



Using the EPSA Rubric and EPSA Score to Evaluate Student Learning at the Course and Program Level

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Introduction

This paper presents the results of implementing the Engineering Professional Skills Assessment (EPSA) method within the ‘ethics’ section of a senior level “Professional Issues” course. During the two years that the course instructors have been using the EPSA method, they have found the interdisciplinary EPSA scenarios to generate more enthusiastic and higher level discussion than case studies that focus solely on ethics. This paper describes the use of the different EPSA scenarios, the standardized questions which are used to prompt the student discussion, the EPSA rubric, the EPSA Summary Score, the facilitation plan, and also describes how the EPSA method can be incorporated for use at both the classroom and program level. All material described in the paper is included in the paper’s appendices.

Background

Engineering programs often contain a senior level “Professional Issues” course to cover topics, such as ethics, which are related to the professional practice of engineering. These courses commonly utilize case studies focusing on ethics as the basis for student discussions.¹ Measuring the student learning resulting from the case study process is often very subjective, difficult to quantify, inconsistent between evaluators, and costly to administer.^{2,3} Determining changes in student learning from freshman to senior year is also difficult to quantify.

Proficiency in engineering professional skills, such as ethics, as described in ABET criterion 3 - student outcomes⁴, is critical for success in the multidisciplinary, intercultural team interactions that characterize 21st century engineering careers. These professional skills may be effectively assessed using a performance assessment that consists of 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.⁵

Funded by the National Science Foundation, investigators at Norwich University, University of Idaho, Rose-Hulman Institute of Technology, and Washington State University have used this three-part performance assessment method to develop and rigorously test the Engineering Professional Skills Assessment (EPSA) as a discussion-based performance vehicle for directly assessing five learning outcomes simultaneously.⁶

The research team that developed EPSA is in the fifth, and final, year of a validity study funded by the National Science Foundation.⁷ As part of this validation study, the team of researchers applied EPSA to test groups of students at three different universities. As a result of the work done on the validity study, the team members introduced other faculty members to EPSA, who then independently implemented the EPSA method in their courses. This paper presents results of how EPSA has been used for two years in a senior level “Professional Issues” course for engineering students and describes the implementation plan that has been developed by the faculty members using EPSA.

Engineering Professional Skill Assessment (EPSA)

The main component of the EPSA is a performance assessment consisting of: 1) a 1-2 page scenario about an interdisciplinary contemporary engineering problem intended to prompt discussion among a group of 5-6 students; 2) a 30-40 minute discussion period where students are asked to address a series of standardized questions about the scenario; and 3) an analytical rubric, which is used to evaluate the students' discussion. The EPSA Summary Score is computed from the individual dimensions of the analytic rubric, and provides a single score that may be used to quickly compare progress over the semester or between school years.

The EPSA process focuses on a group of four to seven students discussing a complex, real-world scenario that includes current, multi-faceted, multidisciplinary engineering issues. Before the 30-40 minute long discussion begins, student participants all read a short scenario that presents some technical and non-technical aspects of the topic.

EPSA scenarios address topics such as impacts of power generation, resource utilization, and natural or man-made disasters. Examples of the scenarios used in the EPSA are presented in Appendix A.

Prior to commencing their discussion, the students are given a set of leading questions that serve to prompt and focus the discussion. These questions ask the students to determine the most important problem/s and to discuss stakeholders, impacts, unknowns, and possible solutions. The EPSA discussion prompts are shown in Appendix B⁸.

After the students have completed their discussion, the EPSA analytical rubric is used to evaluate the students' discussion. The EPSA Rubric has one page for directly measuring each of the professional skills mentioned in ABET Criterion 3. An example from the complete EPSA Rubric is show below in Figure 1. The complete EPSA Rubric is shown in Appendix C⁸ and a one page version of the rubric used for training is shown in Appendix D.⁸

	0 - Missing	1 - Emerging	2 - Developing	3 - Practicing	4 - Maturing	5 - Mastering
Problem Identification	Students do not identify the problem(s) in the scenario.	Students begin to frame the problem(s). Approaches advocated to address the problem(s) may be general and/or naive.		Students are generally successful in distinguishing primary and secondary problems with reasonable accuracy and with justification. There is evidence that they have begun to formulate credible approaches to address the problem(s).		Students convincingly and accurately frame the problem(s) and parse sub-problems, providing justification. They suggest detailed and viable approaches to resolve the problem(s).
Stakeholder Perspective	Students do not identify stakeholders.	Students identify few and/or most obvious stakeholders, perhaps stating their positions in a limited way and/or misrepresenting their positions.		Students explain the perspectives of major stakeholders and convey these with reasonable accuracy.		Students thoughtfully consider perspectives of diverse relevant stakeholders and articulate these with clarity, accuracy, and empathy.
Ethical Considerations	Students do not identify ethical considerations.	Students give passing attention to related ethical considerations. They may focus only on obvious health and safety considerations and/or fair use of funds.		Students are sensitive to relevant ethical considerations and discuss them in context of the problem(s). Students may identify ethical dilemmas and discuss possible trade offs.		Students clearly articulate relevant ethical considerations in the context of the problem(s). Students may discuss ways to mediate dilemmas or suggest trade offs.
Comments						

Figure 1: EPSA Rubric for Understanding of Professional and Ethical Responsibility

Table 1 shows the alignment between the ABET professional skills and the EPSA Rubric.

Table 1. ABET Professional Skills Addressed in the EPSA Rubric

Dimension	Specific Areas Considered
3f. Understanding of Professional and Ethical Responsibility	<ul style="list-style-type: none"> • Stakeholder Perspective • Problem Identification • Ethical Considerations
3g. Ability to Communicate Effectively	<ul style="list-style-type: none"> • Group Interaction • Group Self-Regulation
3h. Understanding of the Impact of Engineering Solutions in Global, Economic, Environmental, and Cultural/Societal Contexts	<ul style="list-style-type: none"> • Impact/Context
3i. Recognition of and Ability to Engage in Life-Long Learning	<ul style="list-style-type: none"> • Scrutinize Information • Knowledge Status
3j. Knowledge of Contemporary Issues	<ul style="list-style-type: none"> • Non-Technical Issues • Technical Issues

McCormack et al. reviewed current practices for administering and using the EPSA rubric⁹. The EPSA method is flexible, easy to implement, and can be used at the course level for teaching and measuring engineering professional skills and the program level at the end of a curricular sequence for evaluating a program's efficacy.

The EPSA Summary Score provides a single composite score that may be used to quickly compare progress over the semester or between school years. This score is computed from the individual dimensions of the analytic rubric, using either a simple average of the individual dimensions, or a weighted average of the individual dimensions. A program may use either method for calculating their EPSA Summary Score, as long as that same method is used consistently, and the weighting factors are included in the presentation of any results. The weighting factors can be either relative value or rank-order weighting. In relative value weighting, some dimensions of the EPSA rubric which are deemed to be more important are weighted higher than others, i.e. "ethics" and "communication" might be assigned weights of 2x, while all other dimensions are weighted at 1x. In rank-order weighting the individual dimensions of the rubric are assigned a weight of 1-5, with the dimension that is deemed to be the highest importance assigned a weight of 5.

EPSA Implementation at Norwich University

In the Fall 2013 semester and the Fall 2014 semester the EPSA method was incorporated into Norwich University's course EG450-Professional Issues. This course is taken by Engineering students and Construction Management students. The implementation generally takes a portion of one class period to introduce the EPSA and practice using the EPSA materials and methods, one class period to conduct each EPSA session and record the assessment, followed by a portion of one class period to review and discuss the results. The detailed facilitation plan for implementing the EPSA in a course is shown in Appendix E, table E-1.

At Norwich University all assessment of the student discussions was conducted in real-time, during the discussions. Instead of using electronic voice recorders as is typically done by the researchers on the NSF sponsored project, all data was collected as the discussions took place,

with the assessors simply writing tally marks and notes directly on the relevant portion of the EPSA Rubric.

The students in each class were divided into teams. Some members of the team were assigned the role of discussant and others assigned the role of observer. The discussants were responsible for conducting the discussion. The observers were each assigned a dimension of the EPSA Rubric to use to assess the discussions. The teams for both practice sessions and the assessment sessions were organized as shown in Table 2.

Table 2. Organization of the Discussant and Observer Teams

Discussion Sub-Team	Observer Sub-Team
3-6 individuals (ideally 4 or 5) Actively participate in group discussion	2013 – Used 2-3 individuals (typically 3) 2014 – Used 4-6 individuals (preferred 5) Observers DO NOT participate in group discussion
<u>Roles</u> Facilitator/moderator Time-keeper Antagonist	<u>Assignment</u> (done individually) Take notes on assigned EPSA Rubric dimensions Assign score within each EPSA Rubric dimension Be prepared to explain rationale during post-discussion debriefing

In the first class period, which served as a practice session, the students were introduced to the EPSA Method, discussion prompts, and the use of the analytic EPSA rubric. In this practice sessions the discussion time was limited to approximately 10 minutes, so that the facilitator and instructor could provide comments and guidance on use of the EPSA method and the EPSA Rubric.

The assessment sessions (one in 2013, two in 2014) begin with the facilitator/moderator student distributing the EPSA scenarios and standardized EPSA discussion prompts and then reading the prompts aloud to the students in the class. The students then reviewed their assigned roles and read the EPSA scenario. The discussants then conducted the discussion while the observers assessed the discussion. The student observers were also expected to read the scenario, listen carefully to the discussion, note evidence heard about their assigned EPSA rubric areas, and provide a rating of the discussion for each dimension of EPSA rubric that was their responsibility. After the discussion the observers presented their analysis of the discussion. The class time used for the EPSA scenario discussion was 75 minutes. This amount of time was found to be helpful in setting-up the groups, the facilitator’s reading of introduction, students reading of the scenario, student discussion, and post discussion analysis.

After the assessment class period, the course instructor used a portion of one class period to review and discuss the results. The results were compared to those from other classes, or those from other institutions, related to the students’ future work in their chosen professions.

Other details about session set-up included the following:

1. Each team of students (discussants and observers) were in a separate room, the faculty member spent time in each room, but did not participate in the discussions.
2. The facilitator /moderator student was responsible for keeping the discussant team focused as the course instructor moved back and forth between discussion groups. No additional faculty members were utilized in this exercise, although they could have been.
3. No electronic recorders were used (unlike the formal EPSA method).

In the Fall 2013 semester, all groups used the Fukushima Nuclear Power Plant Disaster⁸ scenario for the practice session. In the Fall 2014 semester, all groups used the Offshore Wind Farm⁸ scenario for the practice session. In 2013 due to Norwich University's proximity to local land-based wind farms, the professor selected the "Offshore Wind Farm⁸" scenario for the record section for all teams. In 2014 the professor selected the Hydraulic Fracturing scenario for the first record section for three teams and the Power Grid Vulnerabilities scenario for the second record section for three teams. The scenarios used for the fall 2014 classes are shown in Appendix A. All of the scenarios used for the record sections include economic, political, regulatory, ethical, and environmental considerations, including such issues as public use vs. private rights related to land-use, effects of regulations on utility prices, reliability of renewable energy, global warming, and the international markets for energy.

During the Fall 2013 semester there were two sections of the class, one section with 14 students and one section of 31 students. Both sections contained a mixture of Engineering and Construction Management students. During the Fall 2014 semester there were also two sections of the class, one section with 12 students and one section with 26 students. The 12 student section was composed entirely of Construction Management students, while the 26 student section was composed of Engineering students.

For both years, the first section was divided into one team of discussants and observers and the second section was divided into two teams of discussants and observers. In the Fall Semester of 2013, all teams included both Construction Management students and Engineering students. In the Fall Semester of 2014, the teams were divided by major, with teams consisting entirely of either Engineering majors or Construction Management majors.

Other differences between the two years are as follows: In the Fall 2013 semester, student roles were changed between the practice day and the record day to provide each student a variety of roles, and each observer was assigned responsibility for two dimensions of the EPSA Rubric. In the Fall 2014 semester two record sessions were conducted for each class, allowing every student to participate as both a discussant and an observer, in addition each observer was assigned primary responsibility for only a single dimension of the EPSA Rubric

Table 3 summarizes the observer findings. Scores are on the 5 point EPSA scale (1=emerging, 2=developing, 3=practicing, 4=maturing, 5=mastering).

Table 3. Summary of Observer’s Notes, EPSA Rubric Ratings, and Overall EPSA Score

ABET Criterion	Fall 2013				Fall 2014			
	# of Notes	Mean	Low	High	# of Notes	Mean	Low	High
ABET Skill 3f –ethical responsibility	15	3.74	2.0	5.0	12	3.51	2.0	5.0
ABET Skill 3g – Ability to communicate effectively	18	3.77	2.0	5.0	13	3.38	2.0	5.0
ABET Skill 3h – Broad impact of solutions	13	3.95	3.0	5.0	12	3.36	0.5	5.0
ABET Skill 3i – life-long learning	12	3.62	2.0	5.0	14	3.56	2.0	5.0
ABET Skill 3j – Knowledge of contemporary issues	13	3.5	2.5	5.0	9	3.77	2.0	5.0
EPSA Score	-	3.72	-	-		3.52		

Note: Due to the differences in collecting data, the results 2013 and the results from 2014 are not directly comparable.

Table 4. EPSA Ratings: By Scenario, for Engineering Majors and Construction Management Majors, Fall 2014 (based upon number of notes for each team)

ABET Criterion	Hydraulic Fracturing Scenario			Power Grid Vulnerability Scenario			Both Scenarios		
	Engr (2 teams)	CM (1 team)	Scenario Ave.	Engr (2 teams)	CM (1 team)	Scenario Ave.	Engr	CM	Overall Average
ABET Skill 3f – ethics	3.50	3.50	3.50	3.39	3.83	3.47	3.44	3.67	3.51
ABET Skill 3g – communicate	3.21	4.75	3.59	2.94	3.50	3.05	3.07	4.13	3.38
ABET Skill 3h – impact of solutions	3.56	4.00	3.69	3.50	0.50	2.90	3.53	2.25	3.36
ABET Skill 3i – life-long learning	3.71	2.25	3.39	3.90	3.75	3.87	3.81	3.00	3.56
ABET Skill 3j – issues	3.75	4.00	3.80	4.00	3.00	3.88	3.88	3.50	3.78
EPSA Score	3.55	3.70	3.59	3.55	2.92	3.41	3.55	3.31	3.52

Based upon the 2014 test data, the ratings of the Engineering students were fairly consistent for each scenario. One team of students was rated very low in the area of “Impact of Solutions, which possibly indicates an area for further emphasis in course coverage.

Faculty Evaluation of the EPSA Implementation

After reflecting upon the Fall 2013 EPSA sessions, the instructor expressed several concerns about the implementation. Recommendations to address each concern were proposed:

- Concern #1: Do we need two practice sessions or is that overkill?
Recommendation: Do only one practice session and two record sections. Allocate some general class time after the session to exchange general feedback on the process, the outcomes, and the lessons learned.
Action: This was incorporated into the 2014 sessions.
Results: Student feedback indicated that the students appreciated the opportunity to participate as both a discussant and an observer.
- Concern #2: During the record sessions, each observer was assigned responsibility for multiple dimensions of the EPSA Rubric. Several of the observers felt that they were overwhelmed and missed portions of the discussion while trying to conduct their ratings.
Recommendation: Reduce the workload of the observers.
Action: This was incorporated into the 2014 sessions. The number of observers was increased, such that each observer was assigned primary responsibility for only a single dimension of the EPSA Rubric, and a secondary responsibility for a second dimension of the rubric.
Results: Post activity discussion indicated that the observers felt that they had better reflections of the discussions.
- Concern #3: Feedback from some students indicated that 45 minutes was too long for a discussion period.
Recommendation: Reduce discussion to 30-40 minutes. (The EPSA team has experimented with shorter time periods, and found that after the students have read the scenario, allowing 30-35 minutes is usually adequate.)
Action: This was incorporated into the 2014 sessions.
Results: Student feedback indicated that the student discussions were more focused, and that there were fewer digressions towards the end of the discussion periods.
- Concern #4: Feedback from some students questioned whether they could receive the scenarios and rubrics in advance to allow the student to do some research on their own to better understand the dilemma and examine the EPSA rubric in more detail.
Recommendation: Provide EPSA rubric to students in advance. It was not recommended that the scenarios be provided in advance, so that all students in the discussion had an equal starting point for the discussion.
Action: This was incorporated into the 2014 sessions.
Results: Student feedback indicated that the some were still interested in receiving the scenarios before the discussion session.

Student Evaluation of the EPSA Implementation

In the Norwich University's course evaluation system, the majority of students numerically rated the EPSA experience in their assessment of the course. Of those who provided a numerical rating of this experience, less than 1/6th ranked the experience in the lower half of all the experiences in the course. Overall, the students thought it was a valuable experience and should be retained in future courses.

Conclusions

The interdisciplinary EPSA scenarios generated more enthusiastic and higher level discussion than case studies that focus solely on ethics.¹⁰ For example, one professor has selected to use the EPSA "Offshore Wind Farm" scenario due to the University's proximity to local land-based wind farms. Another faculty member was interested in the Power Grid Vulnerability scenario due to recent adoption of smart-meters in the state. These scenarios include economic, political, regulatory, ethical, and environmental considerations, including such issues as public use vs. private rights related to land-use, effects of regulations on utility prices, reliability of renewable energy, global warming, and the international markets for energy. Since the scenarios are situated in contemporary contexts and show the interdisciplinary and complexity of real-world engineering problems, the EPSA affords students to practice holistic engineering problem solving thinking with fellow students.

The EPSA Rubric provides a standardized means for faculty to evaluate the quality of student discussions and to make evaluation of students' work more consistent between the multiple sections of the course. In addition, through the evaluation process, faculty gain insights into the strengths and weaknesses of students' abilities to pinpoint primary and secondary problems, identify stakeholders, work well in group discussion and consider the impact of potential solutions on different contexts, they then can determine where and when in the curriculum to improve teaching and learning of the outcomes.

The EPSA Summary score provides a composite score based upon all of the dimensions in the EPSA Rubric. This composite score provides an easy means to compare results between groups of students, or between current and prior groups of students, and may be used for classroom purposes as well as program purposes.

The flexibility of the EPSA Method allows it to be readily adapted for use in courses at all levels in the curriculum. The course instructor plans on using the EPSA method in subsequent years as a means to assess the ABET Professional skills at the program level.

At Norwich University, the faculty members used the EPSA Method in the Spring 2015 semester, incorporating the lessons learned from both of the previous trials in the Fall of 2013 and Fall of 2014. All materials required to implement EPSA are included in the appendices.

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Appendix A. EPSA Scenario Examples

Natural Gas from Hydraulic Fracturing of Shale

As the world's energy demands increase, the cross-continental search to tap natural gas reserves is on the rise. Local and national governments, oil and gas companies, energy officials and environmental protection agencies are caught in a vigorous debate over the benefits and drawbacks of hydraulic fracturing, otherwise known as "fracking." Fracking frees natural gas that previously was unrecoverable because of technology limitations.

This is how fracking works: Millions of gallons of a high pressure mixture of water, sand and chemicals are injected through a well into rock to release shale gas deposits buried deep underground. These wells typically descend vertically for approximately 5-10,000 feet into the shale layer where it turns and runs horizontally for a substantial distance. Next, explosives blow holes through the well casing to facilitate injection of the high pressure liquid that fractures the shale in numerous places. The resulting shale fissures allow the previously enclosed natural gas to escape into the well and up to the surface, where it is gathered for processing. Chemicals in the fracking fluid assist in the fracturing process, while sand is used to hold the fissures open allowing the "shale gas" to travel around the sand particles.

Natural gas is a clean burning fuel used to heat half of the homes in the US and is used to produce 1/5 of the electric energy consumed in the US. In the US, the Marcellus shale region (primarily in Pennsylvania, New York, West Virginia, and Ohio) contains enough natural gas to supply the entire US for about 7 years. In 2012 there were around 1.2 million fracking wells. 35,000 new fracking wells are estimated to be added each year. Due to domestic shale gas from fracking, the US has practically eliminated the importation of natural gas from other countries.

The US is not the only country with shale gas reserves. In ranked order, the five countries holding the largest quantities of shale gas are China, US, Argentina, Mexico and South Africa. China, the US and South Africa have shale gas quantities estimated at 1,275; 827 and 486 trillion cubic feet, respectively, with the US's amount sufficient to provide US natural gas needs for up to 100 years.

Countries such as South Africa, who imports 60% of its gas and oil, are especially interested in becoming more self-reliant in meeting its citizens' energy needs. Environmentalists in South Africa are fighting fracking in a pristine arid region that is home to the threatened black rhinoceros and the planned location of a \$1.87 billion radio telescope that requires a very large buffer zone between it and the nearest industrial activity. South Africa currently has a moratorium on drilling exploratory fracking wells.

European nations have drawn widely varying conclusions regarding fracking. Poland views fracking as the path to energy diversity and energy security while Bulgaria and France currently ban fracking. With technology-intensive horizontal drilling and fracking techniques the probability of getting a dry well is very low and in fact the success rate for wells drilled in 2011 was 99%. More daunting is the fact that once the decision is made to develop a new shale gas region the time to production can be as long as ten years.

Concerns about water diversion, water contamination and air pollution introduce controversy into analysis of the energy and economic benefits of fracking. Water concerns stem from 1) the large volume of water needed; 2) the toxicity of chemicals used in the fracturing process; 3) the close proximity of the fracking wells to drinking water sources; and 4) challenges associated with reclaiming the flowback wastewater brine that typically contains chemical species such as sodium ions, chloride ions, barium, strontium, magnesium, calcium, iron, manganese, sulphate, silica, total dissolved solids, arsenic, selenium and radionuclides.

The depth of the shale that entrains the natural gas is well below the depth of the water table. Drilling companies claim that this difference in depth prevents the fracking chemicals from contaminating drinking water. However, examples of environmental damage exist: A) USGS and EPA data appear to show that fracking activities have caused some contamination of the Wind River aquifer near Pavillion, Wyoming and B) a shale gas well in northern Pennsylvania blew out during fracking and spilled thousands of gallons of fracking fluid onto surrounding land.

Another concern is methane from the wells polluting either the air or water. A study performed by researchers at Cornell University suggested that up to 7.9% of the methane from wells escapes to the atmosphere. By not reducing the leak rate of methane to the atmosphere, the environmental benefits of burning natural gas as opposed to coal would be eliminated.

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Power Grid Vulnerabilities

Electric power grids are vulnerable to wide area failures from events that include: 1) malicious computer software introduced by criminals or saboteurs; 2) natural phenomena such as space weather that interacts with the earth's ionosphere; 3) man-made catastrophes such as nuclear explosions; and 4) human errors at the system operator level or the system design level.

In 2010, the US power industry received \$3.4 billion as part of the economic stimulus package to modernize the US electric power grid, increase energy efficiency and minimize the likelihood of wide area failures. A 2011 report by the American Society for Civil Engineers (ASCE) states that the distribution networks in the US are deteriorating at an alarming rate. ASCE recommends an infusion of almost \$70 billion to replace existing devices or retrofit those already in use. Overhead high-voltage lines in lattice transmission towers are particularly vulnerable to blasts, given their crucial function and geographical dispersion across remote areas.

While all of the concerns listed above are critical to stabilizing the US infrastructure, cyber security is currently primary concern at the Pentagon. In January, 2013, Department of Defense officials announced that it would significantly expand its workforce dedicated to protecting the networks that support that US power grid and other critical infrastructures, such as those under military purview.

Computer security experts are concerned that there will be increased vulnerability of the systems used to manage and monitor the smart grid infrastructure. Supervisory Control and Data Acquisition (SCADA) systems represent the legacy technology most prevalent for today's power grid energy management system. SCADA systems are susceptible to cyber attacks because many are built around older technologies with weaker communication protocol. To increase access to management and operational data, these systems and their underlying networks are progressively more interconnected. An example of data required from a large interconnected system is the potentially damaging low frequency mass-spring type electric power oscillations that slowly shuttle energy between Canada and Mexico via the US power grid.

Contemporary hackers may circumvent security measures by targeting a user within the utility instead of hacking directly into the grid. For example, a cyber attacker could be employed by a business that sells products or services to a company, allowing regular e-mail interactions with the internal procurement office. The hacker could circumvent the company's firewall by sending emails with a Trojan horse or advanced malware, thus creating a virtual tunnel to the procurement office's computers. This would give the hacker undetected direct access to the company's network which could be used to launch further attacks.

Malware on the smart grid can cause broad area power outages, but also vandalism to the consumer's home. A wireless local area network will eventually exist in the consumer's home to network smart appliances with the smart grid. Concern is that a computer virus will spread throughout the household network and appliances then infect the neighbor's network and appliances and perhaps an entire neighborhood could experience a blackout or other side effects.

Since 2000, successful cyber attacks to the SCADA systems of a number of US power generation, petroleum production, water treatment facilities, and nuclear plants have increased dramatically. In April 2010, a Texas electric utility was attacked from Internet addresses outside

the US. In late 2010 and early 2011, Iranian nuclear power plants and German-headquartered industrial giant Siemens witnessed the powers of Stuxnet, the sophisticated malware designed to penetrate industrial control systems. The software took control of valves and rotors at the plant causing substantial damage and disruptions. Experts warn that Stuxnet or next-generation worms could incapacitate machines critical to the US electric power grid. Stuxnet-type malware circumvents digital data systems and thwarts human operators by indicating that all systems are normal, when they are actually being destroyed. As of April 2012, analysts warn that these “back door” vulnerabilities could undermine US power grid systems as well as lead to other national cyber security issues.

Official US governmental standards for power grid cyber security are not yet robust enough to ensure against such threats. According to a January 2011 Department of Energy audit, the current standards are not “adequate to ensure that systems-related risks to the nation’s power grid were mitigated or addressed in a timely manner.” While the 2012 cyber security act did not pass, this issue remains one of great concern to many, the Department of Defense has deemed this issue of enough importance to increase its dedicated workforce from 900 to 4000 with a goal of growing it even more across sectors in the coming decade.

1. Sources

1. Elisabeth Bumiller, “Pentagon Expanding Cybersecurity Force to Protect Networks Against Attacks,” *The New York Times*, January 27, 2013.
2. Army Sgt. 1st Class Tyrone C. Marshall Jr., “Cyber Effort Under Way to Safeguard Infrastructure, Official Says,” *American Forces Press Services*, US Department of Defense, February 28, 2013.
3. Daniel D. McClure & Arash E. Zoghi, “Vulnerability of Lattice Towers to Blast Induced Damage Scenarios,” in the American Society for Civil Engineers’ Electrical Transmission and Substation Structures 2012.
4. American Society for Civil Engineers, “Failure to Act: The Economic Impact of Current Investment Trends in Electricity Infrastructure,” 2011.
5. Michael Daniel, “Collaborative and Cross-Cutting Approaches to Cybersecurity,” *The White House Blog*, August 1, 2012, <http://www.whitehouse.gov>
6. U.S. Department of Energy Office of Inspector General Office of Audits and Inspections, DOE/IG-0846, January 2011.

Appendix B. EPSA Discussion Prompts

Imagine that you are a team of engineers working together for a company or organization on the problem/s raised in the scenario.

- 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) Who are the major stakeholders and what are their perspectives?
- 4) What are the potential impacts of ways to address the problems raised in the scenario?
- 5) What would be the team's course of action to learn more about the primary and secondary problems?
- 6) What are some important unknowns that seem critical to address this problem?

You do not need to suggest specific technical solutions -- just agree on what factors are most important and identify one or more viable ways to address the problem.

Please begin by reading the scenario individually. You may begin the group discussion when you are ready. You have 30-40 minutes from this point on to complete your discussion.

Engineering Professional Skills Assessment (EPSA) Rubric

Washington State University - College of Engineering and Architecture,
University of Idaho - College of Engineering, Norwich University - David Crawford School of Engineering, Rose-Hulman Institute of Technology

Rater's Name: _____ Date: _____ Student Work: _____

Note: The engineering professional skills that comprise this rubric are taken directly from the ABET Engineering Criterion 3, Student Outcomes. Each dimension of the EPSA Rubric comprises one ABET student outcome, an EPSA definition of the outcome, and the outcome's performance indicators. Thus, "ABET skill 3 f" can also be read as "ABET criterion 3 student outcome 3f" with three performance indicators: stakeholder perspective, problem identification, & ethical considerations.

Scoring Protocol:

1. Skim the scenario students used for the discussion.
2. Quickly read the discussion, marking passages where a given skill is exhibited. A given passage may exhibit more than one skill simultaneously.
3. During a second read, highlight passages that provide strong evidence (either positive or negative) related to the skills.
4. Read the skill definition. Assign scores for each of the performance indicators.
5. In the comment boxes, provide line numbers and a short phrase, such as: 3f = lines 109-112: trade off of wall height/plant safety vs costs; lines 828-836: risk analysis. Be sure to refer back to the skill definition.
6. Update your initial scores should the data provide evidence for a score change.
7. Ultimately assign one score for the skill. Use whole numbers; no increments.

General Decision Rules

1. Assess what is transcribed. Don't "read between the lines" (e.g., don't make assumptions about what the group should know given what is transcribed.).
2. When conflicted on assigning a score, reference adjacent score description boxes to determine whether a higher or lower score within the description box is more accurate.
3. Weigh all performance indicators within a category equally in assigning the overall score.
4. Assign the higher score associated with a box only when evidence for all performance criteria is present.
5. Read the skill definition after scoring to check the score for accuracy.
6. When averaging scores for the performance indicators, round down. For example, 2.6 would be a 2 not a 3. The rationale is to report the level they attained, not the level that they almost attained.

Scoring Tips

1. Supply line numbers and/or student numbers for reference in the comment box.
2. Strive to complete transcript review and scoring within a 45-60 minutes.

ABET Skill 3f. Understanding of professional and ethical responsibility

Rater Score for Skill _____

Definition: Students clearly frame the problem(s) raised in the scenario with reasonable accuracy and begin the process of resolution through offering approaches that could address the problem(s). Students recognize relevant stakeholders and their perspectives. Students identify related ethical considerations (e.g. health and safety, fair use of funds, risk, schedule, trade offs, etc. and doing “what is right” for all involved).

	0 - Missing	1 - Emerging	2 - Developing	3 - Practicing	4 - Maturing	5 - Mastering
Problem Identification	Students do not identify the problem(s) in the scenario.	Students begin to frame the problem(s). Approaches advocated to address the problem(s) may be general and/or naive.		Students are generally successful in distinguishing primary and secondary problems with reasonable accuracy and with justification. There is evidence that they have begun to formulate credible approaches to address the problem(s).		Students convincingly and accurately frame the problem(s) and parse sub-problems, providing justification. They suggest detailed and viable approaches to resolve the problem(s).
Stakeholder Perspective	Students do not identify stakeholders.	Students identify few and/or most obvious stakeholders, perhaps stating their positions in a limited way and/or misrepresenting their positions.		Students explain the perspectives of major stakeholders and convey these with reasonable accuracy.		Students thoughtfully consider perspectives of diverse relevant stakeholders and articulate these with clarity, accuracy, and empathy.
Ethical Considerations	Students do not identify ethical considerations.	Students give passing attention to related ethical considerations. They may focus only on obvious health and safety considerations and/or fair use of funds.		Students are sensitive to relevant ethical considerations and discuss them in context of the problem(s). Students may identify ethical dilemmas and discuss possible trade offs.		Students clearly articulate relevant ethical considerations in the context of the problem(s). Students may discuss ways to mediate dilemmas or suggest trade offs.
Comments						

ABET Skill 3g. Ability to communicate effectively

Rater Score for Skill _____

Definition: Students work together to address the problems 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 can include 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
Effective Communication	Students do not stay on task and/or encourage participation of others.	Students pose individual opinions. They may not link what they say to what others. Some students may dominate (inadvertently or on purpose), or become argumentative. Students may attempt to regulate the discussion, but without much success. There may be some tentative, but ineffective, attempts at reaching consensus.	Students give thoughtful input and attempt to build on and/or clarify other's ideas with some success. Students attempt to reach consensus, but may find it challenging to implement strategies that equitably consider multiple perspectives. Students defer quickly to a dominant opinion, converging rather than attempting to reach consensus.	Students clearly encourage participation from all group members, generate ideas together and actively help each other clarify ideas. Students actively work together to reach a consensus in order to clearly frame the problem and develop appropriate, concrete ways to address the problem(s).		
Comments:						

Scoring Rules specific to group communication

1. Consider level of individual engagement (as measured by length and depth of utterances) in weighting score.

ABET Skill 3h. Broad understanding of the impact of engineering solutions in global, economic, environmental, and cultural/ societal contexts Rater Score for Skill _____

1. **Definition:** Students consider how their proposed solutions to address the problem(s) impact relevant global, economic, environmental, and cultural/societal contexts.

NOTE TO RATER: Consider assigning a subscore to each context, similar as is done for individual performance indicators. Recognize that some contexts are not necessarily as relevant as others to the scenario discussed.

Global: Students relate the issue or proposed approaches to larger global issues (such as globalization, world politics, etc.).

Economic: Students relate the issue or proposed approaches to trade and business concerns (such as project costs).

Environmental: Students relate the issue or proposed approaches to local, national or global environmental issues (such as ozone depletion).

Cultural/Societal: Students relate the issue or proposed approaches to the needs of local, national, or ethnic groups affected by the issue.

	0 - Missing	1 - Emerging	2 - Developing	3 - Practicing	4 - Maturing	5 - Mastering
Impact/Context	Students do not consider the impacts of potential solutions.	Students give cursory consideration to how their proposed solutions impact contexts. Contexts considered may not be relevant. Students don't seem to understand the value or point of considering impacts of technical solutions or the contexts within which the solution is proposed.	Students consider how their proposed solutions impact major relevant contexts, and possibly re-think their understanding of the problem(s) themselves. Students justify possible solutions with reasonable accuracy. Impacts considered may be associated with relevant secondary problems.	Students clearly examine and weigh how their proposed solutions impact major relevant contexts. Students justify possible solutions with reasonable accuracy. Impacts considered may be associated with relevant secondary problems. Students understand how different contexts can affect solution effectiveness. Students may decide to reframe the primary and/or secondary problems after considering impacts.		
Comments						

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

Rater Score for Skill _____

Definition: Students refer to and examine the information and sources contained in the scenario. Students differentiate between what they know and do not know. Students utilize their own past experiences as they analyze issues in the scenario.

	0 - Missing	1 - Emerging	2 - Developing	3 - Practicing	4 - Maturing	5 - Mastering
Scrutinize Information	Students do not refer to or scrutinize information presented.	Students refer to the information presented in the scenario (e.g. "it says"). Students may distinguish fact from opinion. Students may question the validity of one or more sources.	Students examine information presented in the scenario. Students may recognize that the sources may have potential biases. Students may recognize what is implied or implicit.	Students identify the parameters of their knowledge of the information presented. Students may connect personal experiences or information read/heard elsewhere, while recognizing the limits of their contributions. Students may refer to related historical events. They may identify specific knowledge gaps, and reliable sources to consult.	Students identify the specific limits of their knowledge of the information presented and how those limitations affect their analysis. Students may check assumptions related to personal experiences or information read/heard elsewhere, including related historical events. They specify a variety of reliable sources to be consulted.	Students examine not only information, but also information sources. Examples include, but are not limited to: discussing potential and probable biases of the information sources, distinguishing fact from opinion in order to determine levels of information validity, analyzing implied information.
Identify Knowledge Status	Students do not differentiate between what they do and do not know.	Students begin to identify the boundaries of their knowledge of the information presented. Students may inject their own life experiences, possibly without questioning the validity in relationship to other sources.	Students identify the parameters of their knowledge of the information presented. Students may connect personal experiences or information read/heard elsewhere, while recognizing the limits of their contributions. Students may refer to related historical events. They may identify specific knowledge gaps, and reliable sources to consult.	Students identify the specific limits of their knowledge of the information presented and how those limitations affect their analysis. Students may check assumptions related to personal experiences or information read/heard elsewhere, including related historical events. They specify a variety of reliable sources to be consulted.	Students identify the specific limits of their knowledge of the information presented and how those limitations affect their analysis. Students may check assumptions related to personal experiences or information read/heard elsewhere, including related historical events. They specify a variety of reliable sources to be consulted.	Students identify the specific limits of their knowledge of the information presented and how those limitations affect their analysis. Students may check assumptions related to personal experiences or information read/heard elsewhere, including related historical events. They specify a variety of reliable sources to be consulted.
Comments						

ABET Skill 3j. Knowledge of contemporary issues

Rater Score for Skill _____

Definition: Students consider non-technical issues, such as contemporary events, political and/or geo-political concerns, in framing the problem(s) and possible solutions to address the problem(s). Students display awareness of relevant modern technical issues/methods/tools relevant to framing and solving the problem(s) with reasonable accuracy.

NOTE TO RATER: *Contemporary* refers to current issues easily accessed in a variety of media and those that have been relevant in the previous year (e.g., a war, civil unrest or strife, economic collapse, deposed head of state, etc.). *Modern* refers to up-to-date engineering methods, technologies and tools relevant to the framing and/or solving of the problem (e.g. fault and risk analysis, concept generation, product or process design/simulation, performance optimization, testing, etc.).

	0 - Missing	1 - Emerging	2 - Developing	3 - Practicing	4 - Maturing	5 - Mastering
Non-Technical Issues	Students do not consider contemporary political or geo-political issues.	Students give limited consideration to contemporary events and/or political and/or geo-political issues. Non-technical issues may be treated in a condescending manner, or without understanding of why an engineer may need to consider non-technical issues.	Students give limited consideration to contemporary events and/or political and/or geo-political issues. Students show some accurate understanding of how non-technical issues may affect framing the problem(s) and possible solutions.	Students give meaningful contemporary events and/or political and/or geo-political issues. Students show some accurate understanding of how non-technical issues may affect framing the problem(s) and possible solutions.	Students give extensive meaningful consideration to contemporary events and/or political and/or geo-political issues. Students fully understand the importance of how the non-technical issues considered impact framing the problem(s) and possible solutions.	Students give extensive meaningful consideration to contemporary events and/or political and/or geo-political issues. Students fully understand the importance of how the non-technical issues considered impact framing the problem(s) and possible solutions.
Technical Issues	Students do not consider modern methods, technologies and/or tools.	Students give passing consideration to modern methods, technologies and/or tools. Students may not show awareness that certain methods, technologies and/or tools are not relevant in framing and/or solving the problem(s).	Students give relevant consideration to modern methods, technologies and/or tools in framing and/or solving the problems(s).	Students give relevant consideration to modern methods, technologies and/or tools in framing and/or solving the problems(s).	Students give extensive relevant consideration to modern methods, technologies and/or tools in framing and/or solving the problems(s).	Students give extensive relevant consideration to modern methods, technologies and/or tools in framing and/or solving the problems(s).
Comments						

Scoring Rules

1. Keep track of the number and depth of non-technical and technical issues raised/discussed. Limited discussion of many possibly non-relevant issues may justify a score of 3 over a 4. In-depth discussion of a few highly relevant issues in both non-technical and technical areas may justify a score of 4 or 5.

Appendix D. One-Page Version of EPSA Rubric

The Engineering Professional Skills (EPSA) Rubric (one-page version 2015)

ABET Skill 3f Understanding of professional and ethical responsibility						
	0 - Missing	1 - Emerging	2 - Developing	3 - Practicing	4 - Maturing	5 - Mastering
Stakeholder Perspective	Students do not identify stakeholders	Students identify few and/or most obvious stakeholders, perhaps stating their positions in a limited way and/or misrepresenting their positions.		Students explain the perspectives of major stakeholders and convey these with reasonable accuracy.		Students thoughtfully consider perspectives of diverse relevant stakeholders and articulate these with great clarity, accuracy, and empathy.
Problem Identification	Students do not identify the problem(s) in the scenario.	Students begin to frame the problem, but have difficulty separating primary and secondary problems. If approaches to address the problem are advocated, they are quite general and may be naive.		Students are generally successful in distinguishing primary and secondary problems with reasonable accuracy and with justification. There is evidence that they have begun to formulate credible approaches to address the problems.		Students convincingly and accurately frame the problem and parse it into sub-problems, providing justification. They suggest detailed and viable approaches to resolve the problems.
Ethical Considerations	Students do not give any attention to ethical considerations.	Students give passing attention to related ethical considerations. They may focus only on obvious health and safety considerations and/or fair use of funds involving primary stakeholders.		Students are sensitive to relevant ethical considerations and discuss them in context of the problem(s). Students make linkages between ethical considerations and stakeholder interests. Students may identify ethical dilemmas and discuss possible trade offs.		Students clearly articulate relevant ethical considerations and address these in discussing approaches to resolve the problem(s). Students make linkages between ethical considerations and stakeholder interests and incorporate them into their analysis and resolutions. Students may discuss ways to mediate dilemmas or suggest trade offs.
ABET Skill 3g Ability to communicate effectively						
	0 - Missing	1 - Emerging	2 - Developing	3 - Practicing	4 - Maturing	5 - Mastering
Effective Communication	Students do not stay on task and/or encourage participation of others.	Students pose individual opinions. They may not link what they say to what others. Some students may dominate (inadvertently or on purpose), or become argumentative. Students may attempt to regulate the discussion, but without much success. There may be some tentative, but ineffective, attempts at reaching consensus.		Students give thoughtful input and attempt to build on and/or clarify other's ideas with some success. Students attempt to reach consensus, but may find it challenging to implement strategies that equitably consider multiple perspectives. Students defer quickly to a dominant opinion, converging rather than attempting to reach consensus.		Students clearly encourage participation from all group members, generate ideas together and actively help each other clarify ideas. Students actively work together to reach a consensus in order to clearly frame the problem and develop appropriate, concrete ways to address the problem(s).
ABET Skill 3h Broad Understanding of the impact of engineering solutions in 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 potential solutions	Students give cursory consideration to how their proposed solutions impact contexts. Contexts considered may not be relevant. Students don't seem to understand the value or point of considering impacts of technical solutions or the contexts within which the solution is proposed.		Students consider how their proposed solutions impact major relevant contexts, and possibly re-think their understanding of the problem(s) themselves, justify possible solutions with reasonable accuracy. Impacts considered may be associated with relevant secondary problems.		Students clearly examine and weigh how their proposed solutions impact major relevant contexts. Students justify possible solutions with reasonable accuracy. Impacts considered may be associated with relevant secondary problems. Students understand how different contexts can affect solution effectiveness.
ABET Skill 3i Recognition of the need for and ability to engage in life-long learning.						
	0 - Missing	1 - Emerging	2 - Developing	3 - Practicing	4 - Maturing	5 - Mastering
Scrutinize Information	Students do not refer to or scrutinize information presented.	Students refer to the information presented in the scenario (e.g. "it says"). Students may distinguish fact from opinion. Students may question the validity of one or more sources.		Students examine information presented in the scenario. Students may recognize that the sources may have potential biases. Students may recognize what is implied or implicit.		Students examine not only information, but also information sources. Examples include, but are not limited to: discussing potential and probable biases of the information sources, distinguishing fact from opinion in order to determine levels of information validity, analyzing implied information.
Identify Knowledge Status	Students do not differentiate between what they do and do not know.	Students begin to identify the boundaries of their knowledge of the information presented. Students may inject their own life experiences, possibly without questioning the validity in relationship to other sources.		Students identify the parameters of their knowledge of the information presented. Students may connect personal experiences or information read/heard elsewhere, while recognizing the limits of their contributions. Students may refer to related historical events. Students may identify specific knowledge gaps, and reliable sources to consult.		Students identify the specific limits of their knowledge of the information presented and how those limitations affect their analysis. Students may check assumptions related to personal experiences or information read/heard elsewhere, including related historical events. Students specify a variety of reliable sources to be consulted.
ABET Skill 3j Knowledge of contemporary issues.						
	0 - Missing	1 - Emerging	2 - Developing	3 - Practicing	4 - Maturing	5 - Mastering
Non-Technical Issues	Students do not consider contemporary political or geo-political issues.	Students give limited consideration to contemporary events and/or political and/or geo-political issues. Non-technical issues may be treated in a condescending manner, or without understanding of why an engineer may need to consider non-technical issues.		Students give meaningful contemporary events and/or political and/or geo-political issues. Students show some accurate understanding of how non-technical issues may affect framing the problem(s) and possible solutions.		Students give extensive meaningful consideration to contemporary political and/or geo-political issues. Students fully understand the importance of how the non-technical issues considered impact framing the problem(s) and possible solutions.
Technical Issues	Students do not consider modern methods, technologies and/or tools.	Students give passing consideration to modern methods, technologies and/or tools. Students may not show awareness that certain methods, technologies and/or tools are not relevant in framing and/or solving the problem(s).		Students give relevant consideration to modern methods, technologies and/or tools in framing and/or solving the problems(s).		Students give extensive relevant consideration to modern methods, technologies and/or tools in framing and/or solving the problems(s).

Appendix E. EPSA Rubric Facilitation Plan

Table E-1. Facilitation Plan for Implementing the EPSA Method

<p>PRIOR CLASS – INTRODUCTION</p> <p>Introduce the one page rubric and the scenario, letting students know that they will receive specific discussion prompts at the start of the EPSA session and that they may be assigned to either a participant or an observer group but they won't know which until the next class period.</p>
<p>EPSA CLASS SESSION(S)</p> <ol style="list-style-type: none">1. Review scenario and discussion prompts - 5 min2. Review/assign roles – 10-15 min<ol style="list-style-type: none">a. Discussion Sub-Teams (3-6 students) use separate roles of Moderator, Timekeeper, Antagonist, and possible Assessor who does a self-scoring of the rubric from inside the teamb. Observer Sub-Teams (4-6 students) work with full page versions of the one of the following rubric pairs (3f-3g), (3f-3h), (3i-3j). Each observer has primary responsibility for one dimension, and secondary responsibility for a second.c. All team members read scenarios – up to 10 min3. Discussion period - 30 to 40 min<ol style="list-style-type: none">a. Discussants strive for their best effort engaging all group membersb. Observers record individually without talking or interveningc. Observers complete the assessment forms4. Debriefing - 10 to 15 min<ol style="list-style-type: none">a. Observers individually report out by skill area 3f, 3g, 3h, 3i, 3j (i.e. all 3f reports followed by others) - 1 min summary each give area score(s), describe greatest strength within in this skill area (and why it's valuable), and greatest area for improvement (and how it could be implemented)b. Discussant Assessor identifies skill areas in which internal perspective may differ from observers - 1 minc. Discussion Sub-Team asks questions of observers - 5 mind. Instructor or TA provides summary from his or her perspective - 3 min
<p>NEXT CLASS PERIOD</p> <p>Class wide report on EPSA performance is given, with advice on taking this forward to professional practice</p>