 2012) to the CCR of all the EST courses for Fall 2012 and the CCR for the total grades for all courses at NECC in Fall 2012.

EST courses included Engineering Essentials and Design, Engineering Design Graphics, Computer-Aided Drafting I, Computer-Aided Drafting II, Statics, and Engineering Circuit Analysis.

	Overall CCR All Students			Overall CCR Only Freshmen			Overall CCR Only Sophomores		
	Total grades	Grades A- C	CCR%	Total grades	Grades A- C	CCR%	Total grades	Grades A- C	CCR%
EST104 (7 sections)	135	102	75.6%	93	68	73.1%	42	34	81.0%
All Other EST - Fall 2012	172	121	70.3%	106	68	64.2%	66	53	80.3%
Total NECC grades	20,521	14,725	71.8%	13,587	9,419	69.3%	6,934	5,306	76.5%

Table 2 Course Completion Rate (CCR) for All Students, Only Freshmen, and Only Sophomores as of the end of Fall 2012 semester.

Table 2 shows that the overall CCR for the seven sections of EST104 was higher than the CCR for all EST courses and the CCR of all courses at NECC in the fall 2012. And it should be noted that this was true for both freshmen and sophomores in fall 2012.

In December 2015, a report[8] from the Director of Institutional Research showed that the higher CCR for both freshmen and sophomores enrolled in EST104 held for one more semester (Spring 2013), but then the CCR for both freshmen and sophomores enrolled in EST104 fell behind the CCRs for All EST and Total CC grades in the fall 2013 semester. Table 3 below summarizes that report and shows that the sophomores outperformed the freshmen in fall 2013 as often happened in a given semester. Because of more college level courses completed by the sophomores including higher level mathematics courses, this result was not really very surprising.

Fall 2013	Overall CCR All Students			Overall CCR Only Freshmen			Overall CCR Only Sophomores		
	Total grades	Grades A- C	CCR%	Total grades	Grades A- C	CCR%	Total grades	Grades A- C	CCR%
EST104	60	41	68.3%	36	21	58.3%	24	20	83.3%
All Other EST	194	140	72.2%	110	75	68.2%	84	65	77.4%
Total NECC grades	20,161	14,519	72.0%	13,332	9,329	70.0%	6,829	5,190	76.0%

Table 3 Course Completion Rates (CCR) for All Students, Only Freshmen, and Only Sophomores Fall 2013.

Tables with the CCRs for each of the six semesters (3 sections of EST104 were offered per semester) from Spring 2013 through Fall 2015 are included in Appendix A and show some fluctuation in the CCR in each semester over that span, but clearly there was a slight decrease overall in the CCR over the six semesters. Table 4 below summarizes the CCRs for the 18 sections of the course which were offered over the six semesters from Spring 2013 to Fall 2015.

Spr 2013 - Fall 2015	Overall CCR All Students			Overall CCR Only Freshmen			Overall CCR Only Sophomores		
	Total grades	Grades A- C	CCR%	Total grades	Grades A- C	CCR%	Total grades	Grades A- C	CCR%
EST104	535	372	69.5%	357	230	64.4%	178	142	79.8%
All Other EST	17452	12743	73.0%	9911	6861	69.2%	7541	5882	78.0%
Total NECC grades	109,215	79,374	72.7%	67,335	46,940	69.7%	41,880	32,434	77.4%

Table 4 Course Completion Rates (CCR) for All Students, Only Freshmen, and Only Sophomores over the period Spring 2013 - Fall 2015.

Conclusions about CCR and Quantity and Quality of Student Work

Table 4 of Course Completion Rates (CCRs), when compared to the CCRs for the first three semesters, shows that the CCRs have declined slightly over the last six semesters.

However, as reported by the course instructors, the quantity and the quality of the work accomplished by the students have risen dramatically. In fall 2011, the first semester that EST104 was offered, only one group of students attempted a final project to automatically move a curette of oil into the sample chamber and correctly identify the type of oil. By fall 2014, most of the teams were at least attempting this activity. By fall 2015, almost all of the teams succeeded in automatically moving the curettes of oil into the sample chamber and correctly identifying the extra virgin olive oil.

Persistence at NECC by Students Completing EST104

In an attempt to gauge the effect on persistence at NECC of students completing EST104 during the first three semesters of its operation, a Success Rate was calculated.

The Success Rate is the percentage of students from a given major receiving a letter grade in EST104 who subsequently received either an Associate's degree or a certificate from NECC or left NECC in Good Academic Standing but without a degree or who were still students and currently enrolled in courses at NECC. Non-successful students were defined as those students receiving a letter grade in EST104 who subsequently left NECC] on probation or left under suspension.

The following table, Table 5 shows what happened to the students, grouped according to major, after they received a grade in EST104 during one of the three semesters. In the tables, ES stands for Engineering Science, ET stands for Electronic Technology, and CIS stands for Computer Information Sciences. LA stands for Liberal Arts and Gen Studies stands for General Studies.

Status (as of February, 2013) of students receiving grade in EST104 in Fall 2011, Spring 2012 and Fall 2012							**Success Rate**
Major	**Rcvd NECC Degree**	**Still at NECC**	**Left NECC in Good Standing**	**Left on Probation**	**Left NECC Suspended**	**Total**	
ES	**8**	**79**	**11**	**4**	**1**	**103**	**95.1%**
ET	**2**	**3**				**5**	**100%**
CIS		**5**				**5**	**100%**
Unclassified					6	6	0%
Business		2		1	3	7	28%
Gen Studies		1				1	
LA		2				2	
Healthcare		1	1			2	100%

Table 5 Persistence as of February, 2013 for all EST104 Students from Fall 2011, Spring 2012 and Fall 2012

Table 5 shows that of the 103 students in engineering who had taken EST104 and received a letter grade, 95.1% of them either received a degree in engineering, were still enrolled students at NECC, or had left NECC in good standing. ("Leaving in good standing" usually means transferring without receiving a degree.)

On March 11, 2016, NECC's Office of Institutional Research reported on the persistence as of the fall of 2015 of those students who had taken EST104 in the spring of 2013.[9]

Table 6 below summarizes the persistence of this cohort.

Status (as of fall 2015) of students receiving grade in EST104 in Spring 2013							Success Rate
	Rec'd NECC Degree /Cert	Trans-ferred	Still at NECC	Left in good standing	Left on Probation or suspension	Total	
Eng Sci	12	7	1	13	1	34	97%
CAD	6			2		8	100%
BM				1		1	100%
BT	1			2		3	100%
Cert Electronic Equip	2					2	100%
CIS			1			1	100%
EKG		1				1	100%
Electronic Tech			1			1	100%
Gen Studies				1		1	100%
LA		1		3		4	100%
Unclassified		1				1	100%
	21	10	3	22	1	57	98%

Table 6 Persistence as of fall 2015 for all EST104 Students from spring 2013

Table 6 shows that the persistence of EST104 students remains strong. The success rate of the students who received a letter grade in the course is 97%, two plus years after the end of the spring 2013 semester. Compared with the cohorts from fall 2011, spring 2012, and fall 2012 whose persistence over two to fourteen months was summarized in Table 5, the persistence of all EST104 Students from spring 2013 is higher and it is measured over a longer span of time, two and one-half years.

Conclusion about Persistence in Engineering

An examination of the persistence of engineering students at NECC as measured by success rate has led NECC to conclude that Engineering Essentials and Design is working very well.

To address concerns that students completing EST104 might not be staying in engineering, the NECC Office of Institutional Research looked again at the data and concluded that as of February, 2016, excluding those students who left on probation or suspension, 81 % of the students from Spring 2013 who remained at NECC were still enrolled in a STEM major; 91 % of the students from Fall 2013 were still enrolled in a STEM major; and 92 % of the students from Spring 2014 were still enrolled in a STEM major.[10]

Challenges

Finding financial support for SI is a challenge. NECC funds are limited and there is institutional pressure to apply what funding is available to courses with historically high failure rates, the so called "gate-keeper" courses. In exchange for on-going NECC training of technicians for Raytheon, a local high tech company, Raytheon has donated funds to NECC, a portion of which funds are used to support SI.

The classroom/lab is cramped with eleven two-person lab benches arranged along the sides and back of the room and 10 two-person tables plus a special desk for students with disabilities arranged in three rows in the middle in front of the instructor's desk. There are also twenty-two adjustable height chairs on rollers to provide seating at either the lab benches or the tables. The two-person tables plus the twenty-two seats all have wheels which does allow for limited reconfiguring of the room, but the reconfiguring must be carefully managed.

The stepper-motor rotors and the controller boxes were built by a local technical school using plans provided by a local university. The rotors and control boxes are often in need of repair. With no NECC technical staff available for repair and refurbishment of this equipment, the Program Coordinator has had to seek funding for repairs from local industry. In exchange for on-going NECC training of Raytheon technicians, Raytheon has sent money to NECC, a portion of which funds are used to support maintenance and repair of the equipment.

An annoying challenge is that a number of students just copy and paste without thinking about what they are doing. These students are satisfied when a MATLAB program apparently works, even if they don't understand why it works. One solution to this problem was finally realized when several examples of possible code to accomplish a specific task were published in the hard-copy of the course tutorials that are distributed to each student but the examples were blocked from appearing in the on-line version of the course tutorials available for downloading from Blackboard. Now, instead of being able to mindlessly "copy and paste," students are required to choose one possible approach from several suggested possibilities and then key the chosen code into the MATLAB editor.

A really significant challenge is for the course instructor to find enough time to assess all of the submissions. Unlike professors at universities where there are TAs, instructors at community colleges have to do all of the grading themselves. If one were to use Table 1 and tally up the submissions from each student over the course of a semester, the total is 61 separate submissions. If 20 students are enrolled in a section of this course, the instructor has to grade 1200 separate submissions over the fifteen weeks, an average of 80 submissions per week.

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Appendix A.

Course Completion Rates from Spring 2013 to Fall 2015 for Fall and Spring terms only. Comparison of All Grades in CC, All Grades in EST Courses, All Grades in EST 104 Engineering Essential & Design. (Note: Freshmen are students with less than 30 earned credits at the beginning of the semester; Sophomores are students with 30 or more earned credits at the beginning of the semester.) Report completed January 20, 2016

Spring 2013	Overall CCR			Overall CCR Only Freshmen			Overall CCR Only Sophomores		
	Total grades	Grades A- C	CCR%	Total grades	Grades A- C	CCR%	Total grades	Grades A- C	CCR%
EST104	57	44	77.2%	35	24	68.6%	22	20	90.9%
All EST	160	113	70.6%	82	53	64.6%	78	60	76.9%
Total CC grades	18,811	13,630	72.5%	10,893	7,531	69.1%	7,918	6,099	77.0%

Fall 2013	Overall CCR			Overall CCR Only Freshmen			Overall CCR Only Sophomores		
	Total grades	Grades A- C	CCR%	Total grades	Grades A- C	CCR%	Total grades	Grades A- C	CCR%
EST104	60	41	68.3%	36	21	58.3%	24	20	83.3%
All EST	194	140	72.2%	110	75	68.2%	84	65	77.4%
Total CC grades	20,161	14,519	72.0%	13,332	9,329	70.0%	6,829	5,190	76.0%

Spring 2014	Overall CCR			Overall CCR Only Freshmen			Overall CCR Only Sophomores		
	Total grades	Grades A- C	CCR%	Total grades	Grades A- C	CCR%	Total grades	Grades A- C	CCR%
EST104	53	40	75.5%	36	29	80.6%	17	11	64.7%
All EST	204	151	74.0%	110	82	74.5%	94	69	73.4%
Total CC grades	17,871	13,078	73.2%	10,349	7,210	69.7%	7,522	5,868	78.0%

Fall 2014	Overall CCR			Overall CCR Only Freshmen			Overall CCR Only Sophomores		
	Total grades	Grades A- C	CCR%	Total grades	Grades A- C	CCR%	Total grades	Grades A- C	CCR%
EST104	58	34	58.6%	47	26	55.3%	11	8	72.7%
All EST	187	132	70.6%	131	88	67.2%	56	44	78.6%
Total CC grades	18,532	13,599	73.4%	12,101	8,531	70.5%	6,431	5,068	78.8%

Spring 2015	Overall CCR			Overall CCR Only Freshmen			Overall CCR Only Sophomores		
	Total grades	Grades A- C	CCR%	Total grades	Grades A- C	CCR%	Total grades	Grades A- C	CCR%
EST104	58	36	62.1%	41	23	56.1%	17	13	76.5%
All EST	190	136	71.6%	115	77	67.0%	75	59	78.7%
Total CC grades	16,357	11,949	73.1%	9,256	6,410	69.3%	7,101	5,539	78.0%

Fall 2015	Overall CCR			Overall CCR Only Freshmen			Overall CCR Only Sophomores		
	Total grades	Grades A- C	CCR%	Total grades	Grades A- C	CCR%	Total grades	Grades A- C	CCR%
EST104	59	41	69.5%	47	30	63.8%	12	11	91.7%
All EST	160	122	76.3%	107	76	71.0%	53	46	86.8%
Total CC grades	17,483	12,599	72.1%	11,404	7,929	69.5%	6,079	4,670	76.8%