ETAC ABET and EvaluateUR-CURE: Findings from Combining Two Assessment Approaches as Indicators of Student Learning Outcomes

Ilya Grinberg and Jill Singer

Abstract

Engineering Technology (ET) programs at community colleges and colleges/universities play a vital role in meeting the growing national demand for STEM graduates. Many accredited ET programs feature design projects that allow students to apply content knowledge and gain valuable workplace skills. Undergraduate research, especially inquiry-based projects, helps students take ownership of their own learning and see the real-world relevance of research as they learn problem-solving skills. EvaluateUR-CURE, an evidence-based method developed at SUNY Buffalo, measures a broad range of desirable outcomes that include both content knowledge and outcomes that are critically important in the workplace, such as communication skills, creativity, autonomy, an ability to overcome obstacles, critical thinking, and problem-solving skills. EvaluateUR-CURE also provides students opportunities to develop metacognitive skills as a way to identify how much academic progress they have made or still need to make. This paper addresses the process of development of performance indicators and presents the results of assessment and evaluation of ETAC ABET student outcomes and outcome categories of EvaluateUR-CURE.

1. Introduction

There is a growing national demand for qualified graduates in science, technology, engineering, and mathematics (STEM). Engineering Technology (ET) programs at community colleges and colleges/universities play an essential role in meeting this demand through the preparation of students who are well qualified to enter the technical workforce. Students enrolled in accredited ET programs conduct design projects that provide opportunities to apply content knowledge and gain valuable workplace skills. These course-based undergraduate research experiences (CUREs) greatly expand the number of students who can benefit from conducting research as the design projects are embedded directly into the curriculum and are taken by all students in the program. Undergraduate research has been shown to help students take ownership of their own learning and helps them to see the real-world relevance of research as they learn problem-solving skills (Healey and Jenkins 2009; Kilgo and Pascarella 2016; Pepper 2010). Inquiry-based projects are beneficial because they require a significant investment of student time and effort over an extended period with frequent constructive feedback from faculty and regular opportunities for reflection (Kuh 2008; Kilgo et al. 2015). This paper addresses the process of development of performance indicators and presents the results of assessment and evaluation of both ETAC ABET and EvaluateUR-CURE student outcomes.

2. EvaluateUR-CURE

EvaluateUR-CURE is a modification of EvaluateUR, a successful student outcomes evaluation/student learning method that helps undergraduate students to become aware of the wide range of competencies and skills they should strive to master in order to succeed in graduate work and/or the workplace and see clearly the knowledge and skills they have gained through their research activities, as well as areas where they need to make more progress. EvaluateUR-CURE measures a broad range of desirable outcomes that include both content knowledge and skills that are critically important in the workplace. EvaluateUR-CURE assessments include 10 outcome categories each defined by three components (Table 1). To assess student progress, each component is scored by both the student and faculty member using a five-point scale with 1=never displays the outcome to 5=always displays the outcome. In common with Evalu-

Table 1. EvaluateUR-CURE Outcomes.

Outcome Categories	Outcome Components
Communication	• Uses and understands professional and discipline-specific language • Expresses ideas orally in an organized, clear, and concise manner • Writes clearly and concisely using correct grammar, spelling, syntax, and sentence structure
Creativity	• Shows ability to approach problems from different perspectives • Uses information in ways that demonstrate intellectual resourcefulness • Effectively connects multiple ideas/approaches
Autonomy	• Demonstrates an ability to work independently and identify when guidance is needed • Accepts constructive criticism and uses feedback effectively • Uses time well to ensure work gets accomplished
Ability to Deal with Obstacles	• Is not discouraged by setbacks or unforeseen problems and perseveres when encountering challenges or setbacks • Shows flexibility and a willingness to take risks and try again • Trouble-shoots problems and searches for ways to do things more effectively
Intellectual Development	• Recognizes that problems are often more complicated than they first appear • Approaches problems with an understanding that there can be more than one right explanation or even none at all • Displays insight into the limits of his or her knowledge and an appreciation for what isn't known
Critical Thinking and Problem Solving	• Maintains a posture of open-minded skepticism when considering potential solutions to problems • Looks for the root causes of problems and develops or recognizes the most appropriate corrective actions • Recognizes flaws, assumptions, and missing elements in arguments
Practice and Process of Inquiry	• Demonstrates ability to formulate questions within the discipline • Demonstrates ability to properly identify and/or generate reliable data • Shows understanding of how knowledge is generated, validated, and communicated within the discipline
Nature of Disciplinary Knowledge	• Shows understanding of the criteria for determining what is valued as a contribution in the discipline • Shows awareness of important contributions in the discipline and who was responsible for those contributions • Reads and applies information obtained from professional journals and other sources
Content Knowledge Skills and Methodology	• Displays knowledge of key facts and concepts relevant to project • Displays a grasp of relevant methods and is clear about how these methods apply to the project being undertaken • Demonstrates an appropriate mastery of skills needed to conduct the project
Teamwork/Collaboration	• Demonstrates ability to manage conflict among colleagues • Displays ability to share distribution of tasks • Shows ability to work effectively in a team

ateUR, EvaluateUR-CURE also contributes to the development and enhancement of student metacognitive skills, characterized by learners becoming more aware of what learning strategies they are pursuing and why, and then using that awareness to improve their learning strategies. A set of metacognitive activities has been developed for EvaluateUR-CURE. These activities are short and do not

require grading, can be used singly or in pairs, and intended to be used either during class time or assigned to be completed outside of class. A guide to metacognition and the activities is provided for the course instructor. More information about EvaluateUR and EvaluateUR-CURE are found at http://serc.carleton.edu/evaluateur.

The steps in EvaluateUR-CURE emphasize the importance of having students understand the method's approach at the beginning of the semester, including learning what the outcomes to be measured are and why they matter. Early in the semester and before the research begins, students complete an assignment that consists of a series of open-ended questions that ask about the student's ideas about conducting research and any prior relevant experiences. The same set of questions is completed a second time near the end of the course semester (Assignment 2). The timing of the two assignments can be adjusted depending on the duration of the CURE (one versus two semesters). The design of EvaluateUR-CURE also ensures that participating faculty have time to observe the students conducting research activities. Assessment 1 is completed soon after research/project begins, and Assessment 2 is completed at the end of the research/project. For CUREs that are two semesters, the assessment can be repeated a third, or even a fourth time. Following the completion of each assessment, score reports are generated for the students showing each outcome component and the score they assigned to the outcome and the score assigned by the faculty. The score report facilitates productive conversations between the student and the faculty member during which time each can talk about the reasons for assigning a particular score. It is emphasized that it is the conversation–more than the scores–that are most beneficial to the student.

The sequence of steps described above provides two pre-post measures: Assignment 1 (pre-) and 2 (post-) and Assessment 1 (pre-) and 2 (post-). Again, the measures reflect the number of times the assessments are repeated. Because EvaluateUR-CURE is intended to provide students with regular feedback, the faculty member teaching the CURE has the flexibility to repeat the assessment multiple times. At the end of the CURE, a built-in statistical package generates several statistical measures that provide data for each outcome component. The data is reported for each member of the course and also group the students into research/design teams with averaged scores. The presentation of the data in these formats makes it easy for faculty teaching the CURE to use these data as part of the course evaluation and supports the continuous improvement of the course.

The two-semester senior design sequence at SUNY Buffalo State was a pilot implementation site for EvaluateUR-CURE because it addresses nearly all of ETAC ABET student outcomes and overlaps with outcome categories and components of EvaluateUR-CURE. In addition, the junior-level electronics course has recently been revised to include students working in groups on a variety of practical design projects. The revised course identified specific performance indicators and grading rubrics to be used for assessment and assigning student grades. EvaluateUR-CURE complements these indicators by providing additional feedback to the student about their progress so adjustments in their learning can be made throughout the semester, not just at the end of the semester when grades are assigned. EvaluateUR-CURE can also help students take greater ownership in their learning as they identify their academic strengths and what strategies they might use to improve in other areas.

3. Senior Design Sequence

In 2016, a two-semester sequence-ENT 465: Electrical Design I (3 credit hours) and ENT 466: Electrical Design II (3 credit hours)-at SUNY Buffalo State replaced a single-semester course. The transition from a single-semester to a two-semester sequence allows for more time for the students to design and conduct design projects that involve learning and applying research methodologies. This sequence integrates knowledge gained by students in prior courses including but not limited to Electronics, Digital Systems, Microcontrollers, and Control Systems I and II. ENT 465 and ENT 466 are taken by all Electrical Engineering Technology students in the fall and spring semesters of their senior year.

The senior design sequence serves as a capstone and integrating experience that further develops student competencies in applying both technical and non-technical capabilities in solving problems (ABET 2020). The purpose of the project conducted over the two-semester sequence is to provide students with a realistic experience similar to what may be expected when the students are hired by industry. The sequence provides student research and design experience, enhances oral and written communication capabilities, and supports presentation opportunities at professional conferences. The experience builds capabilities in seven major areas: (1) team building, (2) project management, (3) design, (4) subject knowledge and tech-

nical merit, (5) documentation, and (6) presentation. In addition, (7) professional responsibilities, ethical responsibilities, respect for diversity, equity, and inclusion, and quality and continuous improvement as well as (8) research methodologies are incorporated into the course (McCulley 2013; Grinberg 2020).

The two-semester senior design sequence has been offered four times since its development with 85 students completing the sequence and is currently in the fifth year (2020-2021) with 22 students enrolled. The sequence has been shown to be successful in meeting ETAC ABET student outcomes requirements. Outcomes data collected from fall 2016 to spring 2019 show an ~17% improvement in attaining Criterion 3, Outcomes 1 and 2 compared to the average from the contributing courses (Grinberg 2020). ENT 465 and ENT 466 were further revised in summer 2020 and the sequence was offered in the fall 2020 and spring 2021 semesters.

4. Performance Indicators for Direct Assessment of Student Outcomes

The direct assessment of student outcomes is based on performance indicators (also known as rubrics). Such performance indicators were developed by the program to assess and evaluate attainment of ETAC ABET Criterion 3 as well as to assess intended capabilities in the senior design sequence. Compilation of performance indicators was based on the body of knowledge necessary for entry into the professional practice of engineering expressed as capabilities. A capability is defined as what an individual is expected to know and be able to do by the time of entry into professional practice in a responsible role and consists of knowledge, skills, and attitudes (NSPE 2013). In the context of the senior design sequence and undergraduate engineering technology education, capabilities were interpreted as what students should know and be able to apply by the time of graduation and therefore treated as a subset of student outcomes. Students were assessed by project industry advisors from local companies on biweekly basis following regular meetings with student project teams. Each team was assigned two industry advisors with expertise in the projects' areas. Evaluation of assessment results was performed by the course instructor and used for the course grading as well as entry points for assessment and evaluation of ETAC ABET outcomes.

The performance indicators used to assess *team building capabilities* (related to ETAC ABET Criterion 3, Outcome 5) include the following: (1) works toward group goals, (2) uses effective interpersonal skills, (3) contributes to group maintenance, (4) takes on a variety of roles. These performance indicators are consistent with teamwork abilities as indicated in NSPE (2013 57-58). Grading criteria to assess team building performance indicators are presented in Appendix A, Table A-1.

Assessment of *project management capabilities* is based on the following performance indicators: (1) identify discrete work tasks and budgets for a portion of a project, (2) direct the project work of one or more team members, (3) monitor project schedules and costs using appropriate tools such as Gantt charts, other bar charts, precedence diagrams, or other appropriate tools. These performance indicators are consistent with project management abilities as indicated in NSPE (2013 55-56). Grading criteria to assess project management performance indicators are presented in Appendix A, Table A-2.

Design capabilities addressed by ETAC ABET Criterion 3, Outcome 2 are assessed by the following performance indicators: (1) formulate the problem and analyze constraints, (2) establish design requirements, (3) generate alternative solutions, (4) build a prototype/perform simulation when it is impossible to build a prototype, (5) analyze performance through testing/simulation, (6) assess the strength and weaknesses of design, (7) identify next steps to improve on design. These performance indicators are consistent with problem recognition and solving abilities, design abilities, and select systems engineering abilities as indicated in NSPE (2013 33-34, 37, 43). Grading criteria to assess design performance indicators are presented in Appendix A, Table A-3.

Subject knowledge and technical merit are related to ETAC ABET Criterion 3, Outcome 1 and assessed using the following performance indicators: (1) applies material from their discipline to the design of a project, (2) identifies and acquires new knowledge as a part of the problem-solving/design process. Grading criteria to assess subject knowledge and technical merit performance indicators are presented in Appendix A, Table A-4.

Documentation capabilities are assessed using the following performance indicators: (1) grammar, (2) graphics, (3) logbook, (4) manual/project report. Grading criteria to assess written and graphical documentation performance indicators are presented in Appendix A, Table A-5. These performance indicators are consistent with communication abilities as indicated in NSPE (2013 49).

Presentation capabilities are assessed using the following performance indicators: (1) appearance, (2) preparedness, (3) delivery, (4) elocution, (5) demonstration (when applicable). Grading criteria to assess presentation performance indicators are presented in Appendix A, Table A-6. These performance indicators are also consistent with communication abilities as indicated in NSPE (2013 49).

Side-by side comparison between granular performance indicators of ETAC ABET outcomes and EvaluateUR-CURE outcomes reveals similarities in construct between them, showing parallels in wording and intent as illustrated by Table 2.

5. Assessment of Attaining Capabilities in Senior Design Sequence

Direct assessment of performance indicators associated with ETAC ABET outcomes was conducted every two weeks. Starting in the Fall 2020 semester, this assessment was performed by industry advisors for each team using the grading rubrics presented in Tables A-2 –A- 6 (please see Appendix

Table 2. Relevance between Performance Indicators (Rubrics) Associated with ETAC ABET Outcomes and EvaluateUR-CURE Outcome Components.

Subject Knowledge and Technical Merit

ABET Outcome 1 "An ability to apply knowledge, techniques, skills and modern tools of mathematics, science, engineering, and technology to solve broadly defined engineering problems appropriate to the discipline"	**Evaluate UR-CURE Outcome Components**
1. Applies material from their discipline to the design of a project	1a. Displays knowledge of key facts and concepts relevant to project 1b. Displays a grasp of relevant methods and is clear about how these methods apply to the project being undertaken 1c. Demonstrates an appropriate mastery of skills needed to conduct the project
2. Identifies and acquires new knowledge as a part of the problem-solving/design process	2a. Reads and applies information obtained from professional journals and other sources 2b. Displays insight into the limits of his or her knowledge and an appreciation for what is not known 2c. Uses information in ways that demonstrate intellectual resourcefulness 2d. Accepts constructive criticism and uses feedback effectively 2e. Shows flexibility and a willingness to take risks and try again

Design Capabilities

ABET Outcome 2 "An ability to design systems, components, or processes meeting specified needs for broadly defined engineering problems appropriate to the discipline"	**Evaluate UR-CURE Outcome Components**
1. Formulate the problem and analyze constraints	1a. Recognizes flaws, assumptions, and missing elements in arguments 1b. Shows understanding of how knowledge is generated, validated, and communicated within the discipline 1c. Recognizes that the problems are often more complicated than they first appear
2. Establish design requirements	2a. Recognizes that the problems are often more complicated than they first appear 2b. Demonstrates ability to formulate questions within the discipline 2c. Demonstrates ability to properly identify and/or generate reliable data
3. Generate alternative solutions	3a. Shows ability to approach problems from different perspectives 3b. Approaches problems with an understanding that there can be more than one right explanation or even none at all 3c. Effectively connects multiple ideas/approaches
4. Build a prototype/perform simulation when it is impossible to build a prototype	*Recommend that faculty consider identifying this outcome as an optional outcome in E-CURE's assessments*
5. Analyze performance through testing/simulation	5a. Trouble-shoots problems and searches for ways to do things more effectively

6. Assess the strength and weaknesses of Design	6a. Looks for the root causes of problems and develops or recognizes the most appropriate corrective actions 6b. Maintains a posture of open-minded skepticism when considering potential solutions to the problem 6c. Effectively connects multiple ideas/approaches 6d. Trouble-shoots problems and searches for ways to do things more effectively
7. Identify next steps to improve on Design	7a. Looks for the root causes of problems and develops or recognizes the most appropriate corrective actions 7b. Maintains a posture of open-minded skepticism when considering potential solutions to problems

Communication Capabilities

ABET Outcome 3 "An ability to apply written, oral, and graphical communication in both technical and non- technical environments, and an ability to identify and use appropriate technical literature"	**Evaluate UR-CURE Outcome Components**
1. An ability to apply written, oral, and graphical communication in both technical and non-technical environments	1a. Uses and understands professional and discipline-specific language 1b. Expresses ideas orally in an organized, clear, and concise manner 1c. Writes clearly and concisely using correct grammar, spelling, syntax, and sentence structure
2. An ability to identify and use appropriate technical literature	2a. Reads and applies information obtained from professional journals and other sources 2b. Shows understanding of the criteria for determining what is valued as a contribution in the discipline 2c. Shows awareness of important contributions in the discipline and who was responsible for those contributions

Teamwork Capabilities

ABET Outcome 5 "An ability to function effectively as a member as well as a leader on technical teams"	**Evaluate UR-CURE Outcome Components**
1. Works toward group goals	1a. Demonstrates ability to manage conflict among colleagues 1b. Is not discouraged by setbacks or unforeseen problems and perseveres when encountering challenges or setbacks
2. Uses effective interpersonal skills	2a. Shows ability to work effectively in a team
3. Contributes to group maintenances	3a. Displays ability to share distribution of tasks
4. Takes on a variety of roles	*Recommend that faculty consider identifying this outcome as an optional outcome in E-CURE's assessments*

Organization and Project Management

ABET Criterion 5, Curriculum, with respect to IEEE program-specific criterion E "The ability to apply project management techniques to electrical/electronic(s) systems"	**Evaluate UR-CURE Outcome Components**
1. Identify discrete work tasks and budgets for a portion of a project	1a. Displays ability to share distribution of tasks
2. Direct the project work of one or more team members	2a. Displays ability to share distribution of tasks 2b. Shows ability to work effectively in a team 2c. Demonstrates ability to manage conflict among colleagues 2d. Demonstrates an ability to work independently and identify when guidance is needed
3. Monitor project schedules and costs using appropriate tools such as Gantt charts, other bar charts, precedence diagrams, or other appropriate tools	3.1. Uses time well to ensure work gets accomplished

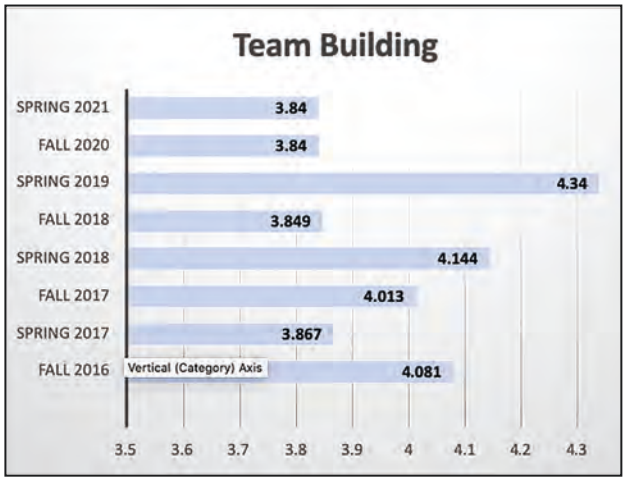
A). The industry advisors are interacting with the students regularly and able to provide feedback to both the students and the faculty advisor. This allowed students to address any industry advisors concerns and work to correct any identified shortcomings in a timely manner. The industry advisors are asked to treat students as their own employees, adding to the realism of the students' experiences. At the end-of-semester, presentations were assessed by both the faculty and industry advisors. The assessment of teamwork was done by the students' peer evaluation according to the grading rubrics in Table A-1 (please see Appendix A).

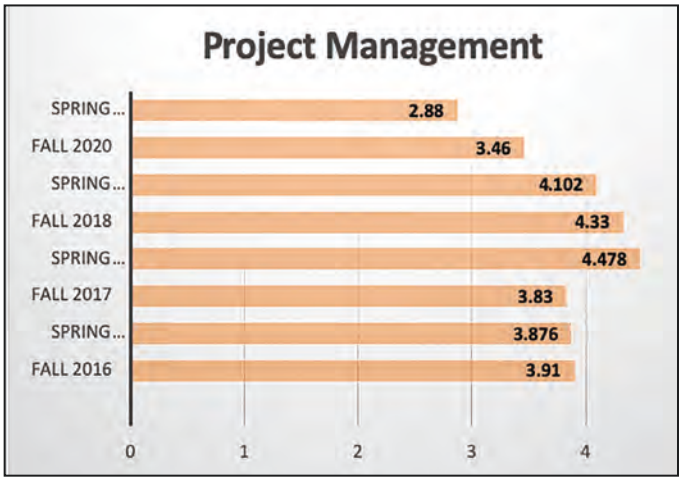
Comparison of assessment results of intended capabilities for senior design sequence is presented in Table 3 and associated graphs, where horizontal axis represents assessment scores as indicated in Appendix A.

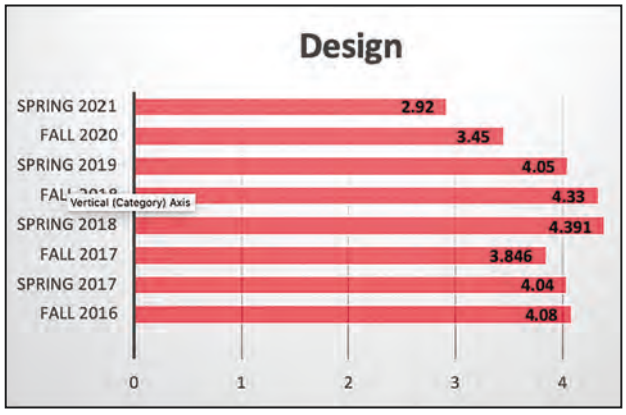
Reduction in performance in Fall 2020 and Spring 2021 compared to previous years can be

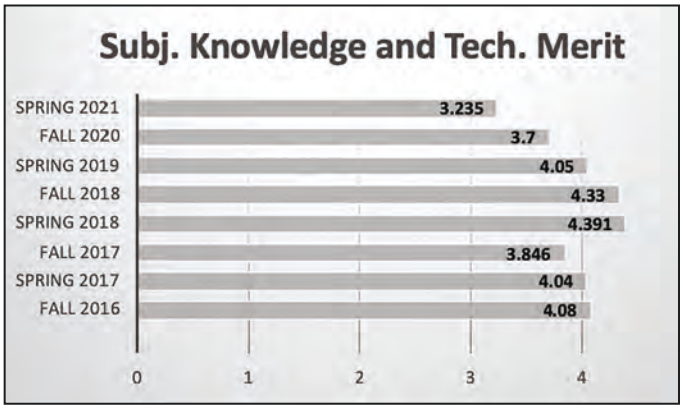
Table 3. Assessment Results of Intended Capabilities.

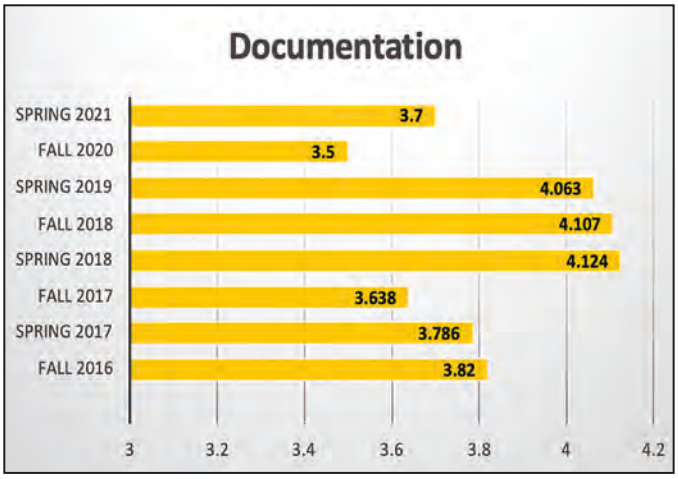
Course	Semester	Team Building	Project Management	Design	Subj. Knowledge and Tech. Merit	Documentation	Presentation
ENT 465	Fall 2016	4.08	3.91	4.08	4.08	3.82	3.92
ENT 466	Spring 2017	3.87	3.88	4.04	4.04	3.79	4.27
ENT 465	Fall 2017	4.01	3.83	3.85	3.85	3.64	4.12
ENT 466	Spring 2018	4.14	4.48	4.39	4.39	4.12	3.95
ENT 465	Fall 2018	3.85	4.33	4.33	4.33	4.11	3.93
ENT 466	Spring 2019	4.34	4.10	4.05	4.05	4.06	4.05
ENT 465	Fall 2020	3.84	3.46	3.45	3.70	3.50	3.50
ENT 466	Spring 2021	3.84	2.88	2.92	3.24	3.70	3.36

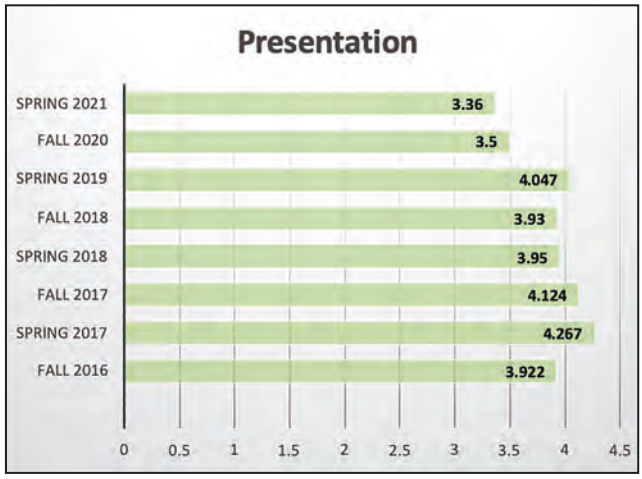












attributed to more detailed and rigorous grading rubrics implemented in Fall 2020, which allow uncovering certain shortcomings. Also, industry advisors tend to be more objective than faculty in their assessment.

EvaluateUR-CURE assessments were completed by students and course instructor once in the fall semester and two additional times in the second course in the CURE sequence. As described earlier in this paper, score reports are generated after each assessment is completed so that the student has a record of the score they assigned to themselves, and the score given by the faculty. This ensures transparency in the method in that the student is made aware of how the faculty views their progress and it also serves to help the student validate their ability to self-reflect and accurately assess their level of knowledge and skills. In conversation with the faculty, it also opens up the opportunity for the student and faculty to consider ways the student might improve in areas of weakness as well as utilize areas where they show particular aptitude. Table 4 illustrates results from EvaluateUR-CURE initial assessment (Fall 2020), mid-research assessment (Spring 2021) and final research assessment (Spring 2021) in outcome categories described in Table 1.

A comparison of EvaluateUR-CURE and ETAC ABET performance indicators is summarized in Table 5. To compare the assessments using the EvaluateUR-CURE outcome components and the ETAC ABET performance indicators, only the faculty mentor scores from EvaluateUR-CURE were used. Because in several cases, more than one EvaluateUR-CURE outcome component aligned with a performance indicator, the average of outcome components was used. Performance indicators are numbered in accordance with the left column of Table 2 and include the average scores from industry advisors grading performance indicators

Table 4. Results from EvaluateUR-CURE assessments.

EvaluateUR-CURE Outcome Categories	**Initial**		**Mid-Research**		**Final**	
	Student Average	Instructor Average	Student Average	Instructor Average	Student Average	Instructor Average
Communication	4.08	3.17	3.68	3.56	4.16	3.70
Creativity	3.84	3.24	3.83	3.71	4.05	4.10
Autonomy	4.21	3.41	3.81	3.73	4.13	4.03
Intellectual Development	4.02	3.38	3.73	3.90	4.08	4.11
Critical Thinking and Problem Solving	4.06	3.27	3.57	3.70	4.10	4.05
Practice and Process of Inquiry	3.90	3.19	3.70	3.70	4.05	4.06
Nature of Disciplinary Knowledge	3.94	3.11	3.49	3.81	4.05	4.00
Content Knowledge Skills and Methodology	3.94	3.05	3.60	3.56	4.21	3.86
Teamwork/Collaboration	4.41	3.54	3.78	4.00	4.13	4.46

Table 5. Comparison of EvaluateUR-CURE and ETAC ABET Performance Indicators Results.

	Preliminary Design	Final Design	Initial Assessment	Final Assessment
Subject Knowledge and Technical Merit				
	ABET Outcome 1		ECURE	
Indicator	Industry Advisors	Industry Advisors	Faculty Mentor	Faculty Mentor
1	3.43	3.28	3.01	3.86
2	3.97	3.19	3.26	4.17
Design Capabilities				
	ABET Outcome 2		ECURE	
Indicator	Industry Advisors	Industry Advisors	Faculty Mentor	Faculty Mentor
1	2.97	3.00	3.205	4.02
2	3.39	2.96	3.26	4.05
3	2.81	3.07	3.28	4.06
4	3.21	2.98		
5	3.26	2.86	3.18	4.14
6	2.70	3.15	3.23	4.11
7	3.317	3.05	3.05	4.10
Communication Capabilities				
	ABET Outcome 3		ECURE	
Indicator	Industry Advisors	Industry Advisors	Faculty Mentor	Faculty Mentor
1	3.50	3.70	3.17	3.80
2			2.950	4.000
Teamwork (overall)				
	ABET Outcome 5		ECURE	
Indicator	Peer Evaluation	Peer Evaluation	Faculty Mentor	Faculty Mentor
1	4.26	4.05	3.52	4.10
2	4.2	3.84	3.59	4.14
3	3.73	3.98	3.5	4.14
4	3.98	3.820		
Organization and Project Management				
	ABET Outcome 5		ECURE	
Indicator	Industry Advisors	Industry Advisors	Faculty Mentor	Faculty Mentor
1	3.41	3.39	3.50	4.14
2	3.42	3.27	3.44	4.07
3	3.01	2.90	3.27	3.91

and the mentor's scores for appropriate EvaluateUR-CURE outcome components.

Results from Table 5 indicate that while there is a modest difference between the industry advisors' average score and faculty mentor score, both the industry advisors and faculty mentor scores for many indicators show improvement between the initial and final assessments. The indicators that were scored lower by the industry advisors likely reflect the greater time the industry advisor had to observe and interact with the students. As mentioned previously, it is the conversations about the assigned scores that are most important in EvaluateUR and there is great value in the students' awareness of how their industry advisor assessed their knowledge and skills. Overall, the average scores were similar, strongly suggesting the value of constructive feedback and good agreement in the measures used by ABET and EvaluateUR-CURE.

6. Concluding Remarks

1. EvaluateUR-CURE facilitates productive conversations between students, course instructor, and industry advisors. The method stresses that it is the conversation more than the assigned scores, students are able to share their thoughts more openly about how they are progressing as well as hear how others view their progress. At the beginning of the semester, the students are introduced to the method and understand that the scores assigned in the EvaluateUR-CURE assessments are not used in determining their final grade in the course. The score reports are used in structuring the bidirectional feedback that takes place several times over the semester has advantages compared to the more traditional student evaluation/grading that occurs at the end of the semester when it likely is too late for the students to make changes.
2. To ultimately improve the engineering/engineering technology program, attention needs to be paid to individual students to ascertain their progress and ensure that they are staying on track and meeting program expectations. EvaluateUR-CURE provides a means by which faculty involved in delivering the curriculum can give regular and structured feedback to the students and be proactive should individual students or a team of students fall behind. The statistics package built into EvaluateUR-CURE readily generates information about whole class student learning gains through data collection that supports ABET performance indicators.

3. There is a very good alignment between ABET ETAC performance indicators and EvaluateUR-CURE outcome components. In several cases, more than one EvaluateUR-CURE outcome component supports the course rubric. This suggests that EvaluateUR-CURE can be of value in helping a student better understand what behavior(s) defines the course rubric and discern what aspect of the rubric might be the underlying cause of the lower score. This awareness can be an important motivation for the student to plan how they might want to address a particular area that needs attention.

In sum, the initial comparison of data from this pilot implementation of EvaluateUR-CURE is promising and we intend to continue our efforts. If proven useful, EvaluateUR-CURE has the potential to be adopted by other engineering/engineering technology departments offering design course(s) as an approach to provide students with constructive feedback about their progress, while at the same time tapping into their students' metacognitive skills. This in turn should be invaluable to the students as they continue their education and enter the workplace.

Acknowledgments

EvaluateUR was developed with support by the National Science Foundation's WIDER program under Grant Number 1347681. EvaluateUR-CURE is supported by the National Science Foundation's ATE program under Grant Number 1836033. Any opinions, findings, and conclusions or recommendations expressed are those of the authors and do not necessarily reflect the views of the National Science Foundation.

Appendix A

Table A-1. Performance Indicators and Grading Criteria for Team Building.

Score	1	2	3	4	5
Works toward group goals	Does not work toward group goals or actively works against them	Communicates a lack of commitment to the group goals	Occasionally communicates commitment to group goals and effectively carries out work to meet them after reminders	Consistently communicates commitment to group goals and effectively carries out work to meet them	Actively helps identify group goals and works hard to meet them
Uses effective interpersonal skills	Does not participate in group interaction even with prompting or expresses ideas and opinions in a way that is insensitive to the feelings or knowledge base of others	Rarely participates in group interaction even with prompting or expresses ideas and opinions without considering the feelings and knowledge base of others	Participates in group interaction with prompting or expresses ideas and opinions without considering the feelings and knowledge base of others	Participates in group interaction without prompting. Expresses ideas and opinions in a way that is sensitive to the feelings and knowledge base of others	Actively promotes effective group interactions and the expression of ideas and opinions in a way that is sensitive to the feelings and knowledge base of others
Contributes to group maintenance	Does not attempt to identify changes or modifications necessary in the group process even when prompted or refuses to work toward carrying out those changes	Rarely helps identify changes or modifications necessary in the group process or is rarely involved in carrying out those changes	When prompted, helps identify changes or modifications necessary in the group process or is occasionally involved in carrying out those changes	Helps identify changes or modifications necessary in the group process and works toward carrying out those changes	Actively helps the group identify changes or modifications necessary in the group process and works toward carrying out those changes
Takes on a variety of roles	Rejects opportunities to perform one role	Makes an attempt to perform one role but has little success	Performs one role within a group	Effectively performs several roles within the group	Effectively performs multiple roles within the group

Table A-2. Performance Indicators and Grading Criteria for Organization and Project Management.

Score	1	2	3	4	5
Identify discrete work tasks and budgets for a portion of a project	Cannot identify discrete work tasks and budgets. Does not have flow chart and/or block diagram of the tasks assigned	Identifies some work tasks and budgets. Has some rudimentary flow charts and/or block diagrams of the tasks assigned. Bi-weekly goals do not correspond to work tasks and are hectic	Identifies most tasks and budgets but lacks proper documentation. Has reasonable flow charts and/or block diagrams for the tasks assigned. Bi-weekly goals somewhat correspond to work tasks	Identifies all tasks and budgets and documents them. Has complete flow charts and/or block diagrams for the tasks assigned. Bi-weekly goals mostly correspond to work tasks	Identifies all tasks and budgets and thoroughly documents them. Has complete and detailed flow charts and/or block diagrams of the tasks assigned. Biweekly goals completely correspond to work tasks
Direct the project work of one or more team members	Does not attempt to direct work of other team members while assuming leadership role in the team. Does not participate in discussions on project work coordination	Inefficient coordination of other team members work while assuming leadership role in the team. Minimum participation in discussions on project work coordination	Reasonably well directs the project work of the team members while assuming leadership role. Participates in team discussions on project work coordination	Direct the project work of the team member well while assuming leadership role in the team. Actively participates in team discussions on project work coordination	Efficiently coordinates the project work of the team members while assuming leadership role in the team. Actively and efficiently participates in team discussions on project work coordination
Monitor project schedules and costs using appropriate tools such as Gantt charts, other bar charts, precedence diagrams, or other appropriate tools	Does not have a schedule and/or budget	Poorly monitors the schedule and budget and is consistently behind schedule and over budget	Somewhat monitors schedule and budget. Occasionally is behind schedule and over budget. Frequently adjusts the schedule and budget to meet the project goals	Monitors schedule and budget well. Is on schedule and on budget	Efficiently monitors schedule and budget. The project is ahead of schedule and under budget

Table A-3. Performance Indicators and Grading Criteria for Design.

Score	1	2	3	4	5
Formulate the problem and analyze constraints	Unable to formulate a problem at all; Does not understand a concept of constraint	Partial formulation, nut missing some key constraints; Understands the concept of constraints but is unable to formulate the problem	Formulates the problem and uses constraints in formulation; Unable to use most efficient formulation	Formulates the problem and analyzes most of relevant constraints; Finds adequate formulation	Formulates the problem and analyzes all relevant constraints; Finds the best formulation
Establish design requirements	Unable to establish fitness criteria; does not understand the concept of trade-offs	Somewhat able to establish fitness criteria and trade-offs with major weaknesses; Misses several critical trade-offs	Establishes fitness criteria and trade-offs with some weaknesses	Establishes complete fitness criteria and trade-offs with minor weaknesses	Establishes complete fitness criteria; Analyzes trade-offs thoroughly
Generate alternative solutions	Unable to derive any meaningful solution	Derive one meaningful solution; Unable to generate alternative solutions	Derives more than one solution; has some weaknesses in evaluation of alternative solutions	Derives multiple solutions; has minor weaknesses in evaluation of alternative solutions	Derives multiple solutions; Performs proper evaluation of alternative solutions

Build a prototype/ perform simulation when it is impossible to build a prototype	Unable to build a proper prototype/ Unable to perform simulation	Builds a prototype/Performs simulation with significant help	Builds an adequate prototype/ simulation with some help	Builds an adequate prototype/ simulation	Builds a well-developed prototype/simulation
Analyze performance through testing/simulation	Unable to analyze performance of the prototype	Shows major weakness in analyzing performance	Somewhat able to analyze performance but requires some help	Somewhat able to analyze performance	Fully analyzes performance
Assess the strength and weaknesses of design	Does not respond adequately to questions or concerns from the last review; Unable to identify weakness in the design	Partially responds to questions/ concerns from the last review; Identifies some weaknesses in design but still missing some important items; Unable to make any improvement to the design	Mostly responds to questions/ concerns from the last review; Identifies key weaknesses of the design; Makes some improvements with some weaknesses	Adequately responds to questions/concerns from the last review; Identifies key weaknesses of the design; makes most improvements with some weaknesses	Completely responds to questions/concerns from the last review; Identifies any weaknesses in the design; Remedies any weaknesses in the design; Determines the best design
Identify next steps to improve on design	Unable to identify next steps to improve on design	Identifies one step to improve on design but does not elaborate sufficiently	Identifies few steps to improve on design; Elaborates adequately	Identifies several steps to improve on design; Elaborates clearly with minor omissions	Clearly identifies and elaborates future development steps to improve on design

Table A-4. Performance Indicators and Grading Criteria for Subject Knowledge and Technical Merit.

Score	1	2	3	4	5
Applies material from their discipline to the design of a project	Cannot identify relevant principles or develop models to apply to their design. Not able to predict or understand parameter effects on the design. Does not understand phenomena and cannot explain. Unable to transfer knowledge from their disciplinary courses to new situations	Have difficulty deciding what principles to use but may develop a close to correct model to apply to their design. Has some difficulty solving equations; frequent errors, problems often partially solved. Difficulty predicting parameter effects on the design. Some understanding of disciplinary concepts, but has to resort to jargon to explain. If the situation is not too novel, occasionally sees application of knowledge & may apply correctly	May include extraneous principles, but ultimately finds correct ones and develops model(s) to apply to their designs. Answers often correct, but may have minor errors. Uses non-optimum strategies. Usually predicts impacts of parameters correctly and explains effects	Reasonably good understanding of disciplinary concepts. Can often explain, but may resort to jargon. Usually sees how to apply disciplinary knowledge to new situations, although may need help	Readily identifies the relevant principles & develops elegant models to apply to their design. Consistently solves problems elegantly & correctly. Excellent at prediction and provides clear explanations of effects. Excellent understanding and clear explanations of disciplinary concepts. Sees the fundamental nature of novel problems and correctly applies knowledge

Identifies and acquires new knowledge as a part of the problem-solving/ design process	Cannot identify any methods or opportunities to improve their own learning. Can not identify resources available nor how to use these resources to enhance their learning. Has not taken any action beyond going to class to acquire skills that would advance	Can identify at least one method to improve learning. Identifies at least one resource to enhance their learning. Made minimal efforts to use available resources to acquire new skills to advance the work of the design	Can identify more than one method to improve own learning. Can identify multiple resources available to enhance own learning	Has taken advantage of at least one resource to acquire a basic understanding of one new skill or knowledge area beyond own coursework	Can identify multiple methods to improve own learning. Can identify multiple resources to enhance own learning. Takes initiative to acquire new skills. Develop competency in at least one new skill applicable to the design work. Mastered new skills or knowledge in areas beyond or as an extension to own coursework

Table A-5. Performance Indicators and Grading Criteria for Written and Graphical Documentation.

Score	1	2	3	4	5
Grammar	Major errors and nearly complete lack of understanding of assignment; poorly organized and poorly written	Many errors in general understanding; poor writing quality; sloppy organization; many unsupported observations and conclusions	Some errors in content, minor writing errors; careless work; some unsupported observations and conclusions	Moderately well-organized assignment indicating full understanding of subject; some personal insight; some writing errors and misspellings; reasonable observations and conclusions	Well organized and well-written assignment; very few spelling or writing errors; thorough comprehension of material; demonstration of personal insight; clear separation of facts, perceptions, and speculations; sound observations and conclusions
Graphics	Unable to produce any graphical output when required. Text output does not describe solution	Student misused graphics inappropriately captioned them or included non-related information. Able to produce graphical content, but it is in the wrong format or scale. Line and marker color/style/ weight causes confusion. No/few labels or legends. Text results are difficult	Student uses graphics that relate to the subject and to the text. Able to produce graphics or provide results of activities to accompany concepts. May not be optimally scaled for available space. Axis labels may not have units or proper format for audience. Line style/color may not be optimal	Able to produce quality graphics or succinctly synthesize results to accompany concepts. Graph axis labels with units, properly formatted labels, aligned axes, appropriately scaled to fit available space	Graphics are correct, complete and elegant. Report is presented in a structured format to provide clear understanding and easy read. Adds to discussion of topics
Logbook	No entrees	Incomplete	Somewhat complete	Complete	Detailed
Manual/ Project Report	Inadequate; Major parts are missing; Does not follow the template	Incomplete; Formally follows the template but missing some required parts	Somewhat complete; Most parts are present but lacking some details	Complete	Complete and all required parts are well documented; The work documented could be easily duplicated and enhanced by others

Table A-6. Performance Indicators and Grading Criteria for Presentation.

Score	1	2	3	4	5
Appearance	Personal appearance is completely inappropriate for the occasion and audience (T-shirt)	Personal appearance is inappropriate for the occasion and audience (Casual)	Personal appearance is somewhat inappropriate for the occasion and audience. (Business casual)	Personal appearance is appropriate for the occasion and audience. (Business attire)	Personal appearance is completely appropriate for the occasion and audience. (Sunday best)
Preparedness	Student is not prepared to present	Student is somewhat prepared, but not rehearsed	Student is somewhat prepared but could use more rehearsal	Student is mostly prepared but could use more rehearsal	Student is prepared and well-rehearsed
Delivery	Student reads all information from electronic presentation or cue cards making no eye contact with audience	Student frequently refers to electronic presentation or cue cards but makes some eye contact with audience	Student refers to bullet items in the electronic presentation or cue card and mostly maintains eye contact with audience	Student refers to bullet items in the electronic presentation or cue card and maintains eye contact with audience	Student rarely refers to the electronic presentation or cue card and maintains eye contact with audience
Elocution	Student speaks unclearly and incorrectly pronounces words	Student speaks softly and pronounces most words correctly	Student speaks mostly clear and most of the time pronounces words correctly	Student speaks clear and pronounces words correctly	Student speaks clearly, projects, and pronounces words correctly
Demonstration (N/A for ENT465)	No Demonstration	Partially functioning demonstration	Fully functioning demonstration of few parts of the project	Fully functioning demonstration of most parts of the project	Fully functioning demonstration of all aspects of the project

References

ABET. 2020. *Criteria for Accrediting Engineering Technology Programs, 202-2021*. https://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-technology-programs-2020-2021/.

Grinberg, Ilya. 2020. "Development of Senior Design Sequence with Integration of Undergraduate Research Component." In *Proceedings of the 2020 Annual Conference of the American Society for Engineering Education, Virtual Conference*, June 22-26.

Healey, M., and A. Jenkins, A. *2009 Developing Undergraduate Research and Inquiry.* York, PA: York HE Academy.

Kilgo, C. A., and E. T. Pascarella. 2016. "Does Independent Research with a Faculty Member Enhance Four-Year Graduation and Graduate/Professional Degree Plans? Convergent Results with Different Analytical Methods." *Higher Education* 71 (4): 575-592.

Kilgo, C. A., J. K. E. Sheets, and E. T. Pascarella. 2015. "The Link between High-Impact Practices and Student Learning: Some Longitudinal Evidence." *Higher Education*, 69 (4): 509-525.

Kuh, G. D. 2008. *High-Impact Educational Practices: What They Are, Who Has Access to Them, and Why They Matter*. Washington, D.C.: Association of American Colleges and Universities.

McCulley, J. 2013. "EET Senior Design Projects Manual. Weber State University Electronics Engineering Technology." Ogden, UT, 84408-1802.

NSPE. 2013. "Professional Engineering Body of Knowledge." https://www.nspe.org/sites/default/files/resources/nspe-body-of-knowledge.pdf.

Pepper, C. 2010. "There's a Lot of Learning Going on but NOT Much Teaching!: Student Perceptions of Problem-Based Learning in Science." *Higher Education Research and Development* 29 (6): 693-707.

Ilya Grinberg

Ilya Grinberg is professor and director of Electrical Engineering Technology in the Department of Engineering Technology at the State University of New York, College in Buffalo (SUNY Buffalo State). He holds Kandidat Nauk degree (equivalent to PhD) in electrical engineering from Moscow State University of Civil Engineering (Moscow, Russia,1 993) and qualification of an Electrical Engineer

(equivalent to MS in electrical engineering) from the National University, "Lviv Polytechnic" (Lviv, Ukraine, 1979). His research interests are in design automation, systems engineering, power systems, smart grid and microgrids, and engineering technology education. He established state-of the art joint Buffalo State/University at Buffalo Smart Grid Laboratory, of which he is director. He served as PI and co-PI on several grants and is a recipient of the SUNY Chancellor's Award for Excellence in Scholarship and Creative Activities (2016). He has been an ETAC ABET program evaluator since 2005 and ETAC ABET Commissioner since 2021.

Jill Singer

Jill Singer is a geologist interested in the transport and deposition of sediments. She has an MA and PhD from Rice University where she investigated glacial marine sediments in the bays and fjords of the northern Antarctic Peninsula. Dr. Singer is a SUNY Distinguished Teaching Professor and for the past 34 years has taught in the Earth Sciences Department at SUNY Buffalo State. Dr. Singer has been actively involved in restoration efforts of the Buffalo River and her experiences include projects funded by the National Science Foundation, USEPA, and the US Department of Justice Environment and Natural Resources Division. For 20 years, Dr. Singer served as the director of the Buffalo State Office of Undergraduate Research and administered programs that supported students in all academic majors. Dr. Singer had an NSF award to scale up to the national level the evaluation program designed to assess student learning and student growth from participating in undergraduate research. This method, known as EvaluateUR, is now being modified to support course-based undergraduate research experiences (EvaluateUR-CURE).