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## **AC 2012-3106: INTRODUCING CONTEMPORARY ISSUES TO ENGINEERING STUDENTS: A CASE STUDY MODULE**

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# Introducing Contemporary Issues to Engineering Students: A Case Study Module

## Abstract

This paper describes the implementation of a case study module in the area of ABET Student Outcome 3j: knowledge of contemporary issues. The module consists of a short (30-40 minute) in-class presentation and student group discussion on a single prepared case study, which is then followed by an untimed online quiz component featuring open-ended short answer questions about both the specific case study and to gauge broader student awareness of contemporary issues. Data is presented in this study from administering this module in 2010/2011 at a small Southwestern university where there had been identified deficiencies in student performance in 3j. The same module was employed there in courses at every level of the curriculum (freshman, sophomore, junior and senior: 120 students in total) and resulted in a strong turnaround in assessment results. The paper concludes with some suggestions for how instructors can develop successful modules using this framework and some discussion of student reaction and response to the module.

## Introduction

The challenges of finding suitable methods to assess student knowledge of contemporary issues are well-known to engineering educators. To begin with, there is the potentially ambiguous nature of what is meant by a “contemporary issue” in the assessment context. Considering that engineering departments can differ in their interpretations of what this term refers to, it is perhaps unsurprising that many students do not even recognize the meaning of this term<sup>1</sup>. The authors proceed in this paper using a broad but context-specific definition for “contemporary issues” defined as “ongoing or recent developments in the world relevant to the interests of engineers”. Once a definition has been established, the key challenge is then identifying suitable metrics to measure student knowledge and engagement in this area. The difficulty is compounded by the fact that few engineering courses have the time and flexibility to incorporate the newest developments in engineering education best practices. For many engineering departments, the teaching of contemporary issues is enigmatic with ill-defined boundaries and unsatisfyingly vague assessment criteria<sup>2</sup>. The requirement to assess ABET student outcome 3j is then either an exercise in creatively branding existing curricular practices or shoehorning a recycled presentation into some corner of the curriculum. This undermines the ‘contemporary’ part of contemporary issues and detracts from the level of engagement of the students in this area. There have been several recent suggestions for how to incorporate this material, ranging from introducing dedicated full courses targeting the so-called “professionalism” group of ABET outcomes<sup>3</sup> to building short modules for addressing 3j<sup>4-6</sup>. In the latter category, one can distinguish between those modules designed to be presented exclusively in a specific course with ties to that course’s content (course-specific) versus those modules which can be presented independently within any host course (course-agnostic).

In this work the authors propose a course-agnostic module that can be used for teaching and assessing material for outcome 3j and present the results from one engineering department that

used the module to produce a turnaround in assessment performance. The module makes it straightforward to integrate the discussion of contemporary issues into every year of the curriculum, requiring only a few hours of instructor preparation (ideally one assigned instructor per department per year, depending on the size of the student body) and a minimal investment of class-time (~30 minutes in any course that can accommodate it). It is suitable for students in any year of an engineering program. The module is based on an ASEE award-winning Engineering Professional Skills Assessment (EPSA) method<sup>6</sup> (Ater Kranov, et al. 2008). It employs a one-page case-study (ideally supplemented by some appropriate video content) followed by a brief guided student discussion in breakout groups. This session is followed by an untimed online quiz component consisting of open-ended short response questions that the students can complete at their leisure within a predetermined period and in consultation with any resources at their disposal. The quality of the responses and extent to which they show evidence of meeting 3j can then be assessed by the instructor using a self-developed rubric, an example of which is provided here.

The authors present data from the first implementation of this module in an engineering department with an identified deficiency in outcome 3j and demonstrate how the deficiency was resolved through this practice. The department in question had established (prior to this effort) two criteria for assessing outcome 3j and these are indicated in Table 1. The first (J1) can be broadly described as an awareness of goings-on in engineering both in the public-arena (e.g. high-profile successes or failures) and in the sense of being aware of some of the current research efforts in engineering sub-disciplines. The second (J2) is concerned with assessing whether the student is aware of the impacts and consequences (realized or potential) of current engineering-related efforts in a variety of contexts (e.g. political, economic, social...). Together these form a picture of both student awareness of issues and the impacts of those issues in the world. Of course, other departments may have their own sub-criteria developed for 3j, however as will be seen in this study, such a division between issues and impacts lends itself to using distinct sets of both broad-based and case-specific quiz questions.

<b>Outcome</b>	<b>Description</b>
J	Knowledge of Contemporary Issues
<b>Criteria</b>	
J1	Knowledge of contemporary issues in engineering/technology
J2	Knowledge of the impacts of contemporary issues in engineering/technology

**Table 1:** Criteria used by the subject university in assessing ABET outcome 3j. A distinction is made between awareness/knowledge of the issues (J1) and of their broader impacts (J2).

### **2010-11 Case Study: Lithium Mining for Li-Ion Electrical Vehicle Batteries**

For the first implementation of the module, the author selected and revised a case study from a list of prepared scenarios by Ater Kranov et al. (2008 & 2011) (Appendix B of [6]). The revised case study (presented here in Appendix A) describes the then-current (2010) state of electric vehicle production, the quantities of lithium involved in lithium-ion battery production, and the geopolitical aspects surrounding its mining and extraction from such locations as Bolivia. It

includes a small data table of facts and the sources of information used. The written case study was supplemented in class by a presentation of a BBC News segment<sup>7</sup> on the same topic.

**Presentation to the Students:** The department employing this module decided to assess outcome 3j at all levels of the curriculum in light of a previously identified deficiency. As a result, the module was presented in many different engineering courses regardless of the course subject. Students were informed of this fact and the presence of the case study in the syllabi for the selected courses, and a small participation grade was allotted to the study to retain student attendance on the scheduled days. The courses selected for the study at the institution are identified as i) a freshman design class teaching computer-aided design, ii) a sophomore introductory circuits laboratory, iii) a junior design class in controls and electronics, and iv) a senior capstone project class.

On the day of the module delivery, the case study was first introduced to students through a short presentation by the instructor assigned to this role during which the one-page case study was read aloud. It is also suggested to include a brief, relevant video clip of a key interview or news segment on the subject to supplement the text. Whenever possible, contrasting viewpoints by different stakeholders can also be expressed through the selection of video clips to elicit interest in the group discussion.

A well-constructed case study module should be presentable with little instructor preparation as it involves reading and viewing prepared materials. In the opinion of the authors, it is desirable for the instructor of this session to have some input in selecting the topic – this is in the hopes of adding to the enthusiasm and interest in the presentation delivery, since topics can be of personal interest to the presenter. The authors feel the benefits of this approach should be weighed against the possibility of introducing a bias into the assessment of the teaching of the module, however should this be a concern it can be mitigated by having a third-party grade the responses and perform the assessment according to the rubric developed for this task.

**Group Discussion Component:** Immediately following the presentation of the material to the students, a group-discussion takes place in which students are encouraged to sit in groups of 5-6 and a series of discussion-provoking questions or topics are read aloud by the instructor. Appropriate questions/topics for this discussion are generally geared towards a) helping the student identify their own opinion or feelings towards the issue, and b) having the students identify key stakeholders and their interests in the topic, and c) having them identify the unknowns that would merit investigation to delve further into the subject. This facilitates later online investigations during the online quiz component. Examples of discussion questions are available in Appendix B for the case study example presented here. Between each introduced question, students are given 3-5 minutes to discuss each topic amongst themselves. The instructor should encourage each group to see if there is a consensus and be present and actively monitoring and engaging with the students during the discussion, however there is no reporting out by the groups in this activity. The function of this time is to stimulate active discussion and learning rather than passivity in the face of a contemporary issue.

**Online Quiz Component & Assessment:** The online quiz component of the module consists of two distinct sets of open-ended short answer questions in an untimed format. In the first set of questions, the content is based on the subject of the case study. Instead of testing the recall of facts, the emphasis of this set of questions is on *identifying impacts/consequences and unknowns*

*in different scenarios* as was consistent with the sub-criteria J2 at the host university. In one example (Appendix C, question 1), the students are asked to consider how technological progress in electric vehicles would affect a diverse assortment of stakeholders, for example: a local utility company, the owner of a corner gas station, and the leader of Bolivia. Students are also probed on what they think are likely consequences of a *lack* of progress in electric vehicles in both obvious (e.g. environmental) and less obvious (e.g. political, cultural) arenas. Another question (Appendix C, question 4) challenges students to investigate a claim by an outside organization that was presented in the case study by identifying assumptions that were made about certain unknowns. All of these questions place the student in the role of “investigator” and require actively imagining scenarios, points of view and personal biases. Recall of facts is rejected in favor of the collection of information and creative synthesis of global knowledge. Questions emphasizing “impacts” or “consequences” are scored for criterion J2 according to evaluation rubric (Appendix D) developed in-house.

The second set of questions are designed to help assess the students’ general awareness of *what issues are currently confronting engineers both in a research context and in the public arena*. It includes such tasks as identifying current research papers and news articles on emerging technologies (providing working links to their sources and/or using proper citation style) as well as describing recent engineering failures/successes they are aware of. Several of these questions (Appendix C, questions 6, 8 & 9) target this knowledge by stimulating an investigation by the student into current affairs in research and the public domain. It is also possible to incorporate other ABET Student Outcomes here with questions on ethical practice, lifelong learning, and other facets of an engineering education. Scoring of this section should follow a rubric such as the one presented here for J1 (Appendix D).

### **Results of the Study in 2010/2011.**

The proposed module was implemented at a small Southwestern university in which the engineering department’s previous method of assessing 3j had revealed deficiencies in student performance. In the 2009-10 academic year, the department’s method of assessing this outcome was to give a 15-20 minute case-study presentation to the entire engineering student body at a general assembly and follow it immediately with an in-class comprehension quiz. Problems of attendance at the assembly, coupled with a general lack of enthusiasm by students and faculty towards this approach contributed to low scores and a low percentage of students meeting the criteria adequately. This percentage fell well below the 70% threshold established by the department for adequacy in J1 and J2 sub-criteria (Figures 1 and 2).

In the 2010-11 year, by contrast, the new module (incorporating guided discussion sessions and an online, open-ended and untimed quiz) was both presented and graded by a single appointed faculty member (also an author of the study) in individual courses where a 30-40 minute block could be found for it in each year of the four-year degree program. Thus, consistency in delivery and evaluation was assured. The class sizes ranged from 45 (freshman) to 20 (junior) and overall 118 students were presented the module and then assessed. The resulting performance of each class ranged from satisfactory (above 70%) to very good (above 85%) in both criteria.

It is important to mention that student responses to the overall format of the presentation and study were very positive, with some students asking if it could be done again sometime. During the group discussion, students were observed to be staying on-topic, and the discussion was

animated to the point that the presenter had to interrupt the students to push on to the next discussion questions. Some students later reported having found the online quiz too long at ten questions, and there seemed to be a wide range of reported times spent completing the quiz (most students took between 2-4 hours – some samples of student responses can be found in Appendix E). However, this did not seem to detract from the interest in the exercise. The presenter was approached the following year by curious students wishing to know the next case study topic.

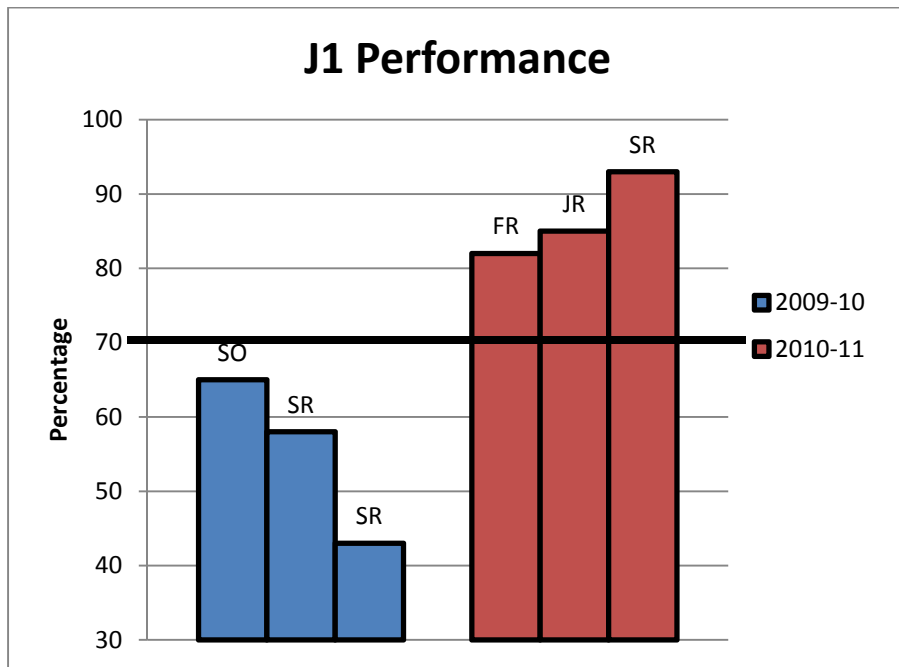
For the curious, the author and presenter at this institution has selected a 2011/2012 case study topic: an exploration of the budget of the National Aeronautics and Space Administration (NASA) in the context of modern public scrutiny of government spending. This is an issue at an intersection of politics, economics and engineering in a way that provokes an engaging discussion of priorities amongst students, with students requesting (in one case, offering) further data on the subject. Copies of this latest study can be obtained from the authors upon request.

### **Remarks**

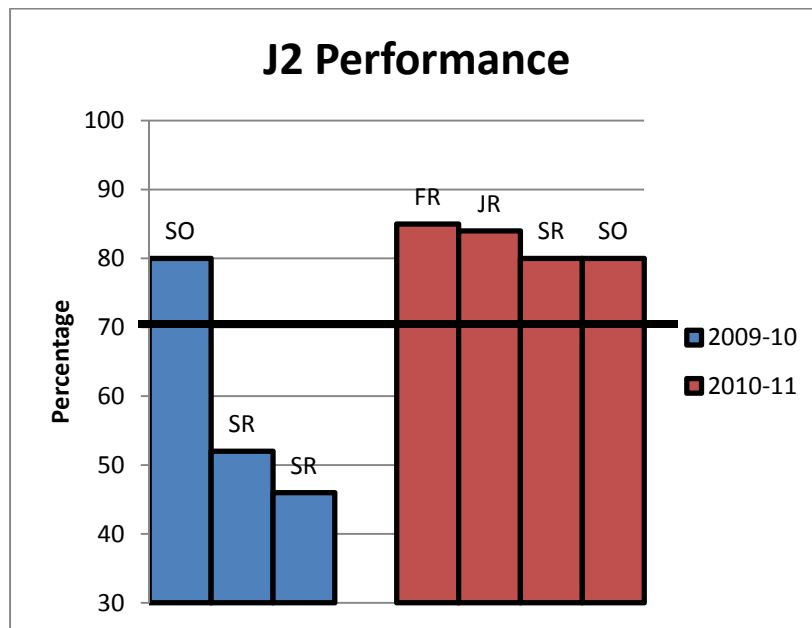
In order to transfer the approach presented in this study to other practitioners, there are a few considerations to be taken. It is certainly plausible, for example, for departments or institutions to share these modules. It is even conceivable that a centralized bank of accessible case-study modules could be established and made available for use, so long as they are updated at regular (2-4 year) intervals to reflect contemporary events. On the whole, the selection of a case study topic that is timely and interesting to both the instructor and the students is fundamental to delivering this module effectively. An instructor looking for inspiration to author such a module can draw topics from emerging technologies, public engineering successes/failures, or even other arenas as they intersect with the lives and careers of engineers (e.g. the federal budget allocation to NASA – too much, too little, or enough?). An engineering department need not farm this task out to instructors in every course, but rather can benefit from designating one instructor to handle the delivery and assessment of the module (where feasible according to the size of the student body). In this way, students and assessment both benefit from consistency, and the presentation delivery is refined. Each year, a new presentation should be created to keep things fresh and suitably “contemporary”, while those online quiz questions from the second set described here (the J1 set on general awareness of issues) may be re-used and refined from year to year. It is the hope of the authors that engineering educators will find this approach helpful in considering how best to incorporate the teaching and assessment of material in ABET Student Outcome 3j into their busy schedules.

### **Areas for Further Research**

It's important to note that the original EPSA method and tool have been successfully used across 10 programs college-wide at Washington State University for the last six years and that the method is currently being validated through a validity study sponsored by the National Science Foundation. As with any assessment method, it's critical that the method be a good fit for the context of the course, a program's resources, the faculty and the students. This pilot study was intended to serve as an initial adaptation of the existing EPSA method to address programmatic needs by embedding the method into a course. The program plans to use the method in other courses and course levels in the coming years in order to add depth to the existing data set for more robust analysis and interpretation.



**Figure 1:** Percentages of students meeting criterion J1 adequately or well based on assessment at a small Southwestern university before (2009-10) and after (2010-11) implementing the proposed module. The year of each sampling of student is indicated (Freshmen FR, Sophomore SO, Junior JR, and Senior SR). Sophomores in 2010 were not given the J1 portion of the quiz as it had yet to be developed at the time.



**Figure 2:** Percentages of students meeting criterion J2 adequately or well based on assessment at a small Southwestern university before (2009-10) and after (2010-11) implementing the proposed module. The year of each sampling of student is indicated (Freshmen FR, Sophomore SO, Junior JR, and Senior SR).

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## APPENDIX A

### **Lithium mining for lithium-ion electrical vehicle batteries**

#### **Scenario**

The US government is investing heavily in sustainable resource research and development in order to decrease national oil consumption, and automotive industries around the world are competing in a global race for “sustainable mobility”. There were about 52 million total vehicles produced in the world in 2009, and replacing a significant amount of them with highly electrified vehicles poses a major challenge. The state of California is targeting 1 million electric vehicles (EVs) on its streets by 2020. By that same date, Nissan forecasts that EVs will become 10% of all global sales.

Battery technology is currently the major bottleneck in EV design. In 2009, President Obama announced \$2.4 billion in grants to accelerate the manufacturing and deployment of next generation batteries and EVs. Lithium-ion batteries are the first choice for the emerging EV generation, (the Chevy Volt, the Volvo C30, the Nissan Leaf), because they feature high power density, manageable operating temperatures, and are relatively easy to recharge on the grid.

In spite of all its potential, lithium may not be the answer to the EV battery challenge. Lithium, which is recovered from lithium carbonate ( $\text{Li}_2\text{CO}_3$ ), is not an unlimited resource. Lithium-based batteries are already used in almost all portable computers, cell phones and small appliances. Utility-scale lithium-based energy storage devices are in the works for smart grid applications, such as balancing energy supply-demand fluctuations. Lithium is also extensively used in a number of processes we take for granted: the manufacturing of glass, grits, greases and aluminum, among others. This makes accurate estimations of future demand in relation to resource availability almost impossible. According to Meridian International Research, an independent renewable-energy think tank, there is insufficient recoverable lithium in the earth's crust to sustain electric vehicle manufacture based on Li-ion batteries in the volumes required by the mass market. Lithium depletion rates would exceed current oil depletion rates, potentially switching dependency from one diminishing resource to another. The United States Geological Survey reports that the Salar de Uyuni salt pans of Bolivia contain the largest untapped reserve of lithium in the world – an estimated 5.4 million metric tons or almost 50% of the global lithium reserve base. Other estimates put the Bolivian resource as high as 9 million metric tons. Bolivian president, Evo Morales, has consistently rejected bids by Mitsubishi and Toyota to mine lithium in his country and has announced plans to develop a state-controlled lithium mining operation. Prices of lithium carbonate ( $\text{Li}_2\text{CO}_3$ ) have more than doubled since 2004. Lithium batteries are costly, too – battery packs for vehicles cost upwards of \$20,000 alone, driving up the overall vehicle cost.

Lithium CAN be recycled, but there is very little existing infrastructure to do so. In 2009, a California company Toxco Waste Management received \$9.5 million in grants from the US Department of Energy to help build the first US-based facility for recycling lithium batteries in anticipation of demand.

**How much lithium is needed to power an electric vehicle?**

Energy requirements.....	16 kilowatt hours (specified for Chevy Volt)
Lithium estimates per kWh.....	0.431 kg (US Department of Transportation estimate)
Total lithium for one Chevy Volt.....	6.86 kg
Total Li <sub>2</sub> CO <sub>3</sub> for one Chevy Volt .....	36.5 kg
Total Li <sub>2</sub> CO <sub>3</sub> one million PHEVs .....	36,500 metric tons

**Sources**

US Department of Energy, Press Release (August 5, 2009)

The Trouble with Lithium: Implications of Future PHEV Production for Lithium Demand, *Meridian International Research* (2007)

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## APPENDIX B

### **Students Group Discussion Instructions**

Imagine that you are a team of engineers working together for a company/organization on the issue raised in the scenario above. Discuss what your team would need to take into consideration to address the issue.

You do not need to suggest specific technical solutions – just try to come to a consensus on what is the most important, and discuss stakeholders, constraints, impacts, and identify important unknowns.

Address each of the questions below:

### **Discussion Guidelines**

1. Identify the primary problems raised in the scenario. Try to identify at least three.
2. Identify related contemporary issues that are NOT directly addressed in the above, but are influenced by it significantly. List as many as you can.
3. Who are the major stakeholders in this issue, and what are their perspectives? Try to list three (bullet-point form).
4. Consider the following contexts: economic, environmental, cultural/societal, and political. What would be the potential impacts of replacing all or most road vehicles with Li-ion battery EVs in each of these contexts?
5. What are some important unknowns that seem critical to properly address the identified issues?
6. Who [or what] would your team need to consult to best address the problems you've identified? What indicators would tell you that these are valid resources?
7. What biases or assumptions do you need to consider in interpreting information from outside sources that you obtain on this scenario?

## APPENDIX C

### Online Quiz Questions

#### **LI-ION BATTERY SCENARIO**

- 1) Imagine that technological progress produces an EV popular enough that in 2020 25% of the cars in the world run on Li-ion batteries alone. Discuss, in a few lines each, the consequences and impact this would have from the perspective of:
  - a. A local utility (electric) company operating in a residential neighborhood
  - b. The American Foundation for the Blind
  - c. The leader of the Bolivian government
  - d. The owner of a corner gas station / convenience store.
  - e. An urban planner.
- 2) Imagine you are the CEO of a major automotive company in 2010 deciding how to invest your company's profits, and you are choosing between investing in building more traditional gas engines, improving the Li-ion battery, or attempting to find another alternative. What are the unknowns you would like to know to make the best decision? Discuss in 200 words or less.
- 3) Consider what would be the result if efforts to develop efficient, marketable alternative energy source vehicles are NOT successful in the long term. Identify (50 words or less each):
  - a. A political consequence on a global scale.
  - b. An economic consequence for a local business (choose any industry and explain your reasoning).
  - c. A cultural/societal consequence for a middle-class family.
  - d. An environmental consequence (global or local).
- 4) Meridian International Research suggested that lithium resources are in danger of being too limited to support a fleet of Li-ion vehicles. Investigate this claim: What assumptions were made in making this claim? What unknowns are involved?
- 5) Name one POSITIVE and one NEGATIVE environmental consequence of a lithium-powered car emerging as the preferred vehicle of choice in the future?

## GENERAL KNOWLEDGE QUESTIONS

For each of these questions, give short responses (between 50-100 words).

- 6) Describe a significant event that took place in the past two years which was predicated by an engineering safety failure. Describe the event and the failure responsible. For the sake of being original, don't choose the BP oil spill.
- 7) Imagine and describe a scenario in which an engineer is met with a conflict of interest while performing his job.
- 8) Identify a specific research challenge in any branch of engineering that is currently being researched. Locate a research paper on this challenge, cite it (any format) and describe the challenge it seeks to address. What issue does the research address that is relevant in society?
- 9) Locate a web-based news article on any new emerging technology, written by a reputable source (no "Bob's personal tech blog" please). Provide the URL to the article (verify that it works), and give an example of how this technology can have a social impact.
- 10) Industry is generally focused on "growth" of profits year after year. Recently, there has been increased discussion of "sustainability". Explain how these two perspectives can come into conflict, and give an example pulled from a current contemporary issue.

**APPENDIX D**

**Assessment Rubric**

**J1: Knowledge of contemporary issues in engineering/technology**

	<b>Does Not Meet</b>	<b>Meets Partially</b>	<b>Meets Adequately</b>	<b>Meets Well</b>
Contemporary Issues, J1	Students are unaware of current global issues of concern to engineers or the relevance of major research efforts	Some evidence of knowledge of current events but offering incomplete analysis, misidentifying certain actors/goals/failures involved	Students can identify major contemporary issues, and show understanding of the fundamental engineering issues involved.	Students can identify and link several contemporary issues to engineering and current research.
<b>Comments:</b> <b>-Assessment based on total responses for Q1, Q3 and Q5 of case study online quiz</b>				

**J2: Knowledge of the impacts of contemporary issues in engineering/technology**

	<b>Does Not Meet</b>	<b>Meets Partially</b>	<b>Meets Adequately</b>	<b>Meets Well</b>
Contemporary Issues, J2	Students do not consider the impacts of issues or demonstrate a poor understanding of the relationship between different spheres of impact (economic, political, societal, environmental...).	Some evidence of knowledge of impacts; causal connections between technology and stated impacts not made clear or only one context considered.	Students consider several impacts for a technology and show some understanding of more than one context.	Students demonstrate a good grasp of multi-faceted relationships in different contexts and consider positive and negative impacts of technological progress.
<b>Comments:</b> <b>-Assessment based on total responses for Q1, Q3, Q4 and Q5 of contemporary issues online quiz</b>				

## Appendix E

### Sample Student Responses

**QUESTION 1:** Imagine that technological progress produces an EV popular enough that in 2020 25% of the cars in the world run on Li-ion batteries alone. Discuss, in a few lines each, the consequences and impact this would have from the perspective of:

- a. A local utility (electric) company operating in a residential neighborhood
- b. Someone who works for the American Foundation for the Blind
- c. The leader of the Bolivian government
- d. The owner of a corner gas station
- e. An engineer working for the city planning the construction of a new suburban community far from downtown.

#### **SAMPLE ANSWER (SOPHOMORE STUDENT):**

a. A local utility owner would be concerned that their utility could not withstand the surge of electricity that would come with the increase in EV's. Yes, they would make more profit, but most likely, their utilities would not be able to support the demand for power during the night and other peak hours. Two hours of driving a day would require more than 25 kWhr; the average household uses 50 kWhr per day. The use of EV's would increase electrical uses two-fold.

sources from <http://www.pluginamerica.org/learn-about-plug-ins/frequently-asked-questions.html> and [http://wiki.answers.com/Q/How\\_much\\_electricity\\_does\\_an\\_average\\_2-story\\_3-bedroom\\_house\\_use\\_per\\_day\\_per\\_month\\_or\\_per\\_year](http://wiki.answers.com/Q/How_much_electricity_does_an_average_2-story_3-bedroom_house_use_per_day_per_month_or_per_year)

b. Someone who works for the American Foundation for the Blind might be opposed to an increase in EV's because electric vehicles are quieter than cars using gas, which poses a hazard to blind people who rely on their hearing to cross streets and parking lots.

c. The Bolivian Government would be split between those who want to make a profit by exploiting the lithium and those who want to protect the natural environment. Also, the government would have to consider the losses associated with the decrease in tourism that would follow if they allow drilling in the Salar de Uyuni and the corresponding economic problems for citizens who make a living by selling crafts to tourists.

d. An owner of a corner gas station would not be keen on the idea of an increase in EV's because less people would buy gas and their profit would dramatically go down due to the decrease in demand. A gas station owner would have the possibility of going out of business.

e. The civil engineer would be concerned about whether most people living in the community would be commuting downtown, increasing the demand for electricity, further complicating the process of charging cars during peak hours.

#### **SAMPLE ANSWER (SENIOR STUDENT)**

a. The local utility would greatly benefit from the increase in EVs throughout the world. With increasing EVs, the homes would require electrical recharge stations and the energy needs of each household would significantly increase bringing the local company larger profits.

b. Since electric cars are significantly quieter, this person would have to investigate ways to assure the safety of blind pedestrians in areas with traffic.

c. The leader of the Bolivian government would be under a lot of economic and political pressure to allow drilling of the lithium reserves to occur. If he gave in, it would potentially help his country develop economically, but it could create negative consequences for his country's environment.

d. The requirements for gas would begin to decline, so the corner gas station owner would see decreasing profits. He could potentially be forced to close the station as many small corner gas stations would inevitably have to do unless he was able to cope with the change by installing new recharge stations.

e. The engineer would have to consider the electricity needs of the community. It would be necessary that he adequately provide electricity lines from the main city.

**QUESTION 6:** Describe a key event that took place in the past two years which was predicated by an engineering safety failure. Describe the event and the failure responsible.

**SAMPLE ANSWER (JUNIOR STUDENT):**

A quite recent engineering failure was the collapse of the mine in which 33 Chilean miners were trapped for weeks on end. Clearly, there was some sort of failure in the mine itself which caused the cave-ins. However, the more significant failure as far as the miners are concerned was the failure to completely install the ladders in the emergency exit shafts. Had these ladders been properly installed, the miners would have been able to escape from the mine without the extended wait or complicated extraction process. The failure, then, is on the part of the engineers or the mining company which disregarded safety requirements for emergency exits and thereby endangered many lives.

**SAMPLE ANSWER (SENIOR STUDENT):**

In May 2010, in Boston, a large 3m diameter water pipe ruptured spilling its contents into the Charles River. This caused the clean water supply to be cut off and water from local ponds had to be rerouted. This caused contamination concerns and required a boil-water command throughout the Boston area. Engineers repaired the pipe the next day fixed the water pressure in the system.