Engaging students in evaluation of engineering situation through information literacy

Abstract

The Accreditation Board for Engineering and Technology (ABET) requires that students in accredited programs be able to, "recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts" (2018). While covering the technical content of engineering courses, faculty sometimes forget our students' need to acquire these crucial non-engineering skills as a part of their preparation to enter into the profession. This paper describes the process of integrating some of those skills, such as information literacy and written communication, into a water resources course in the College of Engineering at California State Polytechnic University, Pomona (Cal Poly Pomona). We will describe a process in which students developed skills in information literacy and written communication that supported the engineering outcomes associated with ethics and professional responsibility. Prior to Fall Semester 2019, students taking this course were required to write a paper regarding a water resources catastrophe. Apart from a prompt that asked them to provide a critical evaluation of a specific failure and to support their position through peer-reviewed sources and other relevant sources, no further course time or additional resources were provided for this project. Following a campus-wide assessment of information literacy skills that revealed approximately 30% of graduating seniors placed at the introductory/developing level for these skills, we determined a revision of this assignment was necessary. Therefore, beginning in Fall Semester 2019, engineering faculty entered into a collaboration with campus librarians to develop a scaffolded assignment for the water resources course to ensure students were learning the information literacy skills necessary to support their claims. This paper will discuss the process of developing the new assignment and the ways in which the combination of instruction sessions by the engineering subject librarian, scaffolded assignments such as an annotated bibliography and a peer-reviewed draft, resulted in improved student ability to obtain evidence, as well as cite and support their claims. Ultimately, students developed skills in information literacy that supported the engineering outcomes associated with ethics and professional responsibility.

Introduction

Assessment provides programs a way to evaluate student learning and develop methods for continuous improvement.[1] Universities and programs present their interpretation of data to accreditation agencies. Accreditation agencies are intermediate organizations, which help provide the public with assurance that universities and programs are accountable for providing students with a quality education. Within the United States, colleges and universities are accredited by six distinct regional accrediting bodies.[2] These accreditation bodies have certain expectations when it comes to student learning which can be different from the expectation of disciplinary accreditation.

In 1994, ASEE's Engineering Education for A Changing World stated that engineering education needed to go beyond the fundamentals of theory, experiment and practice.[4] That is,

they stated that engineering education needed to prepare students with a broad range of skills that would allow them to recognize global, economic, environmental, and societal context of engineering solutions.[4] Developed in 2000 and revised in 2019, ABET's student outcomes went further than mere technical competency. ABET assures that programs show how student outcomes are attained. These attainments may not be directly related to a specific technical area, but do associate with skills essential for students to become engineers.[5,6]

Over several years, Cal Poly Pomona's civil engineering program has focused student learning assessment on Graduation Writing Test (GWT), capstone/senior projects and the Fundamentals of Engineering (FE) exam. GWT, is a required graduation requirement where all students are assessed individually on their written communication skills. Senior projects assess students as a team, not as individuals, while the FE exam is a multiple-choice test. All of the ABET student outcomes are clearly articulated and assessed through these summative measures. However, at times it is difficult to identify continuous improvement strategies within the current curriculum. The program has a curriculum matrix that shows where each of the ABET learning outcomes are taught and assessed. Thus, the department is developing a pilot assessment strategy that includes assessment at the course level. This course level assessment will also aid the university as the campus prepares for institutional assessment on core competencies (i.e. critical thinking, information literacy, written communication, oral communication and quantitative reasoning).

This study develops a pilot assignment within a civil engineering course (directly linked to the curriculum matrix), which could be used to assess both engineering student outcomes and regional core competencies. The main objective of this assignment is for students to develop a written essay associated with a contemporary issue within water resources. The artifacts will be evaluated using a rubric that assess the following learning outcomes:

- Information Literacy - an ability to recognize when information is needed and have the ability to locate, evaluate, and use the needed information for a wide range of purposes.[3]
- Written Communication and ABET SO 3 - an ability to communicate (using written skills) effectively with a range of audiences.[3,5]
- ABET SO 4 - an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.[5]

The study provides a pre- and post-evaluation of student artifacts, which included the addition of library instruction and assignment design to improve student learning.

Technical and Professional Skills Assessment

Students graduating from engineering programs need both technical and professional skills. Teaching and assessing professional skills can be challenging, but has been proven to be possible, either through assessing each skill individually or through an integrated approach.[7]

An area of continued concern in engineering education is students' ability to communicate. Many students take composition and oral communication courses, which are not fully integrated within their discipline. Faculty and practitioners have collaborated to develop a curriculum to

help improve student writing in civil engineering.[10,11] Conrad et al. have developed modular lessons and assignments based on actual professional work that can be embedded within existing curriculum to help practice writing within the civil engineering discipline.[11] Our university has been a partner in this research and results have shown significant improvement in student writing when appropriate context is included. Students are required to take a technical communication course during their sophomore/junior level within the department. However, integrating written communication within the curriculum is essential.[12] Since the written communication instruction is modular, lessons can be incorporated in other courses within the curriculum.

This research also approached using library resources, which allow students to become life-long learners. The relevance of information literacy instruction to the ABET standards has been noted multiple times in the literature. Many of the connections drawn between information literacy skills and the ABET 2000 standards have focused on life-long learning.[5] Rodriguez, asserted that, as most learning done by professional engineers in the field was done on their own, the ability to inform and assess it for accuracy and credibility was a crucial skillset.[13] His arguments are echoed by Callison, Budny and Thomes, who further asserted that "…engineering graduates should be able to teach themselves new concepts and apply information to new and unfamiliar situations".[14] Such abilities, once again, require such graduates to have the ability to find and recognize credible information.

Assessing students' ethical and professional responsibilities are traditionally done through evaluation of case studies.[8,9] These types of assignments ask them to consider what ethical choices the engineer had to make and the professional responsibility of the engineer. At the same time, students can be asked pointed questions that have them critically think about ethical dilemmas that a potential engineering solution could possess.[8,9] This approach allows students to think beyond the case study and consider the impact of their decisions. Other connections have been drawn to the ABET standard on professional and ethical responsibilities.[5] Trussell, focuses heavily on the connections between information literacy concepts and standards on professional and ethical responsibility, particularly, how instruction about plagiarism and proper citation standards play a crucial role in ensuring that engineering graduates can ethically and responsibly use information to make and back up arguments.[13] Fosmire takes this even further by asserting a connection not only between information literacy, life long-learning, and professional and ethical responsibilities, but argue information literacy's relevance to the ABET standards need not be limited to merely questions of ethics or life-long learning[16], but may also be applied to:

- The ability to design and conduct experiments
- The ability to design a system… to meet desired needs within realistic constraints
- The ability to identify, formulate and solve engineering problems
- Possession of a broad education necessary to understand the impact of engineering solutions in a global, economic, environmental and societal context
- Knowledge of contemporary issues

While the literature establishing the connection between information literacy instruction and the ABET standards is considerable, the real need for this instruction and its concrete benefits to engineering students is equally compelling. Ross, et.al., used a combination of survey data coupled with empirical assessments of student work to analyze how well engineering students understood the basic concepts of information literacy (in this case consisting of information retrieval, evaluation and citation) versus how well they thought they understood them.[16] The

results showed that students felt least confident in regards to their abilities to find and evaluate information, though they generally overestimated their research skills in all areas assessed.[16]

The introduction of information literacy instruction to engineering courses has demonstrated improvement in many of the areas noted above. Talikka, Soukka, and Esklinen in a study of Finnish engineering students at the Lappeenranta University of Technology observed that, with information literacy instruction, undergraduate engineering students develop better research questions, use better quality sources for their projects, become more careful at interrogating and evaluating sources, consider topics in greater depth, instead of just listing facts.[18] Van Epps and Nelson observed similar results while studying the effects of information literacy instruction on the projects created by engineering students enrolled in communications courses at Purdue University.[19] After receiving instruction, the student's information-seeking and retrieval habits changed, shifting from easy to access, low quality web sources, toward higher quality journal articles and technical reports.[19]

However, as the literature is also quick to point out, the instruction of engineering students in information literacy concepts is most effective when the instruction sessions are frequent, active, and highly integrated with course curriculum. In a study of first-year engineering students at the University of California, Berkeley, Quigley, and McKenzie asserted that students needed a mixture of explanation, discussion and application (defined by them as "active learning") in order to truly acquire information literacy concepts.[20] Therefore, instruction needs to not only be present in the engineering classroom, but it must be relevant to the assignment at hand as well as participatory in some way by the students.

In order for active learning to be integrated into the curriculum, a close collaboration between subject librarian and the engineering faculty is absolutely crucial, in order for the instruction to be not only timely, but directly relevant to the project the students are pursuing.[21] Furthermore, Barsky, Read, and Greenwood assert that through the experience of a successful collaboration between librarians and engineers at the University of British Columbia, that the most effective way to provide instruction to engineering students is to teach them "where they are," which involves going into engineering classrooms, instead of expecting the classes to come to the library.[22]

In addition to active learning being taken to where the students are, a series of studies (Bakermans and Plotke 2018, Van Epps and Nelson 2013, Callison, Budny and Thomes 2005) all emphasize that a single instruction session provided during the semester is insufficient to allow engineering students (or any students for that matter) to acquire an understanding of information literacy concepts.[14, 23] Bakermans and Plotke use the example of having a librarian embedded in a problem-based learning course at Worchester Polytechnic Institute.[23] Over the course of a semester, the embedded librarian would provide several instruction sessions focused on teaching concepts and skills the students would need for the next phase of their project. Van Epps and Nelson noted that the information-seeking and retrieval habits of the engineering students they observed only showed significant change in sections where, instead of a single 50-minute long instruction session at the beginning of the semester, the students received brief 15-minute instruction sessions focused on the next assignment just prior to that assignment being given.[19] Finally Callison, Budny, and Thomes observed that students' mastery of information

literacy concepts not only improved with multiple instruction sessions spread throughout the semester, but with the incorporation of scaffolded assignments (such as an annotated bibliography) which helped the students practice the application of these concepts prior to engaging in their final project.[14]

Overall, the literature illustrates that information literacy instruction is linked to a number of different ABET standards, and a mastery of these concepts provide engineering graduates with a strong foundation for beginning their professional careers. In addition, the results of numerous studies demonstrate that, beyond providing skills required by ABET standards, information literacy instruction results in engineering students finding higher quality information sources, developing better research questions, more deeply evaluating the credibility of the sources they gather, and generally producing better research. While all of this is encouraging, the literature also asserts, repeatedly, that effective instruction in information literacy goes far beyond a single, generalized lecture provided by a librarian at the beginning of a semester. In order for information literacy instruction to be truly effective, it must be integrated into the course work, through multiple instruction sessions relevant to and directly focused on the assignment or project at hand. These sessions should provide hands-on opportunities for students to apply the concepts they are being taught and reinforced through scaffolded assignments that allow the students to practice the concepts they are being taught. The combination of all of these practices allows students to achieve mastery of the skills and ideas

Course and Assignment Design

Over the course of several years, faculty within Cal Poly Pomona's civil engineering program have been looking at unique ways to evaluate student's professional and ethical responsibilities (SO 4), and written communication (SO 3) skills. In spring 2019, the students were asked to provide a critical evaluation on a specific contemporary issue associated with water resources and support their position through peer-reviewed and other relevant sources. The students were told they would be evaluated on the following criteria:

- Identify and summarize the problems
- Identify and present your perspective/position
- Use evidence to support you position
- Draw an adequate conclusion given the evidence
- Quality of writing
- Work Cited

In class students were provided background regarding Oroville Dam, readings to and written communication modules. However, the students were not provided a grading rubric, instruction on evidence, and resources to evaluate ethical and professional responsibilities.

Concurrently, there was a campus-wide initiative to assess information literacy and written communication skills across campus. In spring 2019 faculty from all eight colleges provided the Office of Assessment and Program Review at the university with assignments and student artifacts to assess information literacy and written communication. In the summer of 2019, faculty normed and scored the student artifact on a 4-point rubric (Mastery, Proficient, Developing and Introductory). The results showed

- 30% scored at developing and introductory for Evidence and Sources;
- 45% scored at developing and introductory for Citation;
- 30% scored a developing and introductory for Development of ideas; and
- over 80% of seniors scored at mastery and proficient for Grammar and Mechanics.[24]

In the summer of 2019, the Office of Assessment and Program Review (OAPR) hosted a two-day Summer Assessment Institute featuring various presenters from across campus to discuss topics associated with assessment. There were three distinct workshops that started to close the loop: Assignment Design, Assessing Student Writing in your Discipline, and Information Literacy. The presentations and literature provided faculty with a unique opportunity to improve the student learning experience.

Faculty from civil engineering and campus librarians collaborated to improve student learning through a scaffolded approach in instruction and assignment design. The engineering librarian visited the course twice over the semester to provide detailed instruction on finding, evaluating, and citing sources. The assignment was further improved based on a transparent assignment template. The students were provided with a clear purpose, learning objective, tasks, and evaluation criteria. The overall project still asked students to write an essay associated with contemporary catastrophe within water resources.

Before the librarian met with the class, the librarian created an online research guide for the course. The research guide was designed to help students find good information on water resources engineering, specifically resources applicable to their class assignment. The guide provided online information about how to find relevant books, how to use the library databases, and how to create proper citations. The guide was designed as a supplement for students to access after the in-person library instruction. During the first in-person class meeting the librarian taught students how to evaluate sources and find reliable and relevant information for their paper. The class was researching water resource issues, so the professor provided the librarian with a specific topic to search for as an example, Oroville Dam. The first in-person session was to instruct students on how to find reliable sources using Google. The librarian demonstrated that a simple keyword search of Oroville Dam using Google would produce multiple types of sources. These included, but was not limited to the Wikipedia entry, videos of the reopening of the spillway, general websites, and articles from newspapers. These sources had a lot of information, but students needed to find reliable information from trusted sources, such as government websites. The professor wanted the students to learn to find information from government websites because the Federal and State governments publish a huge amount of material and statistics and are generally considered authoritative, credible sources of information. By limiting the search to government websites, students were able to access information from agencies such as the California Department of Water Resources, the California Natural Resources Agency, California Department of Parks and Recreation, and the National Oceanic and Atmospheric Administration. In addition, the librarian presented the Currency, Relevancy, Authority, Accuracy, and Purpose (CRAAP), which is a tool used to help evaluate the reliability and accuracy of an information source.

- Currency: when was the source published or posted?
- Relevancy: does the source have information that pertains to your research question?

- Authority: does the authors of the source have the necessary credentials in the field of question?
- Accuracy: is the information supported by evidence?
- Purpose: is the information fact or opinion? Does the author provide a specific point of view?

In addition, the librarian also provided instruction on how to use the library databases, specifically the library OneSearch. OneSearch is the library search engine that searches keywords from multiple library databases and from different subject areas. Students can use OneSearch to search for terms across multiple disciplines and a variety of sources, such as peer-reviewed journals, trade journals, magazines, books, etc. The librarian showed the students how to access the library OneSearch from the library homepage, and how to narrow their results to access peer-reviewed, academic journal articles. At the end of the instructions, students were to use the library OneSearch and find a relevant peer-reviewed article on their topic.

The second instruction session provided students an overview on citations. The librarian used the online research guide for the course to teach students how to properly cite their sources. In addition, the librarian discussed the importance of citations. Students were taught that they must cite all of their sources and provide citations in-text and in their work cited page. The librarian also discussed the importance of providing good citations, in that it helps future researchers who may read their paper to continue their own research.

In addition to scaffolding the library instruction, the overall assignment was scaffolded to help improve student learning on the final essay. That is, each phase of the assignment was graded to ensure that students took the work seriously. The first assignment was to develop an annotated bibliography. Each annotated bibliography identified the source, provided appropriate citation, and provided a summary and explanation of how the source will support the student's position. A rubric was presented and provided to the students to ensure clear communication of the expectations of the paper. Next, the students wrote a draft paper. Each draft paper was peer-reviewed by two colleagues using the rubric provided within the assignment. After the peer-review, the engineering librarian returned to class to further help students with in-text citation and incorporation of evidence within their papers. Finally, the students submitted a final paper.

Evaluation

Student essays on contemporary issues from a water resources course were used to evaluate written communication (SO 3), professional and ethical responsibilities (SO 4), and information literacy (IL). An innovative and collaborative approach was taken to develop this multi-point rubric with faculty and librarians. The resulting assessment tool is presented in Table 1. Each criteria is directly linked to a specific learning outcome, as shown in column one.

Table 1 – Assessment Rubric

Criteria	Mastery 4pt	Proficiency 3pt	Development 2pt	Introductory 1pt
Problem/Issues SO 3 & SO 4	Identifies the main problem (ethical/professional) clearly or accurately, and address implicit or embedded issues and their relations.	Identifies several impacts of the problem (ethical/professional) and its relation to engineering, showing understanding of more than one context.	Identifies some evidence of knowledge of the problem (ethical/professional); causal connections between problem and engineering. Engineering impacts not made clear or only one context considered.	Failed to identify or summarize the problem (ethical/professional) accurately and/or completely, and confuses main and subordinate issues.
Organization SO 3 & SO 4	Organization of key ideas fully supports the purpose of the written work.	Organization of key ideas supports the purpose of the written work, however there is a disproportional emphasis from one idea to another (i.e. inconsistently organized).	Organization of key ideas partially supports the purpose of the written work and there is a disproportional emphasis from one idea to another (i.e. inconsistently organized).	Organization of key ideas does not support the purpose and ideas are random.
Development SO 3 & IL	Development of ideas is logical, appropriate, relevant, thorough, and compelling to illustrate mastery of the topic. Transitions between ideas must be effective.	Development of ideas is logical, appropriate, relevant and adequate which explores ideas of the topic. Transitions between ideas are smooth and reasonable.	Development of ideas are appropriate and relevant which explores ideas through portions of the work. Transitions between ideas are abrupt.	Ideas are appropriate and relevant which provides a simple and or shallowly development of ideas. There is little connection between ideas.
Perspective SO3 & IL	States specific position taking into account the complexity of the issue and acknowledging others point of view; accurately notes limitations of other positions by clearly showing problems with the arguments/evidence used to support them; recognizes limits to one's own view as well	States specific position and acknowledges different sides of the issues and attempts to take into account the complexity of the subject matter; however, the analysis of other positions is overly simplistic or uncharitable	States a position but is unclear or simplistic and obvious; recognizes the positions others take but cannot articulate those positions or recognize or properly evaluate them	No position is stated, no perspective defined or fails to recognize the positions that others take. No proper articulation of position or proper evaluation
Citations SO 3 & IL	Three or more relevant sources, cited. (Student correctly (all the time) provides citations and references of all material presented.	Two relevant sources, cited (Most of the time, student correctly provides citations and references of most material presented)	One relevant source, cited. (Occasionally, student correctly provides citations and references of all material presented.)	Relevant sources are not on topic. (Student does not correctly provide citations and references of all material presented.)
Evidence SO 3 & IL	Use of evidence and sources to directly support writing. (This is what well integrated evidence would look like: Makes few or no fallacious inferences. Clearly distinguishes fact, opinion and value judgement.)	Use of evidence and sources to support writing, however, is not fully integrated. (This is what not fully integrated looks like: Makes some fallacious inferences. Sometimes distinguishes fact, opinion and value judgement.)	Uses Evidence and sources are in an attempt to support ideas in the writing. (This is what it looks like: Merely repeats information provided, taking it as truth, or denies evidence without adequate justification. Makes many fallacious inferences. Does not distinguish fact, opinion and value judgement)	Use of Evidence and sources do not support ideas in the writing. (This is what this may look like: Work is unorganized without structure. Fails to provide sense on the topic.)
Conclusions SO 3 & SO 4	Comes to a clear conclusion based on relevant information/evidence; thoroughly discuss consequences/implications of the conclusion which integrated professional/ethical responsibilities	Comes to a partial conclusion based on somewhat adequate analysis of information/evidence; discuss consequences/implications of the conclusion which includes professional/ethical responsibilities	Does not or cannot come to a conclusion based on the information or evidence presented or discussed; Does not or cannot see consequences/implications of the conclusion as they are associated with professional/ethical responsibilities.	Work is unorganized without structure. Fails to provide conclusions associated with professional/ethical responsibility.

To evaluate the student outcomes, artifacts from spring 2019 and fall 2019 were used. A total of 15 artifacts were randomly sampled and scored for each semester resulting in a total of 30 artifacts. Though the sample size was small it provided significant findings on student learning, assignment design and instruction. All identifying information (e.g., names, course details) was redacted from artifacts. Each artifact was scored by two independent readers. The readers consisted of faculty and librarians. Scores for each student were calculated by computing an average and rounding the value down to the nearest whole number for each criterion.

Results

The results from the assessment were analyzed from spring 2019 to fall 2019. For each of the criteria, 15 individual student artifacts were analyzed. The goal was to see if assignment redesign and library instruction could increase student learning. Figure 1 provides a bar graph to show the percentage of students within each area. Figure 2 shows the average performance on each of the criteria. The value is determined based on the following score breakdown: Introductory 1 point; Developing 2 points; Proficiency 3 points; Mastery 4 points.

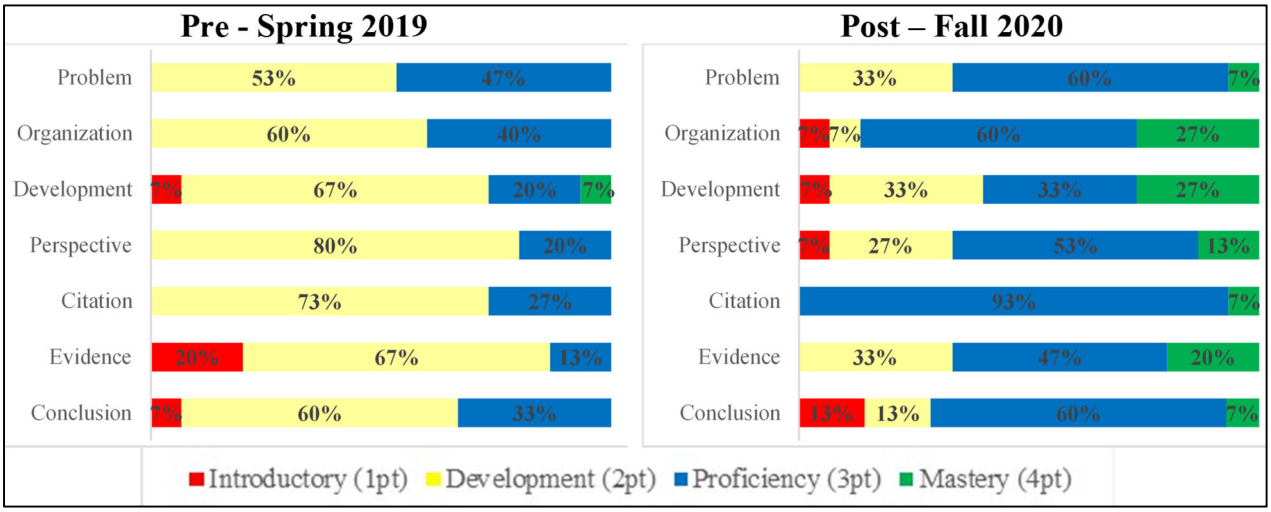

Figure 1 – Percentage of students at each assessment point.

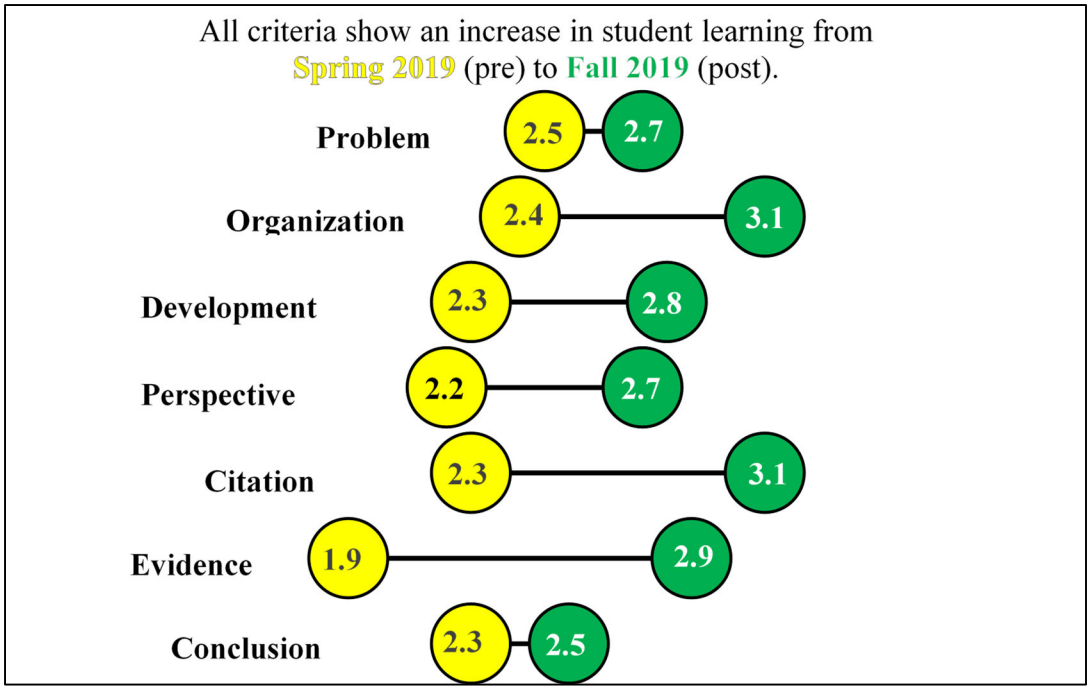

Figure 2 – Average performance for each of the criteria (Introductory 1pt; Developing 2pts; Proficiency 3pts; Mastery 4pts).

Overall, the results show a positive upward trend. With the addition of library instruction and the assignment redesign, students' performance on each of the criteria improved. An independent samples t-test was performed to determine the statistical significance. The results are shown in Table 2.

Table 2 – Average and t-test summary.

Criteria	Average		p-value
	Spring	Fall	
Problem	2.47	2.73	0.100
Organization	2.40	3.07	0.005
Development	2.27	2.80	0.045
Perspective	2.20	2.73	0.015
Citation	2.27	3.07	1.21E-06
Evidence	1.93	2.87	3.58E-04
Conclusion	2.27	2.53	0.176

The results show that Organization, Development, and Perspective has a 95% statistical significance and Citation and Evidence has a 99% statistical significance. While Problem and Conclusion do show improvement in student learning, the change in mean does not have statistical significance. The reason this occurred, was because there was no change in instruction for those two criteria.

Discussion/Conclusion/Next Steps

Of the seven criteria, five are statistically significant. Each of the criteria was grouped based on the learning outcome it addressed. ABET student outcomes 3 (communication) and 4 (professional and ethical responsibility) are captured from the student's ability to identify the problem, organize key ideas, and develop a conclusion. Results show that in spring 2019, 53% to 67% of student are at the "Introductory" and "Developing", while in fall 2019, 67% to 87% of students are at the "Proficient" to "Mastery" level of learning. These results suggest that instruction provided by the instructor and the assignment redesign has improved student learning.

ABET student outcomes 3 (communication) and university outcome on information literacy are captured from the student's ability to develop ideas, provide perspective, include ethical citations, and show evidence. Results show that in spring 2019, 53% to 87% of student are at the "Introductory" and "Developing", while in fall 2019, 60% to 100% of students are at the "Proficient" to "Mastery" level of learning. These results suggest that that library intervention improved student learning.

The results from this assessment are strong and support the idea that intentional library intervention and assignment re-design can be used to assess multiple learning outcomes. It is important to note that when the assignment is designed that all outcomes are clearly evaluated. Though students showed improvement in all criteria, the results indicated that there was additional room to grow in Problem Identification and Conclusion. Part of the reason for less growth in this criterion was because the assignment did not clearly tell students to identify ethical dilemmas that may have been present or will become present in their solutions.

The results of this pilot assessment is being shared within the department assessment committee to guide the department is assessment of various ABET student learning outcomes for the coming years. The results have shown how a course has started to close the loop on student learning on various outcomes. The department plans to use this pilot and collect additional artifacts for future endeavors to assist in instruction intervention, assignment re-design and curriculum changes.

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