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Scenario and Scoring Sheet Development for Engineering Professional Skill Assessment

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Scenario and Scoring Sheet Development for Engineering Professional Skill Assessment

Abstract

The Engineering Professional Skill Assessment (EPSA) was created as a direct method for eliciting and measuring ABET professional skills as described in criterion 3 student outcomes. EPSA is a performance assessment consisting of: 1) a 1-2 page scenario about a contemporary, interdisciplinary engineering problem intended to prompt discussion among a group of 5-6 students; 2) a 45- minute discussion period where students are asked to address a series of generic questions about the scenario; 3) an analytical rubric; and 4) a set of scenario-specific notes about what constitutes exemplary performance. This method and assessment tool can be used at the course level for developing engineering professional skills and providing feedback, as well as at the program level for data collection and accreditation reporting purposes. The EPSA project is currently in the third year of a four year National Science Foundation sponsored validity study.

This paper outlines best practices and provides an assessment tool for crafting timely, relevant, and engaging scenarios. This paper also includes a score sheet that can be used to provide real-time feedback to students immediately following a group discussion. The current version of the analytic rubric used for rating audio transcripts for program-level assessment purposes is provided as well. These practices and tools are illustrated in conjunction with a sample scenario about modern challenges in managing electronic waste. Feedback from project advisory board members are integrated in this discussion.

Background

Engineering programs have an explicit need to define, teach and measure professional skills since their introduction by ABET evaluation criteria for engineering programs in 2000. These skills include ability to function on multidisciplinary teams (3d), understanding of professional and ethical responsibility (3f), ability to communicate effectively (3g), understanding of the impact of engineering solutions in global, economic, environmental, and cultural/societal contexts (3h), recognition of and ability to engage in life-long learning (3i), and knowledge of contemporary issues (3j). A well-grounded method for skill assessment is 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 [1].

Investigators at Washington State University, University of Idaho, and Norwich University have used the performance assessment paradigm to develop and rigorously test the Engineering Professional Skills Assessment (EPSA) as a vehicle for directly assessing ABET defined skill areas [2]. The EPSA method begins with a group of five to seven students discussing a complex, real-world scenario that includes current, multi-faceted, multidisciplinary engineering issues. To initiate the 45 minute long discussion, student participants first read a short scenario that presents some technical and non-technical details of the topic. To guide the discussion after reading the scenario, students are given a discussion prompt in the form of a series of questions that direct the participants to identify problems, consider stakeholder perspectives, and outline a plan to learn more about the problems. McCormack et al. explored best practices for administering and using the EPSA rubric [3].

Student performance with respect to the set of ABET professional skills is determined by scoring the discussion using the EPSA rubric. The EPSA rubric is segmented into five dimensions defined by the ABET Engineering Criterion 3, Student Outcomes (3f, 3g, 3h, 3i, and 3j). The five dimensions of the rubric are then further divided into the specific areas for scoring shown in Table 1. The complete EPSA rubric is included in Appendix A.

Table 1. ABET professional skills addressed in the EPSA scoring rubric

Dimension	**Specific Areas Considered**
3f. Understanding of professional and ethical responsibility	Stakeholder Perspective Problem Identification Ethical Considerations
3g. Ability to communicate effectively	Group Interaction Group Self-Regulation
3h. Understanding of the impact of engineering solutions in global, economic, environmental, and cultural/societal contexts	Impact/Context
3i. Recognition of the need for and ability to engage in life-long learning	Scrutinize Information Knowledge Status
3j. Knowledge of contemporary issues	Non-Technical Issues Technical Issues

To date, the author team has observed over 60 student discussions involving a dozen different scenarios. Early on, the team recognized the importance of having a robust set of scenarios to prompt group discussion. The purpose of this paper is to specify criteria for creating effective EPSA scenarios, outline a methodology for scenario writing, and report feedback about EPSA scenarios from third party users. The resources generated by this work are intended to help other engineering educators generate new EPSA scenarios in response to current events and emerging technologies. Special emphasis is given to incorporating scenario elements that inform ABET criteria 3f, 3h, and 3j. Teaching situations that call for an expanded set of EPSA scenarios include capstone design, mid-program design, engineering economics, engineering ethics, freshman seminars, and campus-wide great issues seminars.

Scenario Use in Education

Diverse uses for scenarios and case studies in teaching/learning are found in curriculum design for engineering, business, law, medicine and other professional degrees. Boller [4] describes how learning scenarios can support transmission and retention of expert knowledge. She cites the importance of defining characters, describing easily recognized contextual elements, and inviting interactivity by the learner in efforts to solve the character's problem. In addition to identifying a fairly specific goal state, this type of scenario inventories key obstacles that the main character encounters and provides tips about problem solving processes that could be employed by the main character. The Aspen Institute maintains an archive of case studies that can be used to teach modules that focus on societal, environmental, and ethical issues in business [5]. These scenarios vary in length (2-10 pages) and are generally deployed over multiple class periods. The primary purpose of most of these scenarios is situational awareness and analysis, attempting to clarify right and wrong actions irrespective of learner beliefs/ethics.

Harris et al. [6] supported the use of case studies as the best method that they observed for learning engineering ethics because they expose students to ethics in technical situations, engage students in ethical analysis, and show that some ethical situations are ambiguous and are handled differently by experts. Harris et al. [7] and Herkert [8,9] noted that cases could be focused on aspirational or preventative action, microethics considerations, or macroethics. Gentile [10] explains how ethics scenarios can be inverted by encouraging learners to give voice to their own values. These stress rehearsing personal actions in authentic workplace situations rather than judging personal actions under hypothetical conditions. Scenarios are often part of discussion prompts in online learning. Ideally, discussion prompts serve as the kernel for a cooperative activity that is best gauged by the degree to which students engage with the topic through unique, critical, and personally substantive postings [11]. EPSA scenarios share characteristics with both scenarios and discussion prompts as defined in the literature. They are the discussion kernel for student led learning experience, but are different than scenarios and discussion prompts in the literature in some key ways. EPSA scenarios are unlike scenarios in the literature because they are the kernel for an authentic discussion, not role play and are unlike discussion prompts in the literature because they are seeds real-time, face-to-face discussions not asynchronous exchanges.

EPSA Scenario Development

Putchinski [11] articulated three criteria for effective discussion prompts: (1) make the prompt relevant to your course content, (2) make the prompt current by referencing something recently in the news, and (3) add novelty to the prompt through unexpected information or an ethical dilemma. These principles lie at the heart of EPSA scenario construction. EPSA scenario design is further scaffolded by the EPSA discussion instructions given in Table 2. The instructions in Table 2 are given to student groups along with a scenario in preparation for an EPSA discussion. From the discussion instructions, questions 1, 2, and 3 relate to ABET 3f, question 4 relates to ABET 3h, and questions 5 and 6 relate to both ABET 3i and 3j.

Table 2. EPSA discussion instructions

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.

In order to make a compelling scenario as well as one that balances information related to all six aspects in the discussion instructions, the EPSA leadership team identified the seven criteria described in Table 3. These criteria also form the basis for scenario assessment form that contains space for recording comments on strengths and weakness associated with each criterion. An example of this form appears in Table 9 in conjunction with an example scenario about E-Waste.

Table 3. Criteria for an EPSA Scenario

Criterion	Description
Interdisciplinary Scope	The scenario involves more than one discipline within and beyond engineering. The issue/problem in the scenario should be able to be tackled by an interdisciplinary group at any level in the program.
Relevant problem	The scenario has some kind of unresolved problem, tension, a disagreement, or competing perspectives on how to address the problem. The problem is not emotionally disruptive and will be relevant for five to ten years.
Non-technical complexity	The complex and multifaceted scenario has multiple stakeholders including public, private, global, groups, and individual constituents. The diversity of stakeholders is representative of a problem with ethical, societal/cultural, economic, environmental, and global concerns. Any solution requires all critical stakeholders to be on board with the solution(s).
Technical complexity	The scenario includes some technical data for students to “hang on to” as they tackle the problem. The problem has a core component of technicality, benefiting from engineers on the solution team.
Elicits engagement	Scenario draws in the reader and engages the student group in deep discussions because the problem is complex and multifaceted without an obvious, quick fix solution.
References	The scenario has multiple references (3-4) from varied sources such as refereed journal articles, solid news sources, and publications from professional societies. The selection of references is objective and balanced.
Packaging for classroom use	The scenario can be read and understood by all engineering undergraduates in 5-7 minutes as a common starting point for a 30-40 minute group discussion. There should be no pictures or tables. Lists are acceptable. The written text must be no more than 1.5 pages, 12-point font, and 1.5 spacing.

EPSA Scenario Writing Methodology

The scenario creation process is divided into three phases (Table 4). Scenario creation begins with a scoping phase to determine the need and subject for a new scenario. This phase begins with the recognition of the need for a new scenario. New scenarios may be generated when an instructor finds a new, compelling engineering topic or sees that existing scenarios are no longer sufficiently current. A good practice is for the author of the scenario to review the best existing scenarios. The author then brainstorms possible topics by reviewing current issues receiving media coverage. The author then selects a topic that is most likely to satisfy the requirements presented in the scenario assessment form (Table 3) while considering the likely audience.

The scenario is incrementally developed in the second phase of scenario creation. To begin this phase, the author gathers several (5-10) references from refereed papers and/or acceptable media outlets for sources for the scenario. From the references, the author builds an annotated bibliography. The annotated bibliography can include quoted passages, summary statements, and ideas for the scenario storyline. The author then builds an outline of the scenario content using the major dimensions of EPSA rubric (Appendix B) as a guide. While this does not produce a temporal outline, this outline ensures that the author has uncovered and synthesized sufficient topical content with respect to the dimensions of the EPSA rubric. It is a good idea now for the author to visualize a typical student discussion with respect to this scenario. Key questions that the author should ask are, "Is this topic prevalent enough that students will uncover the fundamental problems?", "Are the core stakeholder groups obscure?", and "Is this topic compelling to the level and discipline of the students involved?" If the scenario still seems appropriate, or can be repaired, the author moves on to developing the discussion check sheet. The discussion check sheet acts as a scenario specific, real-time scoring guide for the instructor. This can be used in concert with the EPSA rubric, empowering the instructor to gather evidence for real-time scoring. The scenario specific discussion check sheet can be easily generated from a quality scenario outline. The discussion check sheet is generated by reducing outline items to 3-4 short phrases per rubric dimension and 2-3 supporting points. Note that rubric areas 3g and 3i are more focused on generally applicable discussion related skills and do not benefit from scenario specific data. The author then drafts the scenario from the supporting documentation.

In the third phase of scenario creation, the scenario is assessed and refined accordingly. The author first recruits a colleague to assess the draft of the scenario using the scenario assessment form (Table 3). Based on the assessment, the author will then revise the scenario, outline, and check sheet. It is not necessary, but helpful, if the author has the opportunity to pilot the scenario. The pilot may use graduate students, other faculty, or experienced students instead of the targeted undergraduate students for more comprehensive feedback. Finally, the scenario is revised based on the pilot study observations and feedback.

Table 4. Process for creating a new EPSA scenario

1. Scenario Scoping 1.1. Recognize need for new scenario 1.2. Review successful existing scenarios (see list in Table 10) 1.3. Brainstorm possible new scenario topics 1.4. Select most promising topic 2. Scenario Development 2.1. Locate key reference documents 2.2. Create annotated bibliography (see example in Table 5) 2.3. Outline scenario using EPSA rubric (see example in Tables 6-8) 2.4. Visualize student discussion 2.5. Generate scoring check sheet (see example in Appendix C, D and E) 2.6. Draft scenario (see example in Appendix B) 3. Scenario Assessment and Testing 3.1. Assess scenario (use template in Table 9) 3.2. Revise outline, scenario, and scoring check sheet 3.3. Pilot with students 3.4. Adjust final draft for optimal impact

Case Study: E-Waste

A scenario discussing the lifecycle of E-waste was created using this process. The artifacts at different stages of creating this scenario are shown in Table 5 (annotated bibliography), Tables 6-8 (outline), and Table 9 (scenario assessment form). The annotated bibliography (Table 5) was created from seven references. Each reference is categorized under a topic heading, provides the location of the source (web address), and the facts/quotes that were extracted from the reference. Information was extracted from the annotated bibliography to complete the outline (Tables 6-8). A detailed outline greatly facilitates realization of a scenario draft. If there is difficulty completing the outline, this is a sign that one or more additional resources are needed. The E-waste scenario was reviewed by a colleague on our EPSA team using the scenario assessment form shown in Table 9. The reviewer noted an issue with the potential of the scenario in eliciting engagement and suggested the addition of a hook at the front-end of the scenario. The author added the italicized text to the scenario to grab the reader's attention. The completed scenario and discussion scoring check sheet are placed in the appendix along with the latest version of the EPSA rubric. This forms a package that is ready-to-use by interested readers.

Table 5. Annotated Bibliography for the E-waste scenario

Guiyu - Electronic waste capital of the world

- http://content.time.com/time/magazine/article/0,9171,1870485,00.html
- "Guiyu — and places like it in India and Africa — flourish because it is far cheaper to break down e-waste there than it is in the developing world, where companies must follow strict guidelines."

http://sometimes-interesting.com/2011/07/17/electronic-waste-dump-of-the-world/

- It is estimated Guiyu earns over $75 million dollars a year from the processing of over 1.5 million tons of e-waste – and those numbers increase every year.
- "the air is not safe to breathe and the water not safe to drink. Lead and other poisonous metals course through the veins of the residents."
- Greenpeace sent crews to Guiyu to measure ground samples and test the water supply. Over 10 heavy and poisonous metals were found.
- Drinking water has to be trucked in as the local river and underground water table are poisonous. Guiyu has the highest level of cancer-causing dioxins in the world; pregnancies are six times more likely to end in miscarriage and seven out of ten children are born with 50% higher levels of lead in their blood than children born elsewhere.
- "A sad reality of Guiyu is 88% of workers suffer from neurological, respiratory, or digestive abnormalities. A similar number also suffer from various forms of skin disease."

A company's responsibility to minimize E-waste

http://techcrunch.com/2012/08/14/apple-is-creating-an-e-waste-problem/

- Apple's e-waste contribution by changing the iPhone connector

Product lifespans are shortening

http://science.time.com/2012/03/08/e-waste-how-the-new-ipad-adds-to-electronic-garbage/

Lead free solder

http://www.ecnmag.com/articles/2011/12/was-lead-free-solder-worth-effort

- Was lead free solder actually worse for the environment?
- "Lead-free assembly is not better for the environment, it is worse. The additional tin mining required to produce high-purity tin alloys, plus the mining of other precious metals required to alloy with tin in substitution for lead is a poor trade for the use of existing lead, much of which comes from recycled products. This information comes from a study conducted by the U.S. EPA. The study undercuts the primary basis for RoHS.
- "Lead-free assembly is less reliable than lead-based assembly. That's why they grant exceptions for military and high-reliability applications that still use SnPb solder."

Quantities of E-Waste - Expectations

http://www.marketsandmarkets.com/Market-Reports/electronic-waste-management-market-373.html

- The global volume of e-waste generated is expected to reach 93.5 million tons in 2016 from 41.5 million tons in 2011 at a CAGR of 17.6% from 2011 to 2016.

Volume of E-Waste Recycling

http://www.treehugger.com/clean-technology/crazy-e-waste-statistics-explored-in-infographic.html

- every year – 20 to 50 million metric tons of E-waste – recycling only 10-18%
- E-waste growing by 5% annually

Table 6. Outline for the E-Waste scenario – ABET 3f

Understanding of professional and ethical responsibility

- **Problem ID**
    - Breaking down E-waste for recycling makes the materials available for reuse but also can release harmful material if not handled properly.
    - Crushed E-waste contains carcinogenic agents that can contaminate ground water and are harmful if airborne.
    - It is cheaper to process E-waste in third world locations because of low labor costs and lack of regulation.
    - A change to lead free solder was mandated to reduce the amount of harmful materials in E-waste, but lead free solder has been problematic in practice, resulting in more total waste.
    - Major electronic device companies have instituted recycling programs but are producing more E-waste from shortened product lifecycles and product modifications.
    - E-waste contains valuable materials that are environmentally damaging to extract from natural sources.
- **Stakeholders**
    - consumers (computers, phones, tablets, laptops, MP3 players, televisions, monitors, printer)
    - manufacturers (OEM)
    - landfill operators
    - regulators
    - reprocessing organizations
    - management
    - workers
    - residents of E-waste producing countries
- **Ethical Issues**
    - While there are no federal laws, there are many state regulations that prohibit large producers of E-waste from landfilling.
    - Some countries have strong E-waste related laws.
    - Green certification of new products is often a plus in the marketplace but requires lifecycle management of hazardous materials.
    - Technology driven consumer culture has enabled electronics manufacturers to produce products with shorter lifespans.

Table 7. Outline for the E-Waste scenario – ABET 3h

Understanding of the impact of engineering solutions in global, economic, environmental, and cultural/societal contexts

- **Global Impact:**
  - E-waste producers and re-processors are typically in different countries. (as are the manufacturers.)
- **Economic Impact:**
  - There is economic incentive to recover materials from E-waste compared with extraction from natural sources.
- **Environmental Impact:**
  - There is more focus on environmentally responsible manufacturing in first world vs. third countries.
  - Without proper infrastructure, recovery exposes workers and communities to high levels of water and air pollution.
- **Cultural/Societal:**
  - A society that accepts "disposable electronics" is resulting in an increase in E-waste.
  - A society that expects innovation in electronics also promotes disposability.

Table 8. Outline for the E-Waste scenario – ABET 3j

Knowledge of contemporary issues

- **Technical**
  - burning plastics
  - lead free solder technical details
  - hazardous materials in E-waste: mercury, sulfur, lead, BFR, cadmium, beryllium oxide, hexavalent chromium, PTFE
  - non-hazardous materials: tin, copper, aluminum, germanium, silicon, iron, nickel, lithium, zinc, gold
  - designed obsolescence vs. pure technological advancement
  - recovery methods
- **Non-technical**
  - Basel action network
  - EPA
  - lead free solder laws
  - international shipping
  - wage differential
  - E-waste recycle programs from manufacturers or third party networks importance of "green image" of a company

Table 9. Completed assessment form for the E-waste scenario with reviewer comments

Criterion	Description	Reviewer Comments	Y/N
Interdisciplinary Scope	Scenario involves more than one discipline within and beyond engineering. The issue/problem in the scenario should be able to be tackled by an interdisciplinary group at any level in the program.	The scenario is relevant to multiple branches of engineering – mechanical, electrical, computer, chemical	Y
Relevant problem	The scenario has some kind of unresolved problem, tension, a disagreement, or competing perspectives on how to address the problem. It does not "play on the readers' emotions" by presenting material in a biased manner. The topic will be relevant for five to ten years.	There is tension between the cultural desire for more/better electronics and disposal. There is also tension between the need/desire to recycle and the cost to do it properly.	Y
Non-technical complexity	The complex and multifaceted scenario has multiple stakeholders including public, private, global, groups, and individual constituents. The diversity of stakeholders is representative of a problem with ethical, societal/cultural, economic, environmental, and global concerns. Any solution requires all critical stakeholders to be on board with the solution(s).	There are societal issues related to the demand for electronics and short lifespans. There is also a global concern with recycling jobs, the health risks that they pose and the wages those jobs offer.	Y
Technical complexity	The scenario includes some technical data for students to "hang on to" as they tackle the problem. The problem has a core component of technicality, benefiting from engineers on the solution team.	The technical data is not complex. Recycling procedures – maybe a little. Electronics material contents – some. I do not feel that there is technical detail missing, but perhaps this scenario is appropriate for underclass audiences.	Y
Elicits engagement	Scenario draws in the reader and engages the student group in deep discussions because the problem is complex and multifaceted without an obvious, quick fix solution.	The multiple elements of tension should engage the reader and it is related to products that students use every day BUT a more powerful opening hook to draw in the reader is needed!	N
References	The scenario has multiple references (3-4) from varied sources such as refereed journal articles, solid news sources, and publications from professional societies. The selection of references is objective and balanced.	The sources are fine. Perhaps some additional technical references would beef up the technical complexity.	Y
Packaging for classroom use	The scenario can be read and understood by all engineering undergraduates in 5-7 minutes as a common starting point for a 30-40 minute group discussion. There should be no pictures or tables. Lists are acceptable. The written text must be no more than 1.5 pages, 12-point font, and 1.5 spacing.	The length of the scenario and opportunity for sufficient discussion is fine.	Y

External Assessment

Scenario assessment was performed by a set of 11 external advisors who were experienced industry advisors, engineering educators, and/or educational researchers. Feedback was collected by presenting each external advisor with a scenario and the scenario assessment form. The assessment took place during the first year of the project using the original set of scenarios that the project team developed. Advisory board feedback pointed to sufficient levels of potential for engagement and disciplinary diversity. Reviewers had conflicting views about the technical complexity within a scenario. To address this concern, the outline method was developed to bridge the creation of a scenario from the annotated bibliography and promote rigor and completeness.

Scenario and Check Sheet Use in the Classroom

With the scenario, discussion instructions, and check sheet prepared, an instructor can conduct an EPSA event. The discussion will take approximately 45 minutes and can be held during a single class period. To prepare for this class, the instructor pre-defines groups of 4-6 students. Each group will need a moderator which can be the instructor, other faculty, or another student (for a different kind of learning opportunity). Each student in the group is given a copy of the instructions and scenario and are told to read them, and begin the discussion when ready. During the discussion, the moderator marks off items on the check sheet corresponding to discussion topics. The moderator may also make some notes with respect to other noteworthy student discussion topics. Before beginning the discussion, the moderator should be familiar with the scenario, the check sheet, and can review the complete EPSA rubric for further details on expectations. If the course instructor is using students as moderators, assigning the rubric for review by the entire class as a pre-class assignment might be helpful. It is unrealistic to expect students to carryon a substantive conversation and review the complete rubric in a 45 minute time period. Ideally, discussion feedback should be delivered directly to the student groups after the discussion (if time remains) or during the next class period. The scenario checklist along with accompanying notes gives concrete examples of items that were addressed or omitted by the student group. This should enable students to visualize their performance within the more general context of the EPSA rubric. Gathering check sheets and rubric scores across multiple discussion groups, provides also provides a learning opportunity for an entire class.

Conclusions and Recommendations

This paper outlines a method for developing scenarios about engaging, real-world problems that are aligned with the Engineering Professional Skills Assessment (EPSA) rubric. The methodology includes author-friendly steps related to scenario selection/scoping, scenario outlining/drafting, and scenario assessment/testing. The purpose of these scenarios is to prompt productive group discussion about professionalism, solution impacts, and contemporary issues associated with the scenario. It is not necessary or desirable that the scenarios be all-inclusive as the intention is not to have students only ferret out data contained in the scenario. Ideally, students should be able to read an EPSA scenario along with the discussion guidelines in 5-7 minutes. The scenario creation process should draw on readily available information sources that include technical elements, non-technical elements, and diverse perspectives. The resulting scenario package includes an annotated bibliography, an outline that addresses professional issues, solution impacts, and contemporary issues structured using the EPSA rubric; a scenario that responds to six EPSA assessment criteria, and a scenario scoring check sheet that is convenient to use a during real-time student discussion. The package can be easily reviewed and revised, beginning with the annotated bibliography, as new information about the scenario topic appears in the media. This 3-part package appears in the appendix for the E-Waste scenario.

The authors are now in the final year of a four-year NSF sponsored validity and reliability study associated with the EPSA rubric. Project results, including scenario writing, are being integrated in a comprehensive administrative manual for EPSA users. A project site available in fall 2014 will provide access to a wide range of scenarios that have been created using the method described here (see Table 10), as well as other resources. All of these scenarios were used to gather more than 50 transcripts of student discussions that were examined by pairs of raters. Additional pilot testing with real-time scoring methods involving multiple disciplines is planned. Readers interested in being part of a diverse pilot team should contact the authors. This paper has focused on course-level implementation of the EPSA method. Program-level implementation is discussed in another ASEE publication [12].

Table 10. Ready to use EPSA scenarios.

Scenario	Description
Lithium mining for lithium-ion electrical vehicle batteries	Lithium is a core component to battery technology today but it is limited in its retrieval.
Development of Offshore Wind Resources	Wind farms offer potential for energy production but may have societal and environmental ramifications.
Energy Critical Materials: Issues with Supply and Demand	Rare earth elements are used on many high tech products but are both environmentally challenging to extract and politically provocative.
Deepwater Horizon Oil Spill Cleanup	The BP oil spill in 2010 was cleaned up through various methods that had unknown impact.
Fukushima Daiichi Nuclear Disaster	The impact of Japan's nuclear disaster is felt by the workers, the people of Japan, and the stakeholders of the nuclear industry.
Power Grid Vulnerabilities	Modernization of the US power grid may have impacts on the security of the grid with respect to cyber attacks.
Tennessee Valley Coal Ash Spill	In December 2008, 300 million gallons of waste from a TVA coal-burning plant spilled out of an earth dam. The waste had a great impact on the people living and working near the artificial mountain from which it came.
Is hydraulic fracturing worth the risk?	Hydraulic fracturing techniques allow access to large amounts of natural gas but may have negative impacts on the surrounding environment.
Use of Minerals from Conflict Zones	Cell phones, game consoles, laptops and most products with integrated circuits use minerals sourced from conflict-torn Central African mining regions.

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Appendix A. The Engineering Professional Skills Rubric (version 2014)

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 Consideration	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
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. The majority of students give thoughtful input and attempt to build on and/or clarify other's ideas with some success.		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 dominate (inadvertently or on purpose), or become argumentative. Students may attempt to regulate the discussion, but without success. There may be some tentative, but ineffective, attempts at reaching consensus.		Students regulate the discussion by identifying unproductive communication. Students attempt to reach consensus, but may find it challenging to implement strategies that equitably consider multiple perspectives. The majority of students work to achieve consensus in order to frame the problem and propose approaches.		Students use self-regulation strategies to ensure a productive discussion. Students clearly work together to reach a consensus in order to clearly frame the problem and develop appropriate, concrete ways to resolve the problem.

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, justify possible solutions with reasonable accuracy. Impacts considered may be associated with relevant secondary problems, and 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 in the scenario.	Students refer to the information presented in the scenario (e.g. "it says"). Students begin to examine information presented in the scenario. Examples include, but are not limited to: questioning the validity of information sources, distinguishing fact from opinion		Students examine information presented in the scenario, and potentially the information sources. Examples include, but are not limited to: questioning the validity and potential biases of information sources, distinguishing fact from opinion, recognizing what is implied and what is explicit		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 issues raised in the scenario. Examples include, but are not limited to: recognizing information that is new to them, beginning to ask questions, injecting their own life experiences, possibly without questioning the validity in relationship to other sources		Students identify the limits of their knowledge of the issues raised in the scenario. Examples include, but are not limited to: connecting personal experiences or information read/heard elsewhere, recognizing that personal experiences may or may not benefit analysis of the issues, considering related historical events, identifying specific knowledge gaps and reliable sources to consult		Students identify the specific limits of their knowledge of the issues raised in the scenario and how those limitations affect their analysis. Examples include, but are not limited to: checking assumptions related to personal experiences or information read/heard elsewhere, considering related historical events, acknowledging that they learned from the scenario, each other and the discussion, identifying specific knowledge gaps and a variety of reliable sources to consult

ABET Skill 3j Knowledge of contemporary issues.						
	0 - Missing	1 - Emerging	2 - Developing	3 - Practicing	4 - Maturing	5 - Mastering
Non-Technical	Students do not consider contemporary political or geo-political issues.	Students give limited consideration to contemporary 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 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 B. The E-Waste scenario: Lifecycle for E-Waste

Meet Xiao Zhang. This forty-year-old former farmer and current resident of Giuyu, in the Guangdong province of China, has never used a computer, photocopier or iPhone. In spite of this, Xiao has quite possibly interacted with every single high-tech component known to man every day for the last six years. His job? Scavenging electronic parts and melting lead solder off circuit boards in what may be the largest E-waste dump on earth. In exchange, he makes less than three US dollars a day.

Twenty to fifty million metric tons of electronic waste are generated globally each year. Electronic waste, known as E-waste, is composed largely of computers, phones, tablets, laptops, MP3 players, televisions, monitors, printers, etc. Only 10-18% of E-waste is recycled whereas the remaining E-waste is taken directly to landfills. E-waste represents only 2% of trash in US landfills, but constitutes 70% of the overall toxic waste in landfills. The amount of E-waste is growing 5% annually.

There is substantial economic rationale to recover or refurbish E-waste products. When possible, some electronics can be refurbished and used by new users. When a reuse opportunity is not identified, E-waste can be processed to reclaim valuable materials within. E-waste typically has multiple types of valuable material including gold, silver, aluminum, and copper. When processed properly, valuable materials are recovered, hazardous waste is properly treated and expensive and potentially damaging mining operations to acquire additional raw materials can be avoided. Unfortunately, a substantial amount of E-waste is being exported to China, India, and Africa for recycling where labor costs are low and environmental regulations are not prevalent.

In Guiyu, Xiao Zhang and about 100,000 other workers scavenge E-waste for recoverable materials, earning a wage five times more than they would earn as a farmer or laborer. Unfortunately, about 88% of the workers are afflicted with neurological, respiratory, or digestive abnormalities. The local river is poisonous. The water table contents are also undrinkable. A recent reduction of some coal furnaces has returned the air to levels that are technically habitable. The children of that region have 50% more lead in their blood than typical values. The Guiyu scavenging operation is not legal by Chinese standards, but the venture is so profitable that it continues to thrive. E-waste is sold to government organizations like Guiyu because they are the lowest bidders. The exports from the United States alone are substantial. In 2011, Americans disposed of about 130,000 computers and 300,000 cell phones every day.

A number of companies have instituted high profile hardware buyback or recycling programs where consumers can send their products back to the manufacturer for processing and reclamation. This is clearly a positive environmental and marketing move. Many of these same companies have also increased the amount of E-waste produced from their products. Mandated changes to use lead free solder has reduced the amount of harmful materials in the electronics device but has caused design and reliability problems. These problems may be increasing the total amount of E-waste. Additionally, the past 5-10 years has seen a dramatic increase in the "disposable electronics" mentality. Product lifecycles for phones, laptops, televisions, etc. have been reduced and the culture of early adoption forgoes environmental responsibility for the latest, greatest technologies. Manufacturers have fed into this culture of continuous change by designing obsolescence into their products by, for example, changing their car charger plugs so that consumers will have to buy all new accessories.

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Appendix C. The E-waste scoring check sheet (3f)

3f - Understanding of professional and ethical responsibility

Problem ID

- ☐ **Recycling** - breaking down E-waste makes the materials available for reuse but also can release harmful material if not handled properly.
- ☐ **Carcinogens** - Crushed E-waste contains carcinogenic agents that can contaminate ground water and are harmful if airborne.
- ☐ **Labor Cost** - It is cheaper to process E-waste in third world locations because of low labor costs and lack of regulation.
- ☐ **Design Changes** - A change to lead free solder was mandated to reduce the amount of harmful materials in E-waste, but lead free solder has been problematic in practice, resulting in more total waste.
- ☐ **Lifecycle Management** - Major electronic device companies have instituted recycling programs but are producing more E-waste from shortened product lifecycles and product modifications.

Stakeholders

- ☐ Consumers (computers, phones, tablets, laptops, MP3 players, televisions, monitors, printers)
- ☐ Manufacturers (OEM)
- ☐ Landfill operators
- ☐ Regulators
- ☐ Reprocessing organizations (management & workers)
- ☐ Residents of E-waste producing countries

Ethical Issues

- ☐ **Landfill Prohibitions** - While there are no federal laws, there are many state regulations that prohibit large producers of E-waste from landfilling.
- ☐ **Design Prohibitions** - Green certification of new products is often a plus in the marketplace but requires lifecycle management of hazardous materials
- ☐ **Expanding Role of Technology in Society** - Technology driven consumer culture has enabled electronics manufacturers to produce products with shorter lifespans.

Appendix D. The E-waste scoring check sheet (3h)

3h - Understanding of the impact of engineering solutions in global, economic, environmental, and cultural/societal contexts

Global Impact

- ☐ **Geographical Separation**- E-waste producers and re-processors are typically in different countries (as are the manufacturers.)

Economic Impact

- ☐ **Recycling Incentives** - There is economic incentive to recover materials from E-waste compared with extraction from natural sources.

Environmental Impact

- ☐ **Respect for Environment -** There is more focus on environmentally responsible manufacturing in first world vs. third countries.
- ☐ **Recycling Supply Chain** - Without proper infrastructure, recovery exposes workers and communities to high levels of water and air pollution.

Cultural/Societal

- ☐ **Disposal Mindset -** A society that accepts "disposable electronics" results in increased in E-waste.
- ☐ **Thirst for Innovation -** A society that expects innovation in electronics also promotes disposability.

Appendix E. The E-waste scoring check sheet (3j)

3j - Knowledge of contemporary issues

Technical Issues

- ☐ burning plastics
- ☐ lead free solder technical details
- ☐ hazardous materials in E-waste: mercury, sulfur, lead, BFR, cadmium, beryllium oxide, hexavalent chromium, PTFE
- ☐ non-hazardous materials: tin, copper, aluminum, germanium, silicon, iron, nickel, lithium, zinc, gold
- ☐ designed obsolescence vs. pure technological advancement
- ☐ recovery methods

Non-technical Issues

- ☐ Basel action network
- ☐ EPA oversight
- ☐ lead free solder laws
- ☐ international shipping
- ☐ wage differential
- ☐ E-waste recycling programs from manufacturers or third party networks importance of "green" company image