A Direct Method for Simultaneously Teaching and Measuring Engineering Professional Skills

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Abstract – Proficiency in professional skills related to teamwork, ethical responsibility, communication skills, the impact of engineering solutions, life-long learning, and contemporary issues is critical for success in the multi-disciplinary, intercultural team interactions that characterize 21st century engineering careers. Yet, programs across the nation have struggled to define, teach, and measure professional skills since their introduction as ABET criteria for engineering programs in 2000. The Engineering Professional Skills Assessment (EPSA) is a direct method for both teaching and assessing these professional skills at the course or program level. This method is centered on one of several inter-disciplinary scenarios that frame a contemporary societal problem, a generalized set of discussion questions intended to guide a meaningful, 45 minute discussion of multiple scenarios among 4-6 students, and the Engineering Professional Skills (EPS) rubric that is broadly applicable for all scenarios.

Keywords: ABET professional skills, inter-disciplinary scenarios, performance assessment, rubrics

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TEACHING PROFESSIONAL SKILLS IN ENGINEERING EDUCATION

Proficiency in engineering professional skills is critical for success in the multidisciplinary, intercultural team interactions that characterize 21st century engineering careers. To ensure continued competitiveness of American educated and trained engineers in the rapidly changing environment of the world economy and pressing global problems, engineering education must help students integrate professional and technical skills for more robust problem solving [1]. Therefore, there is a critical need to develop in students a deep understanding of the importance of the professional skills. Colleges and universities must align their curricula and teaching with the 21century workplace demands.

Unfortunately, engineering programs across the nation have struggled to define, teach and measure professional skills since their introduction by ABET evaluation criteria for engineering programs in 2000. Although a variety of methods and instruments have been developed by engineering educators around the nation to teach and assess the ABET professional skills, listed in Table 1, most of these instruments evaluate only one skill at a time [2]-[5]. These are fairly cumbersome to implement and more frequently than not, they evaluate given skills indirectly through focus groups, interviews or surveys eliciting student opinions [6].

Table 1.ABET Criterion 3 Professional Skills Student Learning Outcomes

3d	Ability to Function on Multidisciplinary Teams
3f	Understanding of Professional and Ethical Responsibility
3g	Ability to Communicate Effectively
3h	Understanding of the Impact of Engineering Solutions in Global, Economic, Environmental, and Cultural/Societal Contexts
3i	Recognition of and Ability to Engage in Life-Long Learning
3j	Knowledge of Contemporary Issues

ENGINEERING PROFESSIONAL SKILLS ASSESSMENT

In fall 2006, the Washington State University College of Engineering and Architecture partnered with an assessment specialist to create an innovative, direct method to teach and measure the set of ABET professional skills at the program level. Major accomplishments since 2006 include an authentic performance task and measurement system described below, establishment of initial reliability and validity of the instrument, and a dedicated community of 40+ engineering faculty that used the assessment instrument to evaluate the efficacy of their own engineering programs. An ASEE paper on this initial implementation won the best paper award in 2008 [7].

Performance assessment typically has three components: (1) a task that elicits the performance; (2) the performance itself (which is the event or artifact to be assessed); and (3) a criterion-referenced instrument, such as a rubric, to measure the quality of the performance [8]. Correspondingly, the Engineering Professional Skills Assessment (EPSA) has these same three components: (1) a performance task including a scenario and discussion prompts; (2) transcript of student discussion as a response to the task and; (3) an accompanying analytical rubric that is used to measure the quality of the students' performance in demonstrating the engineering professional skills. Since 2009, faculty members at Washington State University, the University of Idaho, and Norwich University have been engaged in a three-year, multi-institution project to expand the set of scenarios as well as rigorously establish inter-rater reliability, content validity, construct validity, and criterion validity of the EPSA method and associated rubric. This effort is sponsored by the NSF Research in Evaluation of Engineering and Science Education (REESE) program [9].

The EPSA process begins with a 45-minute session, in which groups of five to seven students are presented with a complex, real-world scenario that includes current, multi-faceted, multidisciplinary engineering issues. A facilitator uses a prepared script to provide background information about the EPSA process and to provide directions for the discussion. After reading the prepared script, the facilitator distributes the scenario and accompanying discussion prompts. The facilitator does not participate in the discussions. After reading the scenarios, the students are asked to determine the most important problem/s and to discuss stakeholders, impacts, unknowns, and possible solutions. Finally, after the discussions have concluded, trained faculty raters use the analytical Engineering Professional Skills (EPS) rubric to measure the group's performance associated with the entire set of ABET professional skills. The EPSA method is flexible, easy to implement, and can be used at the course or program level for teaching and measuring engineering professional skills.

EPSA Discussion Prompts

The discussion prompts direct the students to imagine that they are a team of engineers working together for a company or organization on the problem/s raised in the scenario. The students are asked to:

1. Identify the primary and secondary problems raised in the scenario.
2. Discuss what your team would need to take into consideration to begin to address the problem.
3. Identify the major stakeholders and what are their perspectives?
4. Determine the potential impacts of ways to address the problems raised in the scenario?
5. Discuss the team's course of action to learn more about the primary and secondary problems?
6. Identify some important unknowns that seem critical to address this problem?

EPSA Scenarios

In the EPSA process, students are presented with a complex, real-world scenario that includes current, multi-faceted, multidisciplinary engineering issues. The scenarios do not include proposed solutions, but present open-ended situations that often include aspects that are outside a student's engineering discipline. Example scenarios are shown in table 2.

Table 2.Summary of Sample Scenarios

Lithium mining for electrical vehicle batteries	Hanford superfund site clean up
Need for prosthetics in land-mine ridden Iraq	Vehicle retrofitting for wheelchair-bound drivers
Strip mining on Navajo ceremonial lands	RFID/GPS tracking device privacy issues
Tennessee Valley coal ash spill impacts	Links between power lines and cancer
BP Deepwater Horizon oil spill	water projects for third world countries
Offshore wind farm development	Effects of the Tsunami on electrical power generation

Student Discussions

During the course of their discussions, the students will generally tend to self-organize, which allows them to more thoroughly cover the items mentioned in the discussion prompts. Over the course of the discussion period, the students learn from each other, and their ideas often evolve reflecting their acquiring a more mature understanding of the material in the scenario. When the student groups are less homogeneous, and are comprised of students with different backgrounds and experiences, a review of the discussion transcripts indicates that they often tend to spend less time on detailed technical issues, and more time identifying the stakeholders, the information that needs to be determined before the problem(s) can be addressed, and the impacts of possible solutions.

The EPS Rubric

The student group discussions are assigned a score of 0-5 using an analytical rubric that describes behaviors and actions for each of the ABET professional skills at three different levels of performance. A common scoring scale is used across all of the ABET professional skills: 0-absent, 1-emerging, 2-developing, 3–competent, 4–effective, and 5–mastering. Examples from the EPS Rubric are shown in the following Figure 1 to Figure 5. Effective use of any rubric requires some rater training and calibration. Since the EPSA method was developed for course or program level assessment, the EPS Rubric is used to evaluate the performance of the group, not the performance of individual students. The transcripts refer to the individual students by numbers, such as "Student #1", instead of their individual names. The use of identification numbers, rather than names, serves to preserve confidentiality and removes a source of potential rater bias.

Skill 3f. Understanding of professional and ethical responsibility Rater Score for Skill_____

Students clearly frame the problem(s) raised in the scenario and begin the process of resolution. Students recognize important stakeholders and their perspectives. Students identify related ethical considerations (e.g. health and safety, fair use of funds, risk, schedule, and doing "what is right" for all involved).

	0 - Missing	1 - Emerging	2 - Developing	3 - Practicing	4 - Maturing	5 - Mastering
Stakeholder Perspective	Students do not identify stakeholders.	Students identify few stakeholders, vaguely stating their positions or misrepresenting their positions.		Students consider perspectives of major stakeholders and convey these with reasonable accuracy.		Students thoughtfully consider perspectives of all stakeholders and articulate these with great clarity, accuracy, and empathy
Problem Identification	Students do not identify the problems in the scenario.	Students begin to frame the problem but have difficulty separating primary and secondary problems. If solutions are advocated, they are quite general and may be naive.		Students are generally successful in distinguishing primary and secondary problems. There is evidence that they have begun to formulate credible solutions.		Students convincingly frame the problem and parse it into sub-problems. They suggest detailed and viable approaches to resolve the problem.
Ethical Considerations	Students do not give any attention to ethical considerations.	Students give passing attention to related ethical considerations.		Students are sensitive to some relevant ethical considerations.		Students clearly articulate relevant ethical considerations and address these in discussing approaches to resolve the problem.
Comments:						

Figure 1. EPS Rubric: Skill 3f

Skill 3g. Ability to communicate effectively Rater Score for Skill_____

Students work together to address the issues raised in the scenario by acknowledging and building on each other's ideas to come to consensus. Students invite and encourage participation of all discussion participants. Note: The ABET communication outcome includes several forms of communication, such as written and oral presentation. This definition focuses on group discussion skills.

	0 - Missing	1 - Emerging / 2 - Developing	3 - Practicing / 4 - Maturing	5 - Mastering
Group Interaction	Students do not interact as a group.	Students pose individual opinions, without considering other student's ideas.	Students try to balance everyone's input and build on/clarify each other's ideas.	Students clearly encourage participation from all group members, generate ideas together and actively help each other clarify ideas.
Group Self-Regulation	There is no evidence of group self-regulation.	Some students may monopolize or become argumentative. There might be some tentative, but ineffective, attempts at reaching consensus.	Students attempt to reach consensus, but have some difficulty in developing approaches that equitably consider multiple perspectives.	Students clearly work together to reach a consensus in order to clearly frame the problem and develop appropriate, concrete approaches to resolve the problem.
Comments:				

Figure 2. EPS Rubric: Skill 3g

Skill 3h. Understanding of the impact of engineering solutions in global, economic, environmental, and cultural/societal contexts Rater Score for Skill_____

Students consider how their ways to address the problem impact relevant global, economic, environmental, and cultural/societal contexts.

	0 - Missing	1 - Emerging / 2 - Developing	3 - Practicing / 4 - Maturing	5 - Mastering
Impact/ Context	Students do not consider the impacts of the solutions.	Students give little or no consideration to how the ways to address the problem impact in relevant contexts.	Students give some consideration to how the ways to address the problem impact in relevant contexts.	Students clearly examine and weigh the impact of the ways to address the problem in all relevant contexts.
Comments:				

Figure 3. EPS Rubric: Skill 3h

Skill 3i. Recognition of the need for and ability to engage in life-long learning Rater Score for Skill_____

Students consider what needs to be learned (what they know and don't know). Students verbalize a credible plan to retrieve and organize needed data. Students take action to respond to personal beliefs that might hinder attainment of a satisfactory solution.

	0 - Missing	1 - Emerging	2 - Developing	3 - Practicing	4 - Maturing	5 - Mastering
Sources/ References	Students do not question sources or references.	Students begin to question sources/references cited in the scenario.		Students question sources/references cited in the scenario.		Students evaluate sources/references cited in the scenario.
Discern fact/opinion	Students do not distinguish between fact and opinion.	Students have difficulty distinguishing between fact and opinion.		Students demonstrate some ability to distinguish between fact and opinion.		Students are successful in distinguishing fact from opinion.
Knowledge Status	Students do not differentiate between what they do and do not know.	Students begin identify what they know as well as what they do not know, but have difficulty differentiating between the two.		Students identify what they know as well as what they don't know.		Students identify what they still need to know and describe methods for obtaining that information.
Presumptions	Students do not recognize presumptions that may hinder their problem solving.	Students begin to recognize their presumptions, but have difficulty recognizing how these presumptions may hinder their problem solving.		Students recognize presumptions that may hinder their problem solving.		Students take action to address presumptions that may hinder their problem solving.
Comments:						

Figure 4. EPS Rubric: Skill 3i

Skill 3j. Knowledge of contemporary issues Rater Score for Skill_____

Students consider current societal, economic and political issues their discussion, identification of the problem and possible ways to address the problem. Students also consider modern technologies and tools in their discussion, identification of the problem and possible ways to address the problem.

	0 - Missing	1 - Emerging	2 - Developing	3 - Practicing	4 - Maturing	5 - Mastering
Non-Technical Issues	Students do not consider any current societal economic, and/or political issues	Students give only a superficial consideration to current societal, economic, and/or political issues. Non-technical issues may be treated in a condescending manner.		Students give some consideration to current societal, economic, and/or political issues		Students give full consideration to current societal, economic, and/or political issues
Technical Issues	Students do not consider modern methods, technologies and/or tools	Students give only passing consideration to modern methods, technologies and/or tools.		Students give some consideration to modern methods, technologies and/or tools		Students give full consideration to modern methods, technologies and/or tools
Comments:						

Figure 5. EPS Rubric: Skill 3j

Summary

The EPSA method is flexible, easy to implement, and can be used at either the course or program level for teaching and measuring engineering professional skills. The method can be used at the end of a course sequence for evaluating a program component and to document the increasing maturity of the students. The EPSA method was designed as a group-based tool which is well-suited as administered/scored for program assessment. One modification that might extend its usefulness as a classroom assessment tool that could be used to assign individual grades would be to have the individual students write a self-assessment of their team's performance using the EPS rubric.

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