Program Assessment Plan

Program: Computer Engineering, B.S.

Department: School of Engineering

College/School: Parks College of Engineering, Aviation and Technology

Date: 5-21-19

Primary Assessment Contact: Kyle Mitchell

Note: Each cell in the table below will expand as needed to accommodate your responses.

#	Program Learning Outcomes	Assessment Mapping	Assessment Methods	Use of Assessment Data
	What do the program faculty expect all students to know, or be able to do, as a result of completing this program? ▪ *Note: These should be measurable, and manageable in number (typically 4-6 are sufficient).*	From what specific courses (or other educational/professional experiences) will artifacts of student learning be analyzed to demonstrate achievement of the outcome? Include courses taught at the Madrid campus and/or online as applicable.	What specific artifacts of student learning will be analyzed? How, and by whom, will they be analyzed? ▪ *Note: the majority should provide direct, rather than indirect, evidence of achievement.* Please note if a rubric is used and, if so, include it as an appendix to this plan.	How and when will analyzed data be used by faculty to make changes in pedagogy, curriculum design, and/or assessment work? How and when will the program evaluate the impact of assessment-informed changes *made in previous years*?
1	*(a) an ability to apply knowledge of mathematics, science, and engineering*		The collected material will be analyzed by the course instructor and by one other instructor knowledgeable in the discipline. These initial assessments will be discussed by the whole department for generation of curriculum change ideas.	Assessment data will be collected each semester based on the cycle presented below. This data will be analyzed once per year at the end of the spring semester. During the analysis changes will be proposed. These changes will be developed and implemented over the next year. This will leave one year to evaluate the material for completeness and one year to collect material for assessment during the next 3rd year cycle.
2	*(b.1) an ability to design and conduct experiments*			
3	*(b.2) an ability to analyze and interpret data*			
4	*(c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic,*			

	environmental, social, etc.			
5	*(d) an ability to function on multidisciplinary teams*			
6	*(e) an ability to identify, formulate, and solve engineering problems*			
7	*(f) an understanding of professional and ethical responsibility*			
8	*(g) an ability to communicate effectively*			
9	*(h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context*			
10	*(i) a recognition of the need for, and an ability to engage in life-long learning*			
11	*(j) a knowledge of contemporary issues*			
12	*(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice*			

Additional Questions

1. On what schedule/cycle will faculty assess each of the above-noted program learning outcomes? *(It is* ***not recommended*** *to try to assess every outcome every year.)*

We will assess the outcomes on a three year rotating basis. A,B,C,D in AY17 and AY20, E,F,G,H in AY18 and AY21, I,J,K in AY19 and AY22.

2. Describe how, and the extent to which, program faculty contributed to the development of this plan.

The outcomes are given to us by our accrediting body. We are free to envision out own outcomes but if we choose to do that we must create a mapping to show these 12 are being measured and assessed by one we create.

The locations, tools and rubrics are a creation of the entire department faculty.

The cycle is determined by the department faculty and necessitated by the accrediting body's six year review cycle.

3. On what schedule/cycle will faculty review and, if needed, modify this assessment plan?

As part of the assessment review at the end of each academic year the plan will undergo minor update. Prior the our ABET every six years the plan will undergo major review.

Minor review being: are we collecting meaning full data, does the assessment rubric measure what we what to measure, are we measuring in the correct place …

Major review being: adoption of new outcomes, revising of the assessment order …

IMPORTANT: Please remember to submit any assessment rubrics (as noted above) along with this report.
See additional documents

CONTINUOUS IMPROVEMENT

Student Outcome Assessment Process

At the time of our last ABET general review in 2012, the Computer Engineering continuous improvement process required further refinement. The department developed and put forth a document that established a roadmap for developing and implementing the process over the course of several years. During this time, the assessment process was developed at the same time course materials were collected and informally evaluated.

The following figure describes the continuous improvement process as conceived by the faculty. The first step in the process was to break down each SO into smaller conceptual parts, which we refer to as *indicators*, that are more easily defined and measured using course materials. The complete set of current indicators are given in subsections to follow. These indicators were initially developed in the spring of 2013 as part of implementing the roadmap, however they have since been modified primarily for clarity.

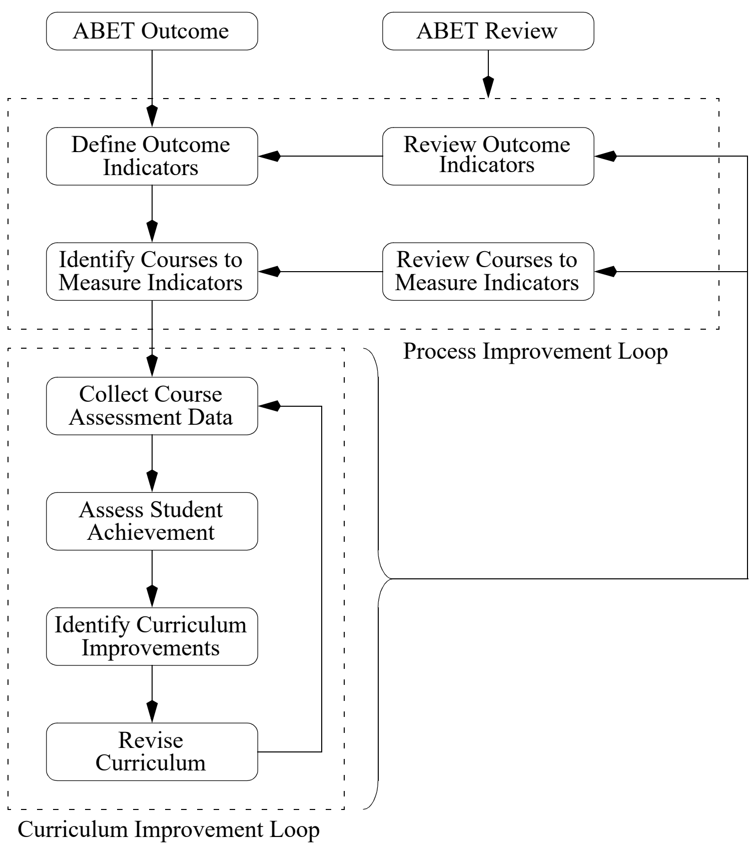

FIGURE 4.1 Overview of continuous improvement process.

The indicators were then associated with various courses in the curriculum and, in most cases, specific assignments were identified for measuring those indicators. In other cases, such as ECE3090 Junior Design and ECE4800/4810 Senior Design, evidence for those indicators were sought in collected materials such as project notebooks, technical reports, and/or technical presentations. A complete list of the SO indicators are given in subsequent subsections.

Each semester, course materials are to be collected and assessed to determine a quantitative measure of how well the outcomes were achieved by a subset of students. For each assessment measure, six (6) examples are selected at random and from those, three (3) are selected, one of which appears high (good), medium (average), and low (below average). The three (3) sample materials are given a quantitative measure of performance in relation to the SO for each indicator using a simple rubric. A complete list of the SO indicator rubrics are given in subsequent subsections.

Each SO is assessed in one or more courses over a span of one academic year, on a 3 year rotating schedule. At the end of an academic year in which an SO is evaluated, that SO is discussed at a faculty meeting, typically in early May, to determine

- What improvements can be made to the program courses in order to enhance that outcome
- What improvements can be made to the assessment process itself, such as which course or which material is used to assess that indicator.

Improvements to the program generally relate to the modification of course material, changes to prerequisites, and/or full course changes in the program curriculum. Improvements in the assessment process itself can involve changing which courses are used to measure an indicator and/or which specific material is collected and assessed. The decisions related to improving the process itself are focused on improving the degree to which the collected data discriminates the student performance for a specific outcome.

Student Outcome Assessment Materials

The assessment of each criteria is to occur every three years to give two complete assessments during a 6 year window. In this sense, the loop is closed twice each interim periods between ABET evaluations. Since our process of continuous improvement for the 2012-2018 ABET cycle was developed during the early part of this period, the loop was closed for each SO only once. In fact, according to our schedule, SO's i, j, and k were not to be assessed and the loop closed until Spring 2019, however, those three SO's were assessed at the end of the Spring 2018 semester so the loop could be closed on those as well.

The Student Outcomes (SO) are assessed in specific courses and generally with specific assignments in those courses. Although the assessments occur in specific courses, all other major courses address, to some degree, various SO's as well. A table showing the SO's for each course in the curriculum in given in the Criterion 5 section. The courses used to assess each SO is given in the following table.

TABLE 4.1 Course assessment matrix.

Course \ SO	**a**	**b.1**	**b.2**	**c**	**d**	**e**	**f**	**g**	**h**	**i**	**j**	**k**
ECE1001 - ECE Intro I											X	
ECE2103 - Circuits II Lab	X											X
ECE2206 - Digital Lab												X
ECE3090 - Junior Design		X	X		X	X		X		X		
ECE3130 - Semiconductors	X											
ECE3132 - Electronics Lab				X								X
ECE3151 - Linear Sys Lab	X	X	X			X						X
ECE3226 - Microprocessors Lab												X
ECE4800/4810 - Senior Design	X	X	X	X	X	X	X	X	X	X	X	

There are a few courses that deserve special mention:

- ECE3090 Junior Design
- ECE3151 Linear Systems Laboratory
- ECE4800 & ECE4810 Senior Design 2-course sequence

The ECE4800 & ECE4810 courses are considered to be especially important because students are required to demonstrate some degree of proficiency in engineering practice by carrying out an engineering design with an engineering team consisting of peers. This is a two-course sequence, 3 credits per course, that spans one complete academic year (fall/spring) with the engineering team intact the entire year.

The ECE3090 course was originally introduced as a preparatory course for the Senior Design course to give students an opportunity to practice some of the unique skills required in Senior Design, with the goal of improving the outcomes in Senior Design. To this end, this course requires, in part, that a student group develop an experiment to measure the internal resistance of a battery and to carry out that experiment. The goal here is to measure a specific set of SO’s. Furthermore, since this assessment tool is given each time this course is taught, it provides a way of comparing the performance of students across different years.

The ECE3151 course requires that student groups work project-based laboratories that have some degree of open-ended requirements. For example, students are required to model systems, create calibration functions, and look up information on their own to solve engineering problems, none of which necessarily have unique solutions. This course is used to measure specific SO’s.

Assessment Schedule

Each Student Outcome is assessed on a 3-year rotating schedule as shown in the figure below.

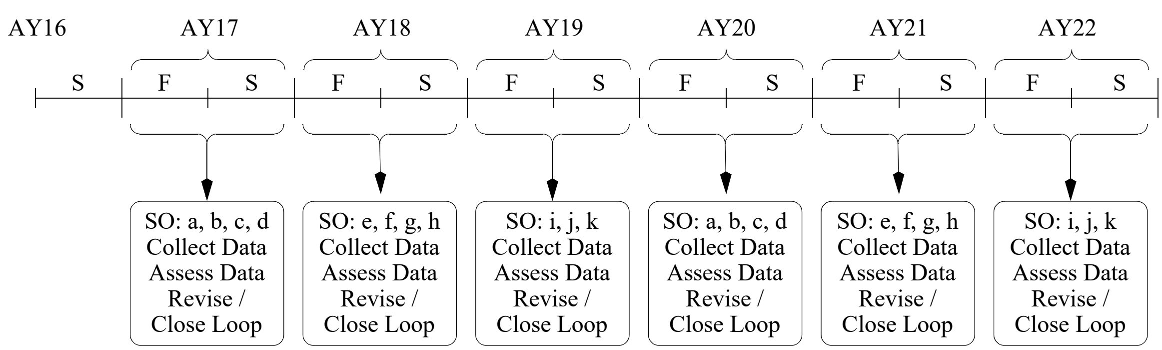

FIGURE 4.2 Student Outcome assessment schedule.

TABLE 4.2 Projected assessment schedule by semester for AY19 through AY24.

Sem	SO	Courses	Dev/Eval
F16	a	ECE3151	evaluate
	b	ECE3151	evaluate
	c	N/A	
	d	N/A	

TABLE 4.2 Projected assessment schedule by semester for AY19 through AY24.

Sem	SO	Courses	Dev/Eval
S17	a	ECE2103, ECE3130, ECE4800/4810	eval/close loop
	b	ECE3090, ECE4800/4810	eval/close loop
	c	ECE3132, ECE4800/4810	eval/close loop
	d	ECE3090, ECE4800/4810	eval/close loop
Faculty “close-the-loop” meeting at the end of final exams in May.			
17	e	ECE3151	evaluate
	f	N/A	
	g	ECE3151	evaluate
	h	N/A	
S18	e	ECE3090, ECE4800/4810	eval/close loop
	f	ECE1002, ECE4800/4810	eval/close loop
	g	ECE1002, ECE3090, ECE4800/4810	eval/close loop
	h	ECE4800/4810	eval/close loop
Faculty “close-the-loop” meeting at the end of final exams in May.			
F18	i	ECE3151	evaluate
	j	N/A	
	k	ECE2206	evaluate
S19	i	ECE3090, ECE4800/4810	eval/close loop
	j	ECE1001, ECE4800/4810	eval/close loop
	k	ECE2103, ECE3132, ECE3226	eval/close loop
Faculty “close-the-loop” meeting at the end of final exams in May.			
F19	a	ECE3151	evaluate
	b	ECE3151	evaluate
	c	N/A	
	d	N/A	
S20	a	ECE2103, ECE3130, ECE4800/4810	eval/close loop
	b	ECE3090, ECE4800/4810	eval/close loop
	c	ECE3132, ECE4800/4810	eval/close loop
	d	ECE3090, ECE4800/4810	eval/close loop
Faculty “close-the-loop” meeting at the end of final exams in May.			
F20	e	ECE3151	evaluate
	f	N/A	
	g	ECE3151	evaluate
	h	N/A	
S21	e	ECE3090, ECE4800/4810	eval/close loop
	f	ECE1002, ECE4800/4810	eval/close loop
	g	ECE1002, ECE3090, ECE4800/4810	eval/close loop
	h	ECE4800/4810	eval/close loop
Faculty “close-the-loop” meeting at the end of final exams in May.			

TABLE 4.2 Projected assessment schedule by semester for AY19 through AY24.

Sem	SO	Courses	Dev/Eval
F21	i	ECE3151	evaluate
	j	N/A	
	k	ECE2206	evaluate
S22	i	ECE3090, ECE4800/4810	eval/close loop
	j	ECE1001, ECE4800/4810	eval/close loop
	k	ECE2103, ECE3132, ECE3226	eval/close loop
Faculty “close-the-loop” meeting at the end of final exams in May.			
F22	a	ECE3151	evaluate
	b	ECE3151	evaluate
	c	N/A	
	d	N/A	
S23	a	ECE2103, ECE3130, ECE4800/4810	eval/close loop
	b	ECE3090, ECE4800/4810	eval/close loop
	c	ECE3132, ECE4800/4810	eval/close loop
	d	ECE3090, ECE4800/4810	eval/close loop
Faculty “close-the-loop” meeting at the end of final exams in May.			
F23	e	ECE3151	evaluate
	f	N/A	
	g	ECE3151	evaluate
	h	N/A	
S24	e	ECE3090, ECE4800/4810	eval/close loop
	f	ECE1002, ECE4800/4810	eval/close loop
	g	ECE1002, ECE3090, ECE4800/4810	eval/close loop
	h	ECE4800/4810	eval/close loop
Faculty meeting at the end of final exams in May.			

The assessment process will include a meeting of the program faculty at the beginning of each semester, the week before classes begin and a meeting at the end of each semester towards the latter part of final exam week. At the beginning-semester meeting, the faculty will review the specific criteria to be assessed in that particular semester and the specific assessment materials that will need to be collected by the end of that semester in order to complete the assessment process. At the end-of-semester meeting, faculty will bring materials to be assessed, those materials will be assessed by at least 2 faculty, and the results discussed. If the end-of-semester meeting is at the end of the Spring semester, then faculty will also discuss and determine whether curricular changes need to be made or whether the assessment instruments need to be changed, effectively *closing the loop*. These meetings are intended to keep the faculty on track to carry out the process of continuous improvement on a regular basis and in real-time.

In order to document the process, meeting minutes will be kept and those minutes will be documented on a library-style website specific to ABET-related materials. All assessed materials, assessment quantitative results, and curricular changes will be uploaded to the website. This website will be accessible to all program faculty and all college administrators for regular dissemination and review of results. If assessment materials are in paper form and of reasonably small size such as laboratory reports, homework, and tests, then those materials will be electronically scanned for upload to the website for ongoing documentation.

With all ABET-related materials uploaded to a website, the opportunity exists to seek input on the assessment process from other constituents, regardless of their proximity to Saint Louis or their personal schedule since they can access the website at their convenience. Such constituents could include IAB members and/or alumni. This will not substitute, however, for convening on-site IAB meetings every other year for the purpose of constituent feedback.

Assessment Indicators and Rubrics

This section describes the *indicators* and corresponding *rubrics* that have been developed for each Student Outcome (SO). The indicators are used to more easily define and measure an SO using course materials. A complete list of indicators for each outcome is given in the tables below. These tables include the courses where each outcome is evaluated along with a brief description of the material collected and assessed. We note that the ECE4800/4810 Senior Design course sequence, and to some degree the ECE3090 Junior Design course, do not identify specific course material to be evaluated, rather evidence is gathered from the project notebooks, technical reports, and the technical presentations seeking evidence as defined in the rubrics.

Quantitative measures are assessed from these materials using a simple 3-level rubric as defined in the following table. The rubric applied is different for each indicator and for each material being assessed and

TABLE 4.3 Generic indicator rubric.

Value	Rubric
3	Exceeds expectations
2	Threshold expectations
1	Does not meet expectations

is a subjective judgement as to how well a particular student work satisfies the indicator. The specific interpretation of what constitutes, for example, *Exceeds expectations* is determined by the faculty performing the assessment in the context of the course expectations and the specific material being assessed. Specific rubrics for each indicator were developed for each of the 3 levels to better define that subjective judgement for the purpose of providing consistent evaluations over the course of time.

It is not reasonable, nor necessarily beneficial, to assess every student work for a particular indicator, especially when it involves assessing project notebooks and other large documents that can take considerable time to read through. The process for selecting student work is rather simple. For each indicator, 6 students are chosen at random and their work briefly scanned for content and ranked from highest to lowest performance. The high, low, and one in the middle are chosen to perform a numerical assessment as indicated in the rubric table shown above, which is recorded.

For example, the first indicator under SO (a) is an *Ability to mathematically describe a system using scientific principles*. Within that indicator, students in ECE2102, Circuits II, are required to find the frequency response of an RLC circuit. Among the collected solutions to this problem, 6 are chosen at random to be considered. From this, the high, middle, and low are chosen for a numerical assessment according to the grade rubric. Each one is assigned a value from 1 through 3 according to the defined rubric given in TABLE 4.6. The final numerical result is the average of the 3 numbers and measures the performance of the students in the class for that particular assessed work. All the assessed works for each indicator for SO (a) are assessed in this way and averaged to create a single quantitative measure of the student performance for SO (a).

As a note, we recognize that there is a difference between assigning a grade to student work and assessing a student work for the purpose of measuring SO performance. For example, a student who does not perform an assignment would be given zero grade credit, but that missing assignment would not be used to measure SO performance because there is no student solution upon which to base an assessment. As another example, a single grade credit score may be given that includes many aspects of a student work whereas evaluating the indicator performance for a particular SO entails a very specific aspect of that work.

The classification of overall student performance of an SO is described in table TABLE 4.4 below. The word *action* refers to either curricular changes or to changes in the assessment process itself which might include which course and which student work is chosen to be assessed. For example, in some cases, the performance is low because the requirements given to the students were not clear enough.

The rest of this section contains the SO indicators and specific rubrics that are currently used to perform assessment, the course material that are used to assess each indicator, and the faculty interpretation.

TABLE 4.4 Classification of SO student performance

Average Performance	**Performance Classification**
2.5 - 3	Acceptable performance - no action required
2 - 2.5	Marginal performance - consider action
< 2	Action required

(a) an ability to apply knowledge of mathematics, science, and engineering

TABLE 4.5 Student Outcome (a) assessment indicators and descriptions.

Indicator	Course	Assessment Description
1. Ability to mathematically describe a system using scientific principles.	ECE2103	Find the frequency response of an RLC circuit.
	ECE3130	Develop an energy band diagram of a semiconductor and calculate the carrier concentration.
	ECE3151	Develop a mapping function from an autocorrelation function estimate to echo gain.
	ECE4800/ ECE4810	Exhibit through technical details found in the Project Notebook, technical reports, or technical presentations.
2. Ability to develop and analyze mathematical models for a system.	ECE2103	Find the Thevenin Equivalent of a circuit.
	ECE3130	Develop a mathematical model for a semiconductor device such as a diode or transistor.
	ECE3151	Develop the impulse response for a filter that eliminates echo in an acoustic signal.
	ECE4800/ ECE4810	Exhibit through technical details found in the Project Notebook, technical reports, or technical presentations.
3. Ability to synthesize components/systems using mathematics and engineering knowledge	ECE2103	Design an RLC circuit with a desired frequency response.
	ECE3151	Develop a software module that eliminates an echo from an acoustic signal.
	ECE4800/ ECE4810	Exhibit through technical details found in the Project Notebook, technical reports, or technical presentations.

This outcome refers to an ability to use the techniques, methods, and concepts of mathematics, science and engineering in order to achieve a goal. By “use” we mean the practical knowledge and ability to carry out appropriate calculations, such as mathematical, or to make appropriate deductions using concepts from science and/or engineering. The “goal” can refer to the simple calculation of a system parameter, formulating a system in a mathematical representation suitable for determining system characteristics, or to synthesize a system for the purpose of design. The 3 indicators chosen for this outcome are focused on the nature of the goal, but in all cases require the application of practical knowledge and require the ability to carry out appropriate calculations or make appropriate deductions using science or engineering principles.

Indicator #1: This indicator refers to the ability to put a system into a mathematical form that illuminates its characteristics.

- ECE2103: The frequency response of an RLC circuit is a mathematical description that indicates whether the circuit is acting as a bandpass filter, a bandreject filter, or a high-Q filter.

  Students will demonstrate an ability to calculate the frequency response of an RLC circuit and classify the filter characteristics as evidenced by laboratory reports.
- ECE3130: *Students will demonstrate the ability to present the energy band diagram of a semiconductor and calculate the position of the Fermi Energy Level given the impurity concentration level as evidenced by the final exam.*
- ECE3151: *Students will demonstrate an ability to develop a matlab function that extracts parameters from the autocorrelation function of an acoustic signal and use those parameters to estimate echo gain as evidenced by laboratory project reports.*

- ECE4800/ECE4810: *Students will demonstrate an ability to use mathematics or science/engineering principles to characterize a system as evidenced in the project notebooks, technical reports, or technical presentations*.

Indicator #2: This indicator refers to the ability to create a system model, which is an alternative form of the system that acts, to some degree, like the original system.

- ECE2103: *Students will demonstrate an ability to find the thevenin equivalent circuit as evidenced by laboratory reports. The Thevenin equivalent circuit is a simplified model that includes only one voltage source and one impedance/resistance. This circuit behaves the same as the one from which it is drawn*.
- ECE3130: *Students will demonstrate the ability to determine/develop the I-V Characteristics equation of semiconductor devices such as diodes and transistors as evidenced by the final exam*.
- ECE3151: *Students will demonstrate an ability to find and implement, via a matlab function, the impulse response of a system to remove an echo from an acoustic signal as evidenced by a Matlab computer program*.
- ECE4800/ECE4810: *Students will demonstrate an ability to use mathematics or science/engineering principles to create a system model as evidenced in the project notebooks, technical reports, or technical presentations*.

Indicator #3. This indicator refers to the ability to synthesize, i.e. create or specify or implement, components/subsystems using mathematics and engineering knowledge to create a larger whole.

- ECE2103: *Students will demonstrate an ability to design an RLC circuit in order to achieve a specific frequency response as evidenced by laboratory reports*.
- ECE3151: *Students will demonstrate an ability to develop a matlab function that eliminates an echo from an acoustic signal as evidenced by a Matlab computer program.* This requires that previous components be synthesized in order to create a complete working system in the form of a computer program.
- ECE4800/ECE4810: *Students will demonstrate an ability to synthesize, i.e. create or specify or implement, components/subsystems using mathematics or science/engineering principles to create a larger whole as evidenced in the project notebooks, technical reports, or technical presentations*.

The assessment rubrics are given in the following table.

TABLE 4.6 Assessment rubrics for Student Outcome (a).

	Rubric		
Ind	**1 = Does not meet Expectations**	**2 = Meets expectations**	**3 = Exceeds expectations**
	ECE2103		
1	Either the frequency response function is not correct, or the filter type is stated incorrectly.	The frequency response function is correct and the filter type is stated correctly. The calculation is either missing or has insufficient details.	The frequency response function is correct, the calculation is shown in detail, and the filter type is stated correctly.
2	Either the thevenin model is incorrect or the model is correct but the component values are incorrect.	The thevenin model is correct and the component values are correct. The calculation details are either missing or are insufficient in details.	The thevenin model is correct, component values are correct, and calculation details are shown.

TABLE 4.6 Assessment rubrics for Student Outcome (a).

	Rubric		
Ind	**1 = Does not meet Expectations**	**2 = Meets expectations**	**3 = Exceeds expectations**
3	The RLC circuit values are incorrect for achieving a filter with the desired frequency response.	The RLC circuit values are correctly for achieving a filter with the desired frequency response. The calculations are either missing or insufficient.	The RLC circuit values are correct for achieving a filter with the desired frequency response. All calculations are present and correct.
ECE3130			
1	The energy band diagram is not correct or the labeling is insufficient.	The energy band diagram is correct and is properly labeled.	The energy band diagram is correct and is properly labeled. All calculations leading to the diagram are present and correct.
2	The I-V characteristic equations are incorrect.	The I-V characteristic equations are correctly stated. The calculations are not necessarily fully detailed.	The I-V characteristic equations are correctly stated and all calculations leading to the equations are present and sufficient detailed.
ECE3151			
1	Either the R[n]/R[0] measurement is incorrect, or the polynomial fit is either incorrect or seriously deficient in modeling the data.	The R[n]/R[0] measurement is correct, the plot of R[n]/R[0] versus alpha is correct, the number of plotted points may not be statistically relevant, and a reasonable polynomial has been fit to the data.	The R[n]/R[0] measurement is correct, the plot of R[n]/R[0] versus alpha is correct, the number of plotted points is statistically relevant, and a reasonable polynomial has been fit to the data.
2	Either the inverse filter form is incorrect or the echo gain and delay are not properly used.	The inverse filter form is correct and the echo gain and delay are used properly but the number of terms is between 2 and 3.	The inverse filter form is correct and the echo gain and delay are used properly and the number of terms is above 3 leading to an accurate system model.
3	The matlab function does not properly combine the echo gain estimation from the autocorrelation function measures with the inverse filter function in order to remove the echo from an acoustic signal.	The matlab function properly combines the echo gain estimation from the autocorrelation function measures with the inverse filter function in order to remove the echo from an acoustic signal. Either one or both the echo gain estimate and inverse filter are not well defined leading to a somewhat high mean square error between the echo-removed signal and the original acoustic signal.	The matlab function properly combines the echo gain estimation from the autocorrelation function measures with the inverse filter function in order to remove the echo from an acoustic signal. Both the echo gain estimate and inverse filter are well defined leading to a low mean square error between the echo-removed signal and the original acoustic signal.
ECE4800/4810			

TABLE 4.6 Assessment rubrics for Student Outcome (a).

	Rubric		
Ind	**1 = Does not meet Expectations**	**2 = Meets expectations**	**3 = Exceeds expectations**
1	There is not sufficient evidence of any examples where mathematics and/or science/engineering principles have been applied to characterize a system.	There is evidence of one example where mathematics and/or science/engineering principles have been applied to characterize a system.	There is evidence of multiple examples where mathematics and/or science/engineering principles have been applied to characterize a system. If mathematics are used, then the system is expressed using appropriate equations along with appropriate values.
2	There is not sufficient evidence of any examples where a system has been modeled as it relates to an engineering design solution or implementation.	There is evidence of one example where a system has been modeled as it relates to an engineering design solution or implementation.	There is evidence of multiple examples where a system has been modeled as it relates to an engineering design solution or implementation.
3	There is not sufficient evidence of any examples where components and/or subsystems have been synthesized to create a larger whole.	There is evidence of one example where components and/or subsystems have been synthesized to create a larger whole.	There is evidence of multiple examples where components and/or subsystems have been synthesized to create a larger whole.

(b.1) an ability to design and conduct experiments

TABLE 4.7 Student Outcome (b.1) assessment indicators and descriptions.

Indicator	Course	Assessment Description
1. Ability to develop a process, involving data collection and analysis, that leads to meaningful conclusions.	ECE3151	Develop a system to recognize the 5 vowel sounds across a group of students.
	ECE3090	Measure the internal resistance of a battery.
	ECE4800/ ECE4810	Exhibit through technical details found in the Project Notebook, technical reports, or technical presentations.
2. Ability to set up an experiment using realistic and readily available components, tools, and test equipment.	ECE3151	Develop a system to recognize the 5 vowel sounds across a group of students.
	ECE3090	Measure the internal resistance of a battery.
	ECE4800/ ECE4810	Exhibit through technical details found in the Project Notebook, technical reports, or technical presentations.
3. Ability to recognize the adequacy of collected data necessary to draw meaningful conclusions.	ECE3151	Develop a system to recognize the 5 vowel sounds across a group of students.
	ECE3090	Measure the internal resistance of a battery.
	ECE4800/ ECE4810	Exhibit through technical details found in the Project Notebook, technical reports, or technical presentations.
4. Ability to find and correct errors in experiment setups and in experimental data.	ECE3151	Develop a system to recognize the 5 vowel sounds across a group of students.
	ECE3090	Measure the internal resistance of a battery.
	ECE4800/ ECE4810	Exhibit through technical details found in the Project Notebook, technical reports, or technical presentations.

This outcome refers to an ability to design and conduct experiments with an appropriate goal. The word "ability" refers to, for example, identifying appropriate and readily available equipment, identifying appropriate range of component values, identifying a sequence of procedure steps to achieve a goal, identifying appropriate measurements, identifying appropriate data analysis calculations to achieve a meaningful goal, identifying sources of experimental error, etc.

In summary, it is all the characteristics of a laboratory experiment necessary to enable that experiment to be practically carried out in a suitable laboratory and to draw meaningful conclusions with confidence.

Indicator #1: This indicator refers to an ability to establish an experimental procedure, including identifying specific measurements to acquire, in order to draw meaningful conclusions.

- ECE3151: Student groups are required to acquire a set of training data of the long vowel sounds for each group member. That training data is to be analyzed in the frequency domain to identify unique spectral energy that allows each specific vowel sound to be uniquely identified among the 5 long vowel sounds and among the group members. The specific energy bands in the frequency domain represent the measurements to be acquired.

  Students will demonstrate an ability to develop a procedure for analyzing the 5 long vowel sounds across the group members in order to establish energy bands that are useful for discriminating the 5 vowel sounds as evidenced by a technical report.
- ECE3090: The battery experiment was first introduced into this course in Spring 2017. Therefore, the assessment is drawn from various project reports prior to Spring 2017 and is drawn specifically from the battery experiment on and after Spring 2017.

Prior to S17: *Students will demonstrate an ability to establish an experimental procedure, including identifying specific measurements to acquire, in order to draw meaningful conclusions as evidenced by the laboratory reports, presentations, or project notebooks*.

S17 and after: Each student group is to establish a process by which the internal resistance of a battery is measured. This process includes establishing an appropriate circuit with appropriate measurements and analysis that leads to a meaningful estimate of the internal battery resistance. This process must include a recognition and specification of the battery test conditions such as battery charge (rechargeable batteries are used), the battery temperature, battery age, etc., that would affect the true value of the internal resistance.

Students will demonstrate an ability to establish an experimental procedure, including identifying specific measurements to acquire, in order to estimate the internal resistance of a battery as evidenced by the battery technical report or the experiment report.

- ECE4800/ECE4810: *Students will demonstrate an ability to establish an experimental procedure, including identifying specific measurements to acquire, in order to draw meaningful conclusions as evidenced in the project notebooks, technical reports, or technical presentations*.

Indicator #2: This indicator refers to an ability to recognize readily available equipment and components, in the ECE facilities, that would allow an experiment to be practically carried out. This indicator also refers to an ability to use that equipment and components to set up an experiment.

- ECE3151: For the long vowel sound experiment, students are provided a set of software functions, provided by the instructor, that are useful for analyzing the long vowel sound data. They also have available a series of software tools in matlab that can be used. *Students will demonstrate an ability to use matlab software functions in order to analyze the vowel sound data as evidenced by a technical report*.
- ECE3090:

  Prior to S17: *Students will demonstrate an ability to recognize readily available equipment and components, in college laboratories, that would allow an experiment to be practically carried out as evidenced by the laboratory reports, presentations, or project notebooks*.

  S17 and after: For the internal battery resistance measurement, students need to identify and be able to use standard laboratory equipment and components that are available in our department. *Students will demonstrate an ability to establish an experimental procedure that uses readily available equipment and components in college laboratories as evidenced by the battery technical report or the experiment report*.
- ECE4800/ECE4810: *Students will demonstrate an ability to recognize and use readily available equipment and components, in college laboratories, that are used to set up and carry out an experiment as evidenced in the project notebooks, technical reports, or technical presentations*.

Indicator #3: This indicator refers to an ability to recognize whether the set of acquired measurements are adequate for drawing meaningful conclusions. By “adequate” we mean that the type and quantity of collected data is sufficient for drawing meaningful conclusions with confidence.

- ECE3151: For the long vowel sound experiment, each student group needs to determine whether the vowel sounds recorded are sufficient for developing a useful decision tree. *Students will demonstrate an ability to recognize whether the set of vowel sounds acquired is sufficient for developing a useful decision tree as evidenced by a technical report*.
- ECE3090:

  Prior to S17: *Students will demonstrate an ability to recognize whether the set of acquired measurements are adequate for drawing meaningful conclusions as evidenced by the laboratory reports, presentations, or project notebooks*.

S17 and after: For the internal battery resistance measurement, students need to determine whether the collected data is sufficient for providing reasonable statistical bounds on the true internal battery resistance. This requires some assessment of how much data to collect. *Students will demonstrate an ability to determine the adequacy of the battery resistance measurements for the purpose of drawing meaningful conclusions with confidence as evidenced by the battery technical report or the experiment report*.

- ECE4800/ECE4810: *Students will demonstrate an ability to recognize whether a set of acquired measurements are adequate for drawing meaningful conclusions with confidence as evidenced in the project notebooks, technical reports, or technical presentations*.

Indicator #4: This indicator refers to an ability to find errors in experimental setups and experimental data. Errors in experimental setups can include things such as improper use of a voltmeter, incorrect setting in a DMM, and improper grounding when an oscilloscope and power supply are used in the same circuit. Errors in data can include things such as corruption, undesirable artifacts, distortion, or simply mis-recorded measurements.

- ECE3151: For the long vowel sound experiment, each student group needs to determine which vowel sounds in the training data are free from undesirable artifacts such as early/late sound truncation, signal saturation, significant signal attenuation into the noise floor, or significant background sounds occurring during vowel sound recording as evidenced by a technical report.

  Students will demonstrate an ability to recognize the adequacy of recorded vowel sounds as evidenced by a technical report.
- ECE3090:

  Prior to S17: *Students will demonstrate an ability to find errors in experimental setups and experimental data as evidenced by reports, presentations, or project notebooks*.

  S17 and after: For the internal battery resistance measurement, students need to determine whether the collected data is sufficient for providing reasonable statistical bounds on the true internal battery resistance. This requires assess how much data needs to be collected. *Students will demonstrate an ability to determine the adequacy of battery resistance measurements for the purpose of drawing meaningful conclusions as evidenced by the battery technical report or the experiment write-up*.
- ECE4800/ECE4810: *Students will demonstrate an ability to find errors in experimental setups and experimental data as evidenced in the project notebooks, technical reports, or technical presentations*.

The assessment rubrics are given in the following table.

TABLE 4.8 Assessment rubrics for Student Outcome (b.1).

	Rubric		
Ind	**1 = Does not meet Expectations**	**2 = Meets expectations**	**3 = Exceeds expectations**
ECE3151			

TABLE 4.8 Assessment rubrics for Student Outcome (b.1).

	Rubric		
Ind	**1 = Does not meet Expectations**	**2 = Meets expectations**	**3 = Exceeds expectations**
1	There is little evidence that unique energy bands are defined resulting from an experimental procedure or that the procedure that was followed did not result in a effective decision tree to classify the 5 long vowel sounds with a degree of reasonable accuracy.	There is evidence that unique energy bands are defined resulting from an experimental procedure that lead to a decision tree for classifying the 5 long vowel sounds across a group of students. The experimental procedure is not well defined or well articulated to the point where another group could follow the same procedure.	There is evidence that unique energy bands are defined resulting from an experimental procedure that lead to a decision tree for classifying the 5 long vowel sounds across a group of students. The experimental procedure is well defined and well articulated to the point where another group could follow the same procedure.
2	There is no evidence that instructor-provided software tools were used for analyzing the long vowel sound acoustic signals.	There is evidence that instructor-provided software tools were used for analyzing the long vowel sound acoustic signals. That evidence mainly involves general statements of usage without clearly articulating how they were used or not illustrating data generated from those tools.	There is evidence that instructor-provided software tools were used for analyzing the long vowel sounds acoustic signals. Furthermore, usage of those functions is clearly articulated with appropriate data illustrating how they were used.
3	There is no meaningful evidence that the collective set of long vowel sounds (25 sounds/long vowel/student) has been assessed to determine whether it is sufficient for developing a reliable classifier tree.	There is evidence that the collective set of long vowel sounds (25 sounds/long vowel/student) has been assessed to determine whether it is sufficient for developing a reliable classifier tree. This assessment is a general statement without references to specific data illustrations.	There is evidence that the collective set of long vowel sounds (25 sounds/long vowel/student) has been assessed to determine whether it is sufficient for developing a reliable classifier tree. This assessment is specific to each vowel sound and is articulated with appropriate data illustrations.
4	There is no evidence that each vowel sound has been assessed to determine if it contains experimental errors such as early/late sound truncation, etc.	There is evidence that each vowel sound has been assessed to determine if it contains experimental errors such as early/late sound truncation, etc. This assessment is a general statement without reference to specific data illustrations or without reference appropriate quantitative measurements.	There is evidence that each vowel sound has been assessed to determine if it contains experimental errors such as early/late sound truncation, etc. This assessment is specific to each vowel sound and examples are articulated with appropriate data illustrations or with appropriate quantitative measurements.
ECE3090			

TABLE 4.8 Assessment rubrics for Student Outcome (b.1).

	Rubric		
Ind	**1 = Does not meet Expectations**	**2 = Meets expectations**	**3 = Exceeds expectations**
1	The experimental procedure is not sufficiently defined to be repeatable by several people working independently.	The experimental procedure is sufficiently detailed with step-by-step instructions and with appropriate setup illustrations so as to be unambiguous and repeatable. Measurements to be taken may not be fully defined by a blank data table.	The experimental procedure is sufficiently detailed with step-by-step instructions, with appropriate setup illustrations, and with detailed blank data tables so as to be unambiguous and repeatable.
2	The experimental procedure requires the use of components and equipment that are not readily available in college laboratories or the components/equipment usage does not satisfy safety requirements. This might include, for example, requiring that the power rating of a resistor be exceeded.	The experimental procedure requires the use of components and equipment that are readily available in college laboratories with the possible exception of a few special-purpose resistors. The required usage of the components and equipment satisfies all safety requirements but without reasonable operational margins.	The experimental procedure requires the use of components and equipment that are readily available in college laboratories with the possible exception of a few special-purpose resistors. The required usage of the components and equipment satisfies all safety requirements and with reasonable operational margins.
3	There is no evidence that the data collected has been assessed to determine whether it is sufficient for estimating the internal resistance of a battery.	There is evidence that the data collected has been assessed to determine whether it is sufficient for estimating the internal resistance of a battery. This assessment is a simple statement and is not supported with appropriate data illustrations nor numeric measures.	There is evidence that the data collected has been assessed to determine whether it is sufficient for estimating the internal resistance of a battery. This assessment is supported with appropriate data illustrations or numeric measures.
4	There is no evidence that errors in experimental setups or experimental data, if they occur, have been identified. If the experimental data does not contain errors, there is not statement to that effect.	There is evidence that errors in experimental setups or experimental data, if they occur, have been identified. If the experimental data does not contain errors, then a statement to that effect is present. The determination as to whether errors occur or not is simply stated and not supported by appropriate illustrations or numeric measures.	There is evidence that errors in experimental setups or experimental data, if they occur, have been identified. If the experimental data does not contain errors, then a statement to that effect is present. The determination as to whether errors occur or not is supported by appropriate illustrations or numeric measures.
ECE4800/4810			
1	There is insufficient evidence where an experimental procedure has been established for the purpose of drawing meaningful conclusions as part of carrying out an engineering design.	There is evidence where an experimental procedure has been established for the purpose of drawing meaningful conclusions as part of carrying out an engineering design. This procedure is not fully defined.	There is evidence where an experimental procedure has been established for the purpose of drawing meaningful conclusions as part of carrying out an engineering design. This procedure is completely define, unambiguous, and repeatable.

TABLE 4.8 Assessment rubrics for Student Outcome (b.1).

	Rubric		
Ind	**1 = Does not meet Expectations**	**2 = Meets expectations**	**3 = Exceeds expectations**
2	There is no evidence of components and equipment being identified for use in carrying out an experimental procedure.	There is evidence where readily available components and equipment have been identified for use in carrying out an experimental procedure. Usage of these components/equipment is not very specific nor detailed.	There is evidence where readily available components and equipment have been identified for use in carrying out an experimental procedure. Usage of these components/equipment is specific and detailed.
3	There is no evidence where measured data has been assessed to determine if it is suitable for drawing meaningful conclusions.	There is evidence where a set of measured data has been assessed to determine if it is suitable for drawing meaningful conclusions related to an engineering design. This assessment is a simple statement and is not supported with appropriate data illustrations or numeric measures.	There is evidence where a set of measured data has been assessed to determine if it is suitable for drawing meaningful conclusions related to an engineering design. This assessment is supported with appropriate data illustrations or numeric measures.
4	There is insufficient evidence where errors in experimental setups or measured data have been considered and addressed.	There is evidence where errors in experimental setups have been identified or where errors in measured data have been identified if they occur. If they do not occur, there is a statement stating this and illustrations or numeric measures given to support this conclusion.	There is evidence where errors in experimental setups have been identified or where errors in measured data have been identified if they occur. If they do not occur, there is a statement stating this and illustrations or numeric measures given to support this conclusion.

(b.2) an ability to analyze and interpret data

TABLE 4.9 Student Outcome (b.2) assessment indicators and descriptions.

Indicator	Course	Assessment Description
1. Ability to recognize the precision of measured data.	ECE3151	Assess the precision of vowel sound metrics for the purpose of developing a vowel sound decision tree.
	ECE3090	Assess the precision of measured data for estimating the internal resistance of a battery.
	ECE4800/ ECE4810	Exhibit through technical details found in the Project Notebook, technical reports, or technical presentations.
2. Ability to recognize the relevancy of measured data.	ECE3151	Assess the relevancy of vowel sound metrics for the purpose of developing a vowel sound decision tree.
	ECE3090	Assess the relevancy of measured data for estimating the internal resistance of a battery.
	ECE4800/ ECE4810	Exhibit through technical details found in the Project Notebook, technical reports, or technical presentations.
3. Ability to observe data trends or data features for the purpose of modeling, prediction, or drawing conclusions.	ECE3151	Observe data features of vowel sound metrics for the purpose of developing a vowel sound decision tree.
	ECE3090	Measure the internal resistance of a battery laboratory report.
	ECE4800/ ECE4810	Exhibit through technical details found in the Project Notebook, technical reports, or technical presentations.

This outcome refers to an ability to analyze and interpret data where the data is either provided or comes from an experiment involving data collection. The word "ability" refers to, for example, plotting data and observing trends or analyzing the plot to measure system parameters such as line slope, maximum value, zero-crossings, etc. It can also mean determining statistical measures associated with collected data to assess measurement precision and/or to determine the relevancy of collected data for drawing meaningful conclusions. The word "relevant" refers to whether the type of data collected is suitable for drawing the intended conclusions.

In summary, it is all the necessary analysis and interpretation of data necessary to draw meaningful conclusions.

Indicator #1: This indicator refers to the ability to recognize the precision of the measured data.

- ECE3151: Each student group is required to convert each vowel sound track into a meric vector. As part of the development of the classification decision tree, the metrics are plotted which provides a setting to qualitatively assess the precision of each vowel sound metric for the purpose of creating a reliable classifier. *Students will demonstrate an ability to assess the precision of the various metrics in order to determine which are most suitable for developing a reliable classifier tree as evidenced by a technical report*.
- ECE3090:

  Prior to S17: *Students will demonstrate an ability to recognize the precision of measured data as evidenced by the laboratory reports, presentations, or project notebooks*.

  S17 and after: *For the internal battery resistance measurement project, students will demonstrate an ability to determine the precision of measured data in order to determine whether meaningful conclusions can be drawn as evidenced by the battery technical report or the experiment report*.

- ECE4800/ECE4810: *Students will demonstrate an ability to recognize the precision of the measured data as evidenced in the project notebooks, technical reports, or technical presentations*.

Indicator #2: This indicator refers to the ability to recognize which measurements do not relate to the intended solution or measurement of interest and should be discarded.

- ECE3151: Each student group will need to sift through the vowel metric vectors in order to recognize which metrics are relevant for creating a reliable classifier tree. Some metric vector components do not provide adequate discrimination of vowels and therefore are not relevant to creating a reliable classifier tree while, generally speaking, others will be relevant. *Students will demonstrate an ability to recognize which metric components are relevant for creating a reliable classifier tree as evidenced by a technical report*.
- ECE3090:

  Prior to S17: *Students will demonstrate an ability to recognize which measurements do not relate to the intended solution or measurement of interest and should be discarded as evidenced by the laboratory reports, presentations, or project notebooks*.

  S17 and after: *For the internal battery resistance measurement project, students will demonstrate an ability to determine the relevancy of the collected data in order to determine which measurements can lead to meaningful conclusions as evidenced by the battery technical report or the experiment report*.
- ECE4800/ECE4810: *Students will demonstrate an ability to recognize the relevancy of measured data as evidenced in the project notebooks, technical reports, or technical presentations*.

Indicator #3: This indicator refers to the ability to observe data trends or data features for the purpose of modeling, prediction, or drawing conclusions.

- ECE3151: Each student group will need to sift through the vowel acoustic spectral data in order to observe trends that lead to determining which metric components are worth considering for developing the classifier tree. *Students will demonstrate an ability to observe trends in either the spectral energy of their vowel sounds or the metric vectors for the purpose of developing a reliable classifier tree as evidenced by a technical report*.
- ECE3090:

  Prior to S17: *Students will demonstrate an ability to observe data trends or data features for the purpose of modeling, prediction, or drawing conclusions as evidenced by the laboratory reports, presentations, or project notebooks*.

  S17 and after: For the internal battery resistance measurement experiment, each student group needs to look at their measurement data to observe trends such as a change in resistance as the battery gets hot (changes temperature) or perhaps to observe the change in resistance over time for the same test. *Students will demonstrate an ability to observe trends or data features in their internal battery resistance measurement experiment as evidenced by the battery technical report or the experiment report*.
- ECE4800/ECE4810: *Students will demonstrate an ability to observe data trends as evidenced in the project notebooks, technical reports, or technical presentations*.

The assessment rubrics are given in the following table.

TABLE 4.10 Assessment rubrics for Student Outcome (b.2).

	Rubric		
Ind	**1 = Does not meet Expectations**	**2 = Meets expectations**	**3 = Exceeds expectations**
ECE3151			
1	There is little or no evidence that metric pairs have been inspected and the precision of the various vowel sounds have been recognized and considered for the purpose of creating a good decision tree.	There is evidence that one or two metric pairs have been inspected and the precision of the various vowel sounds in the metric space have been recognized and considered as part of the metric selection process for the purpose of creating a reliable decision tree.	There is evidence that many metric pairs have been inspected and the precision of the various vowel sounds in the metric space have been recognized and considered as part of the metric selection process for the purpose of creating a reliable decision tree.
2	There is little or no evidence that any of the metric pairs have been assessed and discarded as unsuitable for creating a reliable decision tree are discarded.	There is evidence that some of the metric pairs have been assessed and those deemed unsuitable for creating a reliable decision tree are discarded.	There is evidence that most or all of the metric pairs have been assessed and those deemed unsuitable for creating a reliable decision tree are discarded.
3	There is no evidence that any data trends have been observed in either the spectral energy distributions or the metric vectors for the purpose of simplifying the process of creating a reliable decision tree.	There is evidence that one data trend has been observed in either the spectral energy distributions or the metric vectors for the purpose of simplifying the process of creating a reliable decision tree.	There is evidence that several data trends have been observed in either the spectral energy distributions or the metric vectors for the purpose of simplifying the process of creating a reliable decision tree.
ECE3090			
1	There is no evidence that the experiment results have been numerically nor qualitatively assessed to determine the precision of resistance measurements for the purpose of drawing meaningful conclusions.	There is evidence that the experiment results have been qualitatively assessed to determine the precision of resistance measurements for the purpose of drawing meaningful conclusions.	There is evidence that the experiment results have been numerically assessed to determine the precision of resistance measurements for the purpose of drawing meaningful conclusions.
2	There is no evidence that experiment results have been assessed to determine which, if any, of the measurements should be discarded.	There is evidence that experiment results have been qualitatively assessed to determine which, if any, of the measurements should be discarded.	There is evidence that experiment results have been numerically assessed to determine which, if any, of the measurements should be discarded. If there are none to discard, this is stated and justified using appropriate illustrations or numeric results.
3	There is no evidence that data trends have been observed.	There is evidence that data trends have been observed by qualitative statements.	There is evidence that data trends have been observed and clearly described using illustrations or numerical measures.
ECE4800/4810			

TABLE 4.10 Assessment rubrics for Student Outcome (b.2).

	Rubric		
Ind	**1 = Does not meet Expectations**	**2 = Meets expectations**	**3 = Exceeds expectations**
1	There is no evidence that the precision of experimental data has been recognized and assessed for the purpose of drawing meaningful conclusions.	There is evidence that the precision of experimental data has been recognized and assessed for the purpose of drawing meaningful conclusions. The assessment is described by a simple statement with little or no justification evident.	There is evidence that the precision of experimental data has been recognized and assessed for the purpose of drawing meaningful conclusions. The assessment is clearly described using illustrations or numeric measures.
2	There is no evidence that experiment results have been assessed to determine which, if any, of the measurements should be discarded.	There is evidence that experiment results have been qualitatively assessed to determine which, if any, of the measurements should be discarded.	There is evidence that experiment results have been numerically assessed to determine which, if any, of the measurements should be discarded. If there are none to discard, this is stated and justified using appropriate illustrations or numeric results.
3	There is no evidence that data trends have been observed.	There is evidence that data trends have been observed by qualitative statements.	There is evidence that data trends have been observed and clearly described using illustrations or numerical measures.

(c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, etc.

TABLE 4.11 Student Outcome (c) assessment indicators and descriptions.

Indicator	Course	Assessment Description
1. Awareness of and an ability to discern the importance of realistic constraints for a particular design or design component.	ECE3132	The practical limitations, such as gain and bandwidth, of semiconductor devices.
	ECE4800/ ECE4810	Exhibit through technical details found in the Project Notebook, technical reports, or technical presentations.
2. Ability to translate practical quantitative constraints to appropriate design constraints.	ECE3132	Develop design constraints consistent with the physical limitations of semiconductors for an amplifier design.
	ECE4800/ ECE4810	Exhibit through technical details found in the Project Notebook, technical reports, or technical presentations.
3. Ability to implement a design and verify that it meets the constraints.	ECE3132	Implement the design of an amplifier and demonstrate that it meets the constraints.
	ECE4800/ ECE4810	Exhibit through technical details found in the Project Notebook, technical reports, or technical presentations.

This outcome refers to an ability to consider practical and realistic constraints for the purpose of engineering design. The word “realistic” refers to practical constraints that either lead to a realizable solution or lead to long-term market viability of the resulting design product such as cost, health and safety, sustainability, etc. These constraints might lie outside the typical performance constraints established by a client and may need to be established by the design team internally.

Indicator #1: This indicator refers to an awareness of practical and realistic constraints and an ability to discern which are applicable for a particular design.

- ECE3132: *Students will demonstrate an awareness of and ability to discern the practical limitations, such as gain and bandwidth, of semiconductor devices as evidenced in an experiment report*.
- ECE4800/ECE4810: *Students will demonstrate an awareness of practical and realistic constraints and an ability to discern which are applicable for a particular design as evidenced in the project notebooks, the PDR/CDR/FDR technical reports, or technical presentations*.

Indicator #2: This indicator refers to an ability to assess practical constraints and put them in a quantitative form that directly relates to the technical aspects of the design solution. For example, the constraint that the design must be “safe” would need to be converted into quantitative technical aspects of the design solution which might include constraints such as maximum battery voltage, maximum robot speed, etc. All design constraints ultimately need to be put into a technical/quantitative form so that engineering design decisions can be made.

- ECE3132: *Students will demonstrate an ability to consider the practical limitations of semiconductor devices in order to develop a realizable design solution as evidenced in an experiment report*.
- ECE4800/ECE4810: *Students will demonstrate an ability to assess practical constraints and put them in a quantitative form that directly relates to the technical aspects of the design solution as evidenced in the project notebooks, the PDR/CDR/FDR technical reports, or technical presentations*.

Indicator #3: This indicator refers to an ability to develop and carry out testing procedures in order to verify that the design meets the required constraints. These testing procedures require, to some degree of formality, the development of an experiment that is carried out in order to draw an appropriate conclusion about constraint performance.

- ECE3132: *Students will demonstrate an ability to design an amplifier with given constraints and then carry out an experiment to test whether the amplifier constraints are met as evidenced by an experiment report*.
- ECE4800/ECE4810: *Students will demonstrate an ability to develop and carry out testing procedures in order to verify that the design meets the required constraints as evidenced in the project notebooks, the PDR/CDR/FDR technical reports, or technical presentations*.

The assessment rubrics are given in the following table.

TABLE 4.12 Assessment rubrics for Student Outcome (c).

	Rubric		
Ind	**1 = Does not meet Expectations**	**2 = Meets expectations**	**3 = Exceeds expectations**
ECE3132			
1	There is no evidence that any practical and realistic limitations of a semiconductor device have discerned to be applicable to the design of a semiconductor device.	There is evidence that one practical and realistic limitation of a semiconductor device has been discerned to be applicable to the design of a semiconductor device.	There is evidence that multiple practical and realistic limitations of a semiconductor device have discerned to be applicable to the design of a semiconductor device.
2	There is no evidence that any practical and realistic limitations of a semiconductor device have been quantified for the purpose of carrying out the design of a semiconductor device.	There is evidence that one practical and realistic limitation of a semiconductor device has been quantified for the purpose of carrying out the design of a semiconductor device.	There is evidence that multiple practical and realistic limitations of a semiconductor device have been quantified for the purpose of carrying out the design of a semiconductor device.
3	There is no evidence that any practical and realistic limitations of a semiconductor device have been applied to the design of a semiconductor device.	There is evidence that one practical and realistic limitation of a semiconductor device has been applied to the design of a semiconductor device.	There is evidence that multiple practical and realistic limitations of a semiconductor device have been applied to the design of a semiconductor device.
ECE4800/4810			
1	There is no evidence that any practical and realistic constraints have been identified as being applicable to a particular design component.	There is evidence that one practical and realistic constraint has been identified as being applicable to a particular design component.	There is evidence that multiple practical and realistic constraints have been identified as being applicable to a particular design component.
2	There is no evidence that any practical and realistic constraints have been quantified as they relate to a particular design component.	There is evidence that one practical and realistic constraint has been quantified as they relate to a particular design component.	There is evidence that multiple practical and realistic constraints have been quantified as they relate to a particular design component.
3	There is no evidence that any practical and realistic constraints have been applied to the solution of a particular design component.	There is evidence that one practical and realistic constraint has been applied to the solution of a particular design component.	There is evidence that multiple practical and realistic constraints have been applied to the solution of a particular design component.

(d) an ability to function on multidisciplinary teams

TABLE 4.13 Student Outcome (d) assessment indicators and descriptions.

Indicator	Course	Assessment Description
1. Ability to perform individual tasks in a timely manner with respect to the team-developed timelines.	ECE3090	Exhibit through details found in the Project Notebook.
	ECE4800/ ECE4810	Exhibit through details found in the Project Notebook.
2. Ability to share and fully articulate important and interrelated information with other team members to further a design solution.	ECE3090	Exhibit through details found in the Project Notebook.
	ECE4800/ ECE4810	Exhibit through details found in the Project Notebook.
3. Ability to effectively participate in team meetings.	ECE3090	Exhibit through details found in the Project Notebook.
	ECE4800/ ECE4810	Exhibit through details found in the Project Notebook.
4. Ability to document work in a timely manner and in sufficient detail to speed development.	ECE3090	Exhibit through details found in the Project Notebook.
	ECE4800/ ECE4810	Exhibit through details found in the Project Notebook.

This outcome refers to an ability for a student to be an effective team member. The word "effective" refers to an ability to carry out independent work in a timely manner, to coordinate with other team members in team meetings and otherwise as needed, to properly document work such as computer code, and by maintaining a legally defensible project notebook, etc.

Both ECE3090 Junior Design and ECE4810 Senior Design II require that students maintain a legally defensible project notebook. The notebook is to contain notes related to individual design work and also contain properly documented team meetings.

Indicator #1: This refers to an ability to carry out tasks independently and in a timely manner. This should be evident in the project notebook by the relationship between action items identified at each team meeting and the documented work between team meetings.

- ECE3090 & ECE4800/4810: *Students will demonstrate an ability to carry out tasks independently and in a timely manner as evidenced in the project notebooks*.

Indicator #2: This refers to an ability to share appropriate and interrelated information between team members in order to further the overall team design. This should be evident in the project notebook through documented team meetings and perhaps through documented work between team meetings.

- ECE3090 & ECE4800/4810: *Students will demonstrate an ability to share appropriate and interrelated information between team members in order to further the overall team design as evidenced in the project notebooks*.

Indicator #3: This refers to an ability to properly articulate in a team meeting work accomplished since the last meeting, an ability to engage in a team conversation about the design leading to design decisions, and an ability to articulate action items to be performed by the next meeting. Articulation of work accomplished as well as action items should be as specific as possible and quantitative as appropriate. For example, to write that "I'm working on motors" is not an appropriate action item because it is not a quantitative statement that describes, for example, the required electrical characteristics of the motors.

- ECE3090 & ECE4800/4810: *Students will demonstrate an ability to properly articulate in a team meeting work accomplished since the last meeting, an ability to engage in a team conversation about the design leading to design decisions, and an ability to articulate action items to be performed by the next meeting as evidenced in the project notebooks*.

Indicator #4: This refers to the ability to document work as it is being performed and to demonstrate that the documented work is useful for speeding development. This should be evident in the project notebook with numbered pages, initialed and dated pages, and by evidence that the notebook is being filled out sequentially over time.

- ECE3090 & ECE4800/4810: *Students will demonstrate an ability to document work as it is being performed and to demonstrate that the documented work is useful for speeding development as evidenced in the project notebooks*.

The assessment rubrics are given in the following table.

TABLE 4.14 Assessment rubrics for Student Outcome (d).

	Rubric		
Ind	**1 = Does not meet Expectations**	**2 = Meets expectations**	**3 = Exceeds expectations**
ECE3090 & ECE4800/4810			
1	There is evidence that none or few identified or general tasks have been carried out in a timely manner, typically within one or two weeks of being identified.	There is evidence that some identified or general tasks have been carried out in a timely manner, typically within one or two weeks of being identified.	There is evidence that most identified or general tasks have been carried out in a timely manner, typically within one or two weeks of being identified.
2	There is little or no evidence that interrelated information is shared with other team members.	There is evidence that some interrelated information is qualitatively shared with appropriate team members, but not necessarily in a timely manner.	There is evidence that most interrelated information is quantitatively shared with appropriate team members and in a timely manner.
3	There is little or no evidence that action item progress has been reported in team meetings nor that action items, to be performed by the next meeting, have been established.	There is evidence that, for a few meetings, action item progress has been qualitatively reported in team meetings in a timely manner and that qualitative action items, to be performed by the next meeting, are established.	There is evidence that, for most meetings, action item progress has been quantitatively reported in team meetings in a timely manner and that quantitative action items, to be performed by the next meeting, are established.
4	There is little or no evidence that, between most meetings, work has been documented.	There is evidence that, between a few meetings, work has been appropriately and qualitatively documented in a legally defensible notebook.	There is evidence that, between most meetings, work has been appropriately and quantitatively documented in a legally defensible notebook.

(e) an ability to identify, formulate, and solve engineering problems

TABLE 4.15 Student Outcome (e) assessment indicators and descriptions.

Indicator	Course	Assessment Description
1. Ability to recognize an engineering problem to be solved from observations.	ECE3090	Measure the internal resistance of a battery.
	ECE4800/ ECE4810	Exhibit through technical details found in the Project Notebook, technical reports, or technical presentations.
2. Ability to develop a hardware/ software/math model for an engineering problem to be solved.	ECE3151	Calibrate a PID controller for the purpose of optimizing the motion dynamics of a mobile robot.
	ECE3090	Measure the internal resistance of a battery.
	ECE4800/ ECE4810	Exhibit through technical details found in the Project Notebook, technical reports, or technical presentations.
3. Ability to solve an engineering problem using mathematics and/or engineering principles.	ECE3151	Calibrate a PID controller for the purpose of optimizing the motion dynamics of a mobile robot.
	ECE3090	Measure the internal resistance of a battery.
	ECE4800/ ECE4810	Exhibit through technical details found in the Project Notebook, technical reports, or technical presentations.
4. Ability to assess the performance of an engineering problem solution.	ECE3151	Calibrate a PID controller for the purpose of optimizing the motion dynamics of a mobile robot.
	ECE3090	Measure the internal resistance of a battery.
	ECE4800/ ECE4810	Exhibit through technical details found in the Project Notebook, technical reports, or technical presentations.

This outcome refers to an ability to recognize that a problem needs to be solved, formulate the problem, carry out the solution, and assess the solution. This is fundamentally different that SO (a) because the initiative for recognizing the need to solve an engineering problem and the problem formulation comes from the student rather than an instructor.

Indicator #1: This indicator refers to an ability to recognize that an engineering problem needs to be solved in order to further the design solution. The implication here is that the recognition occurs by the student during the process of carrying out a design, experiment, or project.

- ECE3090:

  Prior to S17: *Students will demonstrate an ability to recognize that an engineering problem needs to be solved in order to further the design solution as evidenced by the laboratory reports, presentations, or project notebooks*.

  S17 and after: The battery experiment requires that a student group measure the internal resistance of a battery. Developing an appropriate experiment for this design requires students to solve a variety of problems which begins with recognition that a problem exists which needs to be solved.

  Students will demonstrate an ability to recognize that an engineering problem needs to be solved related to the battery experiment as evidenced in the project notebooks, technical reports, or technical presentations.
- ECE4800/ECE4810: *Students will demonstrate an ability to recognize that an engineering problem needs to be solved in order to further the design solution as evidenced in the project notebooks, technical reports, or technical presentations*.

Indicator #2: This indicator refers to the ability to develop a structure through which an engineering problem can be solved. This structure might be a mathematical equation, a hardware setup, a software setup, or a procedure.

- ECE3151: Student groups are required to write a computer program that implements a PID controller for the purpose of controlling a software-simulated robot. This requires that the PID controller be calibrated to modify the robot motion dynamics. Calibrating a PID controller requires establishing a procedure for modifying the parameters along with either qualitative observations or quantitative metrics for feedback. *Students will demonstrate an ability to develop a procedure with an appropriate feedback in order to calibrate a PID controller as evidenced by a technical report*.
- ECE3090:

  Prior to S17: *Students will demonstrate an ability to develop a structure through which an engineering problem can be solved as evidenced by the laboratory reports, presentations, or project notebooks*.

  S17 and after: The battery experiment requires that a student group measure the internal resistance of a battery. *Students will demonstrate an ability to solve problems related to the battery experiment as evidenced in the project notebooks, technical reports, or technical presentations*.
- ECE4800/ECE4810: *Students will demonstrate an ability to develop a structure through which an engineering problem can be solved as evidenced in the project notebooks, technical reports, or technical presentations*.

Indicator #3: This indicator refers to the ability to carry out a problem solution using mathematics and/or engineering principles. This might involve solving a mathematical equation, successfully implementing a hardware setup, or successfully implementing a software module.

- ECE3151: Student groups are required to write a computer program that implements a PID controller for the purpose of controlling a software-simulated robot. *Students will demonstrate an ability to carry out the calibration procedure in order to modify the robot movement dynamics as evidenced by a technical report*.
- ECE3090:

  Prior to S17: *Students will demonstrate an ability to carry out a problem solution using mathematics and/or engineering principles as evidenced by the laboratory reports, presentations, or project notebooks*.

  S17 and after: The battery experiment requires that a student group measure the internal resistance of a battery. Developing an appropriate experiment for this design requires students to solve a variety of problems which begins with recognition that a problem exists which needs to be solved.

  Students will demonstrate an ability to carry out a problem solution related to the battery experiment as evidenced in the project notebooks, technical reports, or technical presentations.
- ECE4800/ECE4810: *Students will demonstrate an ability to carry out a problem solution as evidenced in the project notebooks, technical reports, or technical presentations*.

Indicator #4: This indicator refers to the ability to assess the final result of a problem solution. This might include checking a degenerate case with a known solution to ensure solution consistency or it might involve performing a simplified approximation to the answer and comparing with the actual answer.

- ECE3151: Student groups are required to write a computer program that implements a PID controller for the purpose of controlling a software-simulated robot. *Students will demonstrate an ability to assess their calibrated PID controller as it relates to the optimal robot movement as evidenced by a technical report*.
- ECE3090:

  Prior to S17: *Students will demonstrate an ability to assess the final result of a problem solution as evidenced by the laboratory reports, presentations, or project notebooks*.

S17 and after: The battery experiment requires that a student group measure the internal resistance of a battery. *Students will demonstrate an ability to assess a problem solution related to the battery experiment as evidenced in the project notebooks, technical reports, or technical presentations*.

- ECE4800/ECE4810: *Students will demonstrate an ability to assess a problem solution as evidenced in the project notebooks, technical reports, or technical presentations*.

The assessment rubrics are given in the following table.

TABLE 4.16 Assessment rubrics for Student Outcome (e).

	Rubric		
Ind	**1 = Does not meet Expectations**	**2 = Meets expectations**	**3 = Exceeds expectations**
ECE3151			
2	There is little or no evidence that any procedure has been established to tune a PID controller.	There is evidence that a clearly defined procedure has been established to tune a PID controller that has some ambiguities and is not necessarily repeatable.	There is evidence that a clearly defined procedure has been established to tune a PID controller that is unambiguous and repeatable.
3	There is little or no evidence that any procedure for tuning a PID controller has been carried out.	There is evidence that a procedure for tuning a PID controller has been carried out with reported results that are qualitative.	There is evidence that a procedure for tuning a PID controller has been carried out with reported results that are quantitative.
4	There is little or no evidence that the result of applying a procedure to tune a PID controller has been assessed.	There is evidence that the result of applying a procedure to tune a PID controller has been qualitatively assessed.	There is evidence that the result of applying a procedure to tune a PID controller has been quantitatively assessed.
ECE3090			
1	There is little or no evidence that any engineering problems have been recognized as necessary to be solved to further the design of an experiment to measure the internal resistance of a battery.	There is evidence that one engineering problem has been recognized as necessary to be solved to further the design of an experiment to measure the internal resistance of a battery.	There is evidence that most engineering problems have been recognized as necessary to be solved to further the design of an experiment to measure the internal resistance of a battery.
2	There is little or no evidence that any engineering problem to be solved as part of the design of an experiment to measure the internal resistance of a battery, has been properly and quantitatively modeled through an equation, appropriate numerical parameters, etc.	There is evidence that one engineering problem to be solved as part of the design of an experiment to measure the internal resistance of a battery, has been properly and quantitatively modeled through an equation, appropriate numerical parameters, etc.	There is evidence that most engineering problems to be solved as part of the design of an experiment to measure the internal resistance of a battery, have been properly and quantitatively modeled through an equation, appropriate numerical parameters, etc.
3	There is little or no evidence that any engineering problem to be solved as part of the design of an experiment to measure the internal resistance of a battery, has been properly carried out to a numerical solution.	There is evidence that one engineering problem to be solved as part of the design of an experiment to measure the internal resistance of a battery, has been properly carried out to a numerical solution.	There is evidence that most engineering problems to be solved as part of the design of an experiment to measure the internal resistance of a battery, have been properly carried out to a numerical solution.

TABLE 4.16 Assessment rubrics for Student Outcome (e).

	Rubric		
Ind	**1 = Does not meet Expectations**	**2 = Meets expectations**	**3 = Exceeds expectations**
4	There is little or no evidence that any engineering problem, solved as part of the design of an experiment to measure the internal resistance of a battery, has been qualitatively or numerically assessed for correctness.	There is evidence that one engineering problem, solved as part of the design of an experiment to measure the internal resistance of a battery, has been qualitatively or numerically assessed for correctness.	There is evidence that most engineering problems, solved as part of the design of an experiment to measure the internal resistance of a battery, have been qualitatively or numerically assessed for correctness.
ECE4800/4810			
1	There is little or no evidence that any engineering problems have been recognized as necessary to be solved to further a design solution.	There is evidence that one or two engineering problems have been recognized as necessary to be solved to further a design solution.	There is evidence that multiple engineering problems have been recognized as necessary to be solved to further a design solution.
2	There is little or no evidence that any engineering problems to be solved as part of a design solution have been properly and quantitatively modeled through an equation, appropriate numerical parameters, etc.	There is evidence that one engineering problem to be solved as part of a design solution has been properly and quantitatively modeled through an equation, appropriate numerical parameters, etc.	There is evidence that multiple engineering problems to be solved as part of a design solution have been properly and quantitatively modeled through an equation, appropriate numerical parameters, etc.
3	There is little or no evidence that any engineering problem to be solved as part of a design solution has been properly carried out to a numerical solution.	There is evidence that one engineering problem to be solved as part of a design solution has been properly carried out to a numerical solution.	There is evidence that multiple engineering problems to be solved as part of a design solution have been properly carried out to a numerical solution.
4	There is little or no evidence that any engineering problem, solved as part of a design solution, have been assessed for correctness.	There is evidence that one engineering problem, solved as part of a design solution, have been assessed for correctness by a simple statement.	There is evidence that multiple engineering problems, solved as part of a design solution, have been qualitatively or numerically assessed for correctness.

(f) an understanding of professional and ethical responsibility

This outcome refers to an awareness and understanding of professional and ethical responsibilities as they relate to the field of Electrical Engineering and to professional engineers in general. There are two primary sources for guidelines that pertain to these:

- The National Society of Professional Engineers (NSPE)
  https://www.nspe.org/resources/ethics/code-ethics
- The Institute of Electrical and Electronics Engineers (IEEE)
  https://www.ieee.org/about/corporate/governance/p7-8.html

Students are made aware of the NSPE code of ethics in the senior design course ECE4800/ECE4810.

An example of an ethical dilemma problem is the case involving Revlon and Logisticon. Logisticon was a small company that sold inventory software to Revlon. Revlon started using the software and quickly became very reliant upon it. Payment for the software was due but Revlon refused to pay for the inventory software claiming the software never worked properly. Logisticon hacked into Revlon's computers one night and "repossessed" the software without Revlon's knowledge. Logisticon not only issued a command that stopped the software from running, but they scrambled Revlon's computerized information about shipments/inventories. The result forced Revlon to shut down their 2 largest distribution centers (Phoenix, Edison NJ) and forced them to send 400 Revlon workers home for 3 days. Although Revlon was still able to ship products from Jacksonville FL and Oxford NC, they were unable to ship products from the North East US and Western US. Logisticon called their actions repossession, but Revlon called Logisticon's actions commercial terrorism. The questions are:

- Were Logisticon's actions to shut down the software ethical? Take a position and justify it using the NSPE code of ethics.
- Were Logisticon's actions to scramble Revlon's inventory ethical? Take a position and justify it using the NSPE code of ethics.
- Were Revlon's action not to pay ethical? Take a position and justify it using the NSPE code of ethics.

These questions are evaluated in the context of the NSPE and IEEE code of ethics.

- ECE4800/ECE4810: *Student will demonstrate an understanding of professional and ethical responsibility as evidenced by a written response to a position paper on an ethical case study*.

The assessment rubrics are given in the following table.

TABLE 4.17 Assessment rubrics for Student Outcome (f).

	Rubric		
Ind	**1 = Does not meet Expectations**	**2 = Meets expectations**	**3 = Exceeds expectations**
ECE4800/4810			
1	There is little or no evidence that any position regarding an ethical dilemma has been articulated nor that the position is defended with any reference to the NSPE code of ethics.	There is evidence that a somewhat clear position regarding an ethical dilemma has been articulated and that the position is defended with one direct or indirect reference to the NSPE code of ethics.	There is evidence that a clear position regarding an ethical dilemma has been articulated and that the position is defended with at least one direct reference and one indirect reference to the NSPE code of ethics.

(g) an ability to communicate effectively

TABLE 4.18 Student Outcome (g) assessment indicators and descriptions.

Indicator	Course	Assessment Description
1. Ability to write a technical report that details a design including the constraints, solution, performance results and conclusions.	ECE3090	The battery experiment technical report.
	ECE4800/ ECE4810	The PDR, CDR, and/or FDR technical reports.
2. Ability to communicate, in written and/or verbal forms, with non-technical people such as vendors, lawyers, non-technical supervisors, etc.	ECE4800/ ECE4810	Exhibit through a poster presentation given to the public at large at a year-end conference.
3. Ability to write and deliver an effective technical presentation.	ECE3090	The battery experiment presentations.
	ECE4800/ ECE4810	The PDR, CDR, and/or FDR presentations.

This outcome refers to an ability to communicate in a variety of forms and to a variety of people. The phrase "variety of people" can refer to technical people such as peer students and instructors. It can also refer to non-technical people such as vendors, lawyers, etc.

For example, students communicate with one another in team meetings carried out as part of the ECE3090 and ECE4800/ECE4810 courses.

Indicator #1: This refers to an ability to write a technical report to peers and faculty. The technical report is to be written with an appropriate format, with appropriate section headings, and with appropriate writing in each section.

- ECE3090:

  Prior to S17: *Students will demonstrate an ability to write a technical report to peers and faculty as evidenced by a technical report*.

  S17 and after: Student are required to measure the internal resistance of a battery. Besides submitting the experiment document and the experiment report, students are also to turn in a design report that describes details of the experimental design development. *Students will demonstrate an ability to write a technical report as evidenced by a report detailing their design process for the battery experiment*.
- ECE4800/ECE4810: Students are required to write a Preliminary Design Review (PDR) report, a Critical Design Review (CDR) report, and a Final Design Review (FDR) report. These reports collectively contain all the details of the engineering design work carried out as part of the culminating senior design experience. *Students will demonstrate an ability to write a technical report as evidenced by the PDR, CDR or FDR*.

Indicator #2: This refers to an ability to communicate, in written and verbal form, to non-technical people. Each year, all senior design student groups across the University present their projects at a University sponsored symposium targeting both technical and non-technical people

- ECE4800/ECE4810: Students are required to publish their projects at a University symposium through a poster presentation which targets both technical and non-technical people. *Students will demonstrate an ability to communicate, in written form, to non-technical people as evidenced in the poster presentations.*

Indicator #3: This refers to an ability to write and deliver an effective presentation. An effective presentation is evaluated in three main areas: (1) the presentation visual style, (2) the presentation technical content, and (3) the presentation speaker delivery.

- ECE3090:

  Prior to S17: *Students will demonstrate an ability to write and deliver an effective presentation as evidenced by a technical presentation*.

  S17 and after: *Student will demonstrate an ability to write and deliver an effective presentation as evidenced by the presentation written and delivered as part of the battery experiment*.
- ECE4800/ECE4810: *Students will demonstrate an ability to write and deliver an effective presentation as evidenced by the presentation written and delivered for the PDR, CDR, or FDR*.

The assessment rubrics are given in the following table.

TABLE 4.19 Assessment rubrics for Student Outcome (g).

	Rubric		
Ind	**1 = Does not meet Expectations**	**2 = Meets expectations**	**3 = Exceeds expectations**
ECE3090			
1	There is evidence that the technical report for the development of the battery experiment exhibits one or fewer of the following three: (a) has at most very few grammatical or spelling mistakes and the meaning of sentences are mostly clear, (b) is mostly well organized with clear and appropriately defined sections and with mostly appropriate material in each section (c) contains mostly correct technical content, has appropriate conclusions, and it fully complete.	There is evidence that the technical report for the development of the battery experiment exhibits 2 of the following three: (a) has at most very few grammatical or spelling mistakes and the meaning of sentences are mostly clear, (b) is mostly well organized with clear and appropriately defined sections and with mostly appropriate material in each section (c) contains mostly correct technical content, has appropriate conclusions, and it fully complete.	There is evidence that the technical report for the development of the battery experiment exhibits all three of the following: (a) has at most very few grammatical or spelling mistakes and the meaning of sentences are mostly clear, (b) is mostly well organized with clear and appropriately defined sections and with mostly appropriate material in each section (c) contains mostly correct technical content, has appropriate conclusions, and it fully complete.

TABLE 4.19 Assessment rubrics for Student Outcome (g).

	Rubric		
Ind	**1 = Does not meet Expectations**	**2 = Meets expectations**	**3 = Exceeds expectations**
3	There is evidence that the technical presentation exhibits one or fewer of the following: (a) is mostly well organized by containing a logical thought progression by beginning with a title slides, outlines/goals, design definition, followed by appropriately sequenced technical details, and ends with a summary/conclusions, (b) contains appropriate design technical details such as a well conceived design solution, sufficient technical details to assess the feasibility of the solution, and containing critical issues, (c) the speakers spoke clearly, chose effective words, demonstrated a command of the technical material, and answered questions effectively and clearly.	There is evidence that the technical presentation exhibits 2 of the following: (a) is mostly well organized by containing a logical thought progression by beginning with a title slides, outlines/goals, design definition, followed by appropriately sequenced technical details, and ends with a summary/conclusions, (b) contains appropriate design technical details such as a well conceived design solution, sufficient technical details to assess the feasibility of the solution, and containing critical issues, (c) the speakers spoke clearly, chose effective words, demonstrated a command of the technical material, and answered questions effectively and clearly.	There is evidence that the technical presentation exhibits all three of the following: (a) is mostly well organized by containing a logical thought progression by beginning with a title slides, outlines/goals, design definition, followed by appropriately sequenced technical details, and ends with a summary/conclusions, (b) contains appropriate design technical details such as a well conceived design solution, sufficient technical details to assess the feasibility of the solution, and containing critical issues, (c) the speakers spoke clearly, chose effective words, demonstrated a command of the technical material, and answered questions effectively and clearly.
ECE4800/4810			
1	There is evidence that the PDR, CDR, and/or FDR technical report exhibits one or fewer of the following three: (a) has at most very few grammatical or spelling mistakes and the meaning of sentences are mostly clear, (b) is mostly well organized with clear and appropriately defined sections and with mostly appropriate material in each section (c) contains mostly correct technical content, has appropriate conclusions, and it fully complete.	There is evidence that the PDR, CDR, and/or FDR technical report exhibits 2 of the following three: (a) has at most very few grammatical or spelling mistakes and the meaning of sentences are mostly clear, (b) is mostly well organized with clear and appropriately defined sections and with mostly appropriate material in each section (c) contains mostly correct technical content, has appropriate conclusions, and it fully complete.	There is evidence that the PDR, CDR and/or FDR technical report exhibits all three of the following: (a) has at most very few grammatical or spelling mistakes and the meaning of sentences are mostly clear, (b) is mostly well organized with clear and appropriately defined sections and with mostly appropriate material in each section (c) contains mostly correct technical content, has appropriate conclusions, and it fully complete.

TABLE 4.19 Assessment rubrics for Student Outcome (g).

	Rubric		
Ind	**1 = Does not meet Expectations**	**2 = Meets expectations**	**3 = Exceeds expectations**
2	There is evidence that the poster presentation is not appropriate for communicating with non-technical people by exhibiting no more than one of the following: (a) The presentation contains mostly broad design details such as constraints, solution structure, assumptions, performance parameters, and conclusions, (b) Non-technical words are chosen as much as possible or highly technical words are explained, (c) highly technical concepts are presented in non-technical and simplified terms, (d) Conclusions are easily understood by non-technical people	There is evidence that the poster presentation is appropriate for communicating with non-technical people by exhibiting 2 or 3 of the following: (a) The presentation contains mostly broad design details such as constraints, solution structure, assumptions, performance parameters, and conclusions, (b) Non-technical words are chosen as much as possible or highly technical words are explained, (c) highly technical concepts are presented in non-technical and simplified terms, (d) Conclusions are easily understood by non-technical people	There is evidence that the poster presentation is appropriate for communicating with non-technical people by exhibiting all 4 of the following: (a) The presentation contains mostly broad design details such as constraints, solution structure, assumptions, performance parameters, and conclusions, (b) Non-technical words are chosen as much as possible or highly technical words are explained, (c) highly technical concepts are presented in non-technical and simplified terms, (d) Conclusions are easily understood by non-technical people
3	There is evidence that the technical presentation exhibits one or fewer of the following: (a) is mostly well organized by containing a logical thought progression by beginning with a title slides, outlines/goals, design definition, followed by appropriately sequenced technical details, and ends with a summary/conclusions, (b) contains appropriate design technical details such as a well conceived design solution, sufficient technical details to assess the feasibility of the solution, and containing critical issues, (c) the speakers spoke clearly, chose effective words, demonstrated a command of the technical material, and answered questions effectively and clearly.	There is evidence that the technical presentation exhibits 2 of the following: (a) is mostly well organized by containing a logical thought progression by beginning with a title slides, outlines/goals, design definition, followed by appropriately sequenced technical details, and ends with a summary/conclusions, (b) contains appropriate design technical details such as a well conceived design solution, sufficient technical details to assess the feasibility of the solution, and containing critical issues, (c) the speakers spoke clearly, chose effective words, demonstrated a command of the technical material, and answered questions effectively and clearly.	There is evidence that the technical presentation exhibits all three of the following: (a) is mostly well organized by containing a logical thought progression by beginning with a title slides, outlines/goals, design definition, followed by appropriately sequenced technical details, and ends with a summary/conclusions, (b) contains appropriate design technical details such as a well conceived design solution, sufficient technical details to assess the feasibility of the solution, and containing critical issues, (c) the speakers spoke clearly, chose effective words, demonstrated a command of the technical material, and answered questions effectively and clearly.

(h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context

TABLE 4.20 Student Outcome (h) assessment indicators and descriptions.

Indicator	Course	Assessment Description
1. Ability to understand the environmental impact of an engineering design.	ECE4800/ ECE4810	Write a PDR, CDR, and/or FDR reports.
2. Ability to understand the economic impact of an engineering design.	ECE4800/ ECE4810	Write a PDR, CDR, and/or FDR reports.

This outcome refers to an ability to understand the impact of engineering solutions in a broader context.

Indicator #1: This indicator refers to an ability to understand the environmental impact of an engineering design.

- ECE4800/ECE4810: *Students will demonstrate an ability to understand the environmental impact of an engineering design as evidenced in the project notebooks, technical reports, or technical presentations*.

Indicator #2: This indicator refers to an ability to understand the economic impact of an engineering design

- ECE4800/ECE4810: *Students will demonstrate an ability to understand the economic impact of an engineering design as evidenced in the project notebooks, technical reports, or technical presentations*.

The assessment rubrics are given in the following table.

TABLE 4.21 Assessment rubrics for Student Outcome (h).

	Rubric		
Ind	**1 = Does not meet Expectations**	**2 = Meets expectations**	**3 = Exceeds expectations**
ECE4800/4810			
1	There is little or no evidence that the environmental impact of a design is considered.	There is evidence that one aspect of the environmental impact of a design is considered in the design solution.	There is evidence that multiple aspects of the environmental impact of a design are considered in the design solution.
2	There is little or no evidence that the economic impact of a design is considered.	There is evidence that one aspect of the economic impact of a design is considered in the design solution.	There is evidence that multiple aspects of the economic impact of a design are considered in the design solution.

(i) a recognition of the need for, and an ability to engage in life-long learning

TABLE 4.22 Student Outcome (i) assessment indicators and descriptions.

Indicator	Course	Assessment Description
1. Ability to identify the need for additional knowledge to further a design solution.	ECE3090	Measure the internal resistance of a battery.
	ECE4800/ ECE4810	Exhibit through technical details found in the Project Notebook, technical reports, or technical presentations.
2. Ability to identify and evaluate resources for the purpose of acquiring appropriate knowledge to further a design solution.	ECE3151	Build a PID controller so a robot can track a wall.
	ECE3090	Measure the internal resistance of a battery.
	ECE4800/ ECE4810	Exhibit through technical details found in the Project Notebook, technical reports, or technical presentations.
3. Ability to acquire suitable knowledge to further a design solution.	ECE3151	Build a PID controller so a robot can track a wall.
	ECE3090	Measure the internal resistance of a battery.
	ECE4800/ ECE4810	Exhibit through technical details found in the Project Notebook, technical reports, or technical presentations.
4. Ability to apply acquired knowledge to a design solution.	ECE3151	Build a PID controller so a robot can track a wall.
	ECE3090	Measure the internal resistance of a battery.
	ECE4800/ ECE4810	Exhibit through technical details found in the Project Notebook, technical reports, or technical presentations.

This outcome refers to an ability to acquire knowledge and apply that knowledge to further a design solution. The Electrical Engineering program serves to provide an educational foundation for the graduate. When a graduated student enters a school for advanced study or enters industry practice, they will be required to learn new ideas in order to solve problems beyond the specific scope of problems addressed in their undergraduate program. The requires that they develop the skills necessary to acquire new knowledge and apply that knowledge.

There are four indicators associated with this skill. The first involves recognizing the need to acquire knew knowledge. Once this is recognized, the student needs to identify and evaluate sources of information. The plethora of information available today through the internet, much of it either misleading or wrong, requires that sources be vetted. Once sources are vetted and accepted, then the knowledge needs to be acquired and correctly applied.

Indicator #1: This indicator refers to an ability to identify the need for additional knowledge to further a design solution.

- ECE3090:

  Prior to S17: *Students will demonstrate an ability to identify the need for additional knowledge to further a design solution as evidenced by project notebooks, technical reports, or technical presentations*.

  S17 and after: Students are required to measure the internal resistance of a battery. *Students will demonstrate an ability to identify the need for additional knowledge for the purpose of measuring the internal resistance of a battery as evidenced in the project notebooks, technical reports, or technical presentations*.
- ECE4800/ECE4810: *Students will demonstrate an ability to identify the need for additional knowledge as evidenced in the project notebooks, technical reports, or technical presentations*.

Indicator #2: This indicator refers to an ability to identify and evaluate resources for the purpose of acquiring appropriate knowledge to further a design solution.

- ECE3151: Students are required to build and calibrate a PID controller so a simulated robot can track a wall. *Students will demonstrate an ability to identify and evaluate resources for the purpose of calibrating a PID controller as evidenced by a technical report*.
- ECE3090:

  Prior to S17: *Students will demonstrate an ability to identify and evaluate resources for the purpose of acquiring appropriate knowledge to further a design solution as evidenced by project notebooks, technical reports, or technical presentations*.

  S17 and after: Students are required to measure the internal resistance of a battery. *Students will demonstrate an ability to identify and evaluate resources for the purpose of developing a battery measurement experiment as evidenced in the project notebooks, technical reports, or technical presentations*.
- ECE4800/ECE4810: *Students will demonstrate an ability to identify and evaluate resources for the purpose of acquiring appropriate knowledge to further a design solution as evidenced in the project notebooks, technical reports, or technical presentations*.

Indicator #3: This indicator refers to an ability to read and understand material found in appropriate resources to further a design solution.

- ECE3151: *Students will demonstrate an ability to read and understand material found in appropriate resources to calibrate a PID controller as evidenced by a technical report*.
- ECE3090:

  Prior to S17: *Students will demonstrate an ability to read and understand material found in appropriate resources to further a design solution as evidenced by project notebooks, technical reports, or technical presentations*.

  S17 and after: Students are required to measure the internal resistance of a battery. *Students will demonstrate an ability to read and understand material found in appropriate resources for the purpose of developing a battery measurement experiment as evidenced in the project notebooks, technical reports, or technical presentations*.
- ECE4800/ECE4810: *Students will demonstrate an ability to read and understand material found in appropriate resources to further a design solution as evidenced in the project notebooks, technical reports, or technical presentations*.

Indicator #4: This indicator refers to an ability to apply acquired knowledge to further a design solution. By "apply" we mean such things as to mathematically solve problems or to develop hardware or software to further a design solution.

- ECE3151: *Students will demonstrate an ability to apply acquired knowledge to calibrate a PID controller for the purpose of controlling a robot to track a wall, as evidenced by a technical report*.
- ECE3090:

  Prior to S17: *Students will demonstrate an ability to apply acquired knowledge to further a design solution as evidenced by project notebooks, technical reports, or technical presentations*.

  S17 and after: Students are required to measure the internal resistance of a battery. *Students will demonstrate an ability to apply acquired knowledge for the purpose of developing a battery measurement experiment as evidenced in the project notebooks, technical reports, or technical presentations*.
- ECE4800/ECE4810: *Students will demonstrate an ability to apply acquired knowledge to further a design solution as evidenced in the project notebooks, technical reports, or technical presentations*.

The assessment rubrics are given in the following table.

TABLE 4.23 Assessment rubrics for Student Outcome (i).

	Rubric		
Ind	**1 = Does not meet Expectations**	**2 = Meets expectations**	**3 = Exceeds expectations**
ECE3151			
2	There is little or no evidence that any sources have been identified for the purpose of acquiring new knowledge for the purpose of tuning a PID controller.	There is evidence that one source has been identified for the purpose of acquiring new knowledge for the purpose of tuning a PID controller.	There is evidence that multiple sources have been identified for the purpose of acquiring new knowledge for the purpose of tuning a PID controller.
3	There is little or no evidence that any sources have been read and understood for the purpose of tuning a PID controller.	There is evidence that a technique from one source has been read and understood for the purpose of tuning a PID controller.	There is evidence that techniques from multiple sources have been read and understood for the purpose of tuning a PID controller.
4	There is little or no evidence that any techniques for tuning a PID controller have been applied to the problem of controlling a mobile robot.	There is evidence that one technique for tuning a PID controller have been partially applied to the problem of controlling a mobile robot.	There is evidence that one or more techniques for tuning a PID controller have been correctly and fully applied to the problem of controlling a mobile robot.
ECE3090 & ECE4800/4810			
1	There is little of no evidence where the need for new knowledge has been identified as part of an engineering design.	There is evidence of one example where the need for new knowledge has been identified as part of an engineering design.	There is evidence of multiple examples where the need for new knowledge has been identified as part of an engineering design.
2	There is little of no evidence where resources have been identified for the purpose of acquiring new knowledge as part of an engineering design.	There is evidence of one example where resources have been identified for the purpose of acquiring new knowledge as part of an engineering design.	There is evidence of multiple examples where resources have been identified for the purpose of acquiring new knowledge as part of an engineering design.
3	There is little or no evidence where new knowledge has been acquired from resources for the purpose of furthering an engineering design.	There is evidence of one example where new knowledge has been acquired from resources for the purpose of furthering an engineering design.	There is evidence of multiple examples where new knowledge has been acquired from resources for the purpose of furthering an engineering design.
4	There is little or no evidence where new knowledge has been applied for the purpose of furthering an engineering design or that new knowledge has been inappropriately applied.	There is evidence of one example where new knowledge has been appropriately applied for the purpose of furthering an engineering design.	There is evidence of multiple examples where new knowledge has been appropriately applied for the purpose of furthering an engineering design.

(j) a knowledge of contemporary issues

TABLE 4.24 Student Outcome (j) assessment indicators and descriptions.

Indicator	Course	Assessment Description
1. Ability to identify current trends in professionally-related industries.	ECE1001	Summarize a technical paper involving current trends in battery technology.
	ECE4800/ ECE4810	Exhibit through technical details found in the Project Notebook, technical reports, or technical presentations.

This outcome refers to an ability to identify and converse about contemporary issues, such as battery technology for the electric car industry, renewable energy resources and their impact on the environment, or cybersecurity in a world heavily reliant on the internet.

Indicator #1: This indicator refers to an ability to identify current trends in professionally-related industries. These industries might involve battery technology, motor technology, speaker technology, etc.

- ECE1001: *Students will demonstrate an ability to identify current trends in battery technology and motor technology as evidenced by a brief synopsis of a technical paper involving each.*
- ECE4800/ECE4810: *Students will demonstrate an ability to identify current trends in professionally-related industries as evidenced in the project notebooks, technical reports, or technical presentations*.

The assessment rubrics are given in the following table.

TABLE 4.25 Assessment rubrics for Student Outcome (j).

	Rubric		
Ind	**1 = Does not meet Expectations**	**2 = Meets expectations**	**3 = Exceeds expectations**
ECE1001			
1	There is little or no evidence where current trends in a professionally-related industry have been identified.	There is evidence of one example where current trends in a professionally-related industry has been identified.	There is evidence of multiple examples where current trends in a professionally-related industry have been identified.
ECE4800/4810			
1	There is little or no evidence where current trends in a professionally-related industry have been identified.	There is evidence of one example where current trends in a professionally-related industry has been identified.	There is evidence of multiple examples where current trends in a professionally-related industry have been identified.

(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice

TABLE 4.26 Student Outcome (k) assessment indicators and descriptions.

Indicator	Course	Assessment Description
1. Ability to use laboratory test equipment for engineering practice.	ECE2103	Use a DMM to measure voltages/currents in a circuit.
	ECE2206	Use a DMM to measure voltages/currents in a circuit.
	ECE3132	Use an oscilloscope to measure signal parameters.
2. Ability to use appropriate software for engineering practice.	ECE2206	Use the Xilinx software to verify a design.
	ECE3151	Write a Matlab function to eliminate an echo from an acoustic signal.
3. Ability to use appropriate development tools for engineering practice.	ECE1002	Use the Arduino development environment to program a mobile robot.
	ECE2206	Use the Digilent Nexus 2 board and Xilinx software to implement a design.
	ECE3151	Use the Matlab development environment to write a program.
	ECE3226	Use the SDK500 development board to download code onto an ATMEGA 32A AVR chip.

This outcome refers to an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice. Such tools can include PCB layout tools like *Eagle*, oscilloscopes, digital multimeters (DMM), function generators, power supplies, Matlab, Xilinx software, the SDK500 development board, Multisim, etc.

Indicator #1: This indicator refers to an ability to use laboratory test equipment for engineering practice.

- ECE2103: *Students will demonstrate an ability to use a DMM to measure voltages as evidenced in a laboratory report*.
- ECE2206: *Students will demonstrate an ability to use a DMM to measure voltages in a digital circuit as evidenced in laboratory reports*.
- ECE3132: *Students will demonstrate an ability to use an oscilloscope to measure signal parameters as evidenced in a laboratory report*.

Indicator #2: This indicator refers to an ability to use appropriate software for engineering practice.

- ECE2206: *Students will demonstrate an ability to use the Xilinx software to program a digital system as evidenced in laboratory reports*.
- ECE3151: *Students will demonstrate an ability to use Matlab to build a software function that will eliminate the echo from an acoustic signal as evidenced by written software*.

Indicator #3: This indicator refers to an ability to use appropriate development tools for engineering practice.

- ECE1002: *Students will demonstrate an ability to use the Eagle PCB development tool by developing schematic and board files for use in a mobile robotic application as evidenced by the developed board and schematic files*.
- ECE2206: *Students will demonstrate an ability to use Xilinx development tool to program a Digilent Nexus 2 board as evidenced in laboratory reports*.

- ECE3151: *Students will demonstrate an ability to use the matlab development environment to write a computer program as evidenced in laboratory reports.*
- ECE3226: *Students will demonstrate an ability to use the SDK500 development tool to program an ATMEGA 32A AVR chip as evidenced in laboratory reports*.

The assessment rubrics are given in following table.

TABLE 4.27 Assessment rubrics for Student Outcome (k).

	Rubric		
Ind	**1 = Does not meet Expectations**	**2 = Meets expectations**	**3 = Exceeds expectations**
ECE2103			
1	There is little or no evidence where a DMM has been used to correctly measure voltage in a circuit as part of a laboratory experiment.	There is evidence of one example where a DMM has been used to correctly measure voltage in a circuit as part of a laboratory experiment.	There is evidence of multiple examples where a DMM has been used to correctly measure voltages in a circuit as part of a laboratory experiment.
ECE2206			
1	There is little of no evidence where a DMM has been used to correctly measure voltages in a digit circuit as part of a laboratory experiment.	There is evidence of one example where a DMM has been used t correctly measure voltages in a digit circuit as part of a laboratory experiment.	There is evidence of multiple examples where a DMM has been used to correctly measure voltages in a digit circuit as part of a laboratory experiment.
2	There is little or no evidence that the Xilinx software has been used to correctly display the timing diagram for any signal in a digital circuit.	There is evidence that the Xilinx software has been used to correctly display the timing diagram for one signal in a digital circuit.	There is evidence that the Xilinx software has been used to correctly display the timing diagram for multiple signals in a digital circuit.
3	There is little or no evidence that the Xilinx software has been used to program a Digilent Nexus 2 board.	There is evidence that the Xilinx software has been used to program a Digilent Nexus 2 board with an incorrect VHDL program.	There is evidence that the Xilinx software has been used to program a Digilent Nexus 2 board with a correct VHDL program.
ECE3132			
1	There is little or no evidence where an oscilloscope has been used to correctly measure parameters for a time-domain signal as part of a laboratory experiment.	There is evidence of one example where an oscilloscope has been used to correctly measure a parameter for a time-domain signal as part of a laboratory experiment.	There is evidence of multiple examples where an oscilloscope has been used to correctly measure parameters for a time-domain signal as part of a laboratory experiment.
ECE3226			
3	There is little or no evidence that the SDK500 development tool has been used to download any program to the ATMEGA 32A AVR chip.	There is evidence that the SDK500 development tool has been used to download a program with minor errors to the ATMEGA 32A AVR chip.	There is evidence that the SDK500 development tool has been used to download a correct program to the ATMEGA 32A AVR chip.