

Exploring the Range of Methods Used to Assess Engineering Students' Education on Ethical and Societal Impact Issues

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Abstract—This Research to Practice Full Paper explores the methods that are used to assess the outcomes of course-based instruction on ethical and societal impacts (ESI) for engineering and computing students. This investigation is centered around instructors of ESI and targets four research questions: (1) how satisfied are instructors with their ability to assess the outcomes of ESI instruction; among individuals satisfied with ESI assessment do these assessment methods vary among (2) course type, (3) ESI teaching methods, and (4) ESI topics. Data were gathered via two online surveys resulting in 1,448 responses. Most respondents were somewhat satisfied with their ability to assess the outcomes of ESI instruction in their course. In capstone design courses, group-based written assignments were the most commonly used for ESI assessment. Assessment-satisfied instructors who used the two most frequently reported ESI teaching methods, case studies and in-class discussion, most often used individual reflective essays as an assessment method. Instructors who taught the most frequently reported ESI topic, professional practice issues, most frequently used individual assignments graded with a rubric. Discussion of these results focuses on strategies for increasing satisfaction with assessment of ESI in engineering education including alignment of assessment with topics, course types and teaching methods.

Keywords—*ethics education, assessment, macroethics, societal impact*

I. INTRODUCTION

Systematic assessment planning can be an important educational component for achieving desired student outcomes [1]. One specific set of important outcomes of an engineering education are those specified in the newly revised ABET criteria [2]. Among these criteria, Criterion 3 Outcome 4 is the focus in this paper, which targets, “an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider

the impact of engineering solutions in global, economic, environmental, and societal contexts.” This outcome is related to the current investigation on the education of engineering students on ethical and societal impacts (ESI). ESI outcomes are considered critical competencies for professional engineers, yet research has suggested that there is a limited body of knowledge on the impact of ESI instruction on engineering students [3]. Thus, tools to assess ESI educational effectiveness are essential and ESI education is explored in this paper through the lens of assessment. Specifically, the study is concerned with instructors of ESI and their satisfaction with their ability to assess the outcomes of ESI instruction and the range of assessment methods instructors used for specific ESI teaching methods and topics along with various course types that integrate ESI.

The results of this investigation provide ESI instructors with some ideas about the need to use multiple assessment methods and satisfaction with ESI assessment. The results also provide ESI instructors with the most frequently used assessment methods for different ESI teaching methods, topics and course types. This could be useful for new instructors of ESI or instructors who wish to learn more about the practices of other instructors.

II. BACKGROUND

Outcomes assessment has been broadly emphasized in engineering education since the advent of ABET's EC 2000 and the specification of educational outcomes known as Criterion 3, A-K [2]. Of these, Criterion 3, f “an understanding of professional and ethical responsibility,” led to the proliferation of a number of assessment tools designed to measure this outcome. In their review of ethics engineering education literature, Hess and Fore explored 26 articles and characterized eight types of quantitative assessment strategies

and four types of qualitative assessment strategies [3]. Assessment was also included as a component of ethics education exemplars in the National Academy of Engineering's report, *Infusing Ethics into the Development of Engineers: Exemplary Education Activities and Programs* [4]. Despite the attention and designation of exemplars, assessment was rated as the weakest element of ESI exemplars in one study [5].

ESI assessment employs a variety of assessment tools. According to Hess and Fore, one common qualitative ESI assessment tool employed in ESI instruction is the course evaluation where students provide open-ended feedback on ethics curricula contained in a course [3]. One example is the senior thesis at the University of Virginia where students complete a thesis on the ethical and policy issues associated with a technical project as part of a class. The authors state that course evaluations provide short-term immediate feedback [4].

Another type of ethics education assessment tool is based on students' ability to use moral judgement to respond to case studies depicting typical engineering ethics scenarios in a professional setting. An example of this type of tool is the Engineering and Science Issues Test (ESIT) where students' responses can be scored to determine a specific level of ethical reasoning from preconventional to postconventional [6].

Another case study based tool is the Engineering Professional Skill Assessment (EPSA) developed specifically to target ABET professional skills contained in the A-K outcomes [1]. This tool has groups of students discuss common engineering scenarios and employs a rubric tied to the ABET outcomes used to evaluate students' responses in real time. The Pittsburgh-Mines rubric represents yet another case-based ethics assessment tool [7].

Student perceptions of impact and reflective essays are two additional tools employed in ESI interventions. Tips for designing and implementing both of these tools were provided by the Engineering Projects in Community Service (EPICS) program [8]. Other studies have suggested a range of assessment tools to assess professional outcomes such as test questions and team ratings [4].

Fewer studies have investigated instructor satisfaction with ESI assessment and useful association of ESI assessment tools with diverse pedagogy and course types as well as ESI topics, which is the goal of the present study.

To that end, the current investigation specifies four research questions:

- RQ1: How satisfied are instructors with their ability to assess the outcomes of societal context and/or ethics instruction in courses for engineering and computing students and does satisfaction vary with the number of assessment methods used?
- RQ2: From among those who are satisfied with their ESI assessment, do the assessment methods for ESI learning by students vary by course type?
- RQ3: From among those who are satisfied with their ESI assessment, do the assessment methods for ESI instruction in courses for engineering and/or computing

students vary with the ESI teaching methods used in the courses?

- RQ4: From among those who are satisfied with their ESI assessment, do the assessment methods for ESI instruction in courses for engineering and/or computing students vary with the ESI topics taught by the instructor?

III. METHODS

The data for the study were gathered via two online surveys, generating 1,448 responses and using methods approved by the Institutional Review Board for Human Subjects Research at the University of Colorado Boulder [9]. Invitations to the survey were distributed via email to members of four divisions of the American Society for Engineering Education (ASEE): engineering ethics; liberal education & engineering and society; community engagement; educational research and methods. Invitations to the survey were also emailed to the faculty mentors of university student chapters of the American Society of Civil Engineers (ASCE), American Institute of Chemical Engineers (AIChE), AIAA, and Engineers Without Borders-USA. Also invited were individuals who authored papers on engineering and computing ethics education, NSF grantees on engineering ethics education, the Principal Investigators of NSF-sponsored REU sites with an engineering component, and mentors of co-curricular groups.

Among 1,448 responses to the survey, 1,184 described their satisfaction level with assessment of ESI learning outcomes. These individuals each described a course where they believed they were most effective in teaching ESI. The respondents included individuals primarily teaching at public (72%) and doctoral-awarding institutions (79%), in tenured/tenure-track positions (81%). The respondents taught a range of engineering and computing disciplines (civil 24%; mechanical 22%; computer 17%; electrical 13%; environmental 13%; chemical 12%; biomedical 10%; individuals could indicate multiple disciplines that they taught), and were over-represented in women (33%). There were only a small number of the survey respondents, 118, who rated their assessment satisfaction for ESI in a second course. In total, ESI assessment satisfaction and teaching methods were described for 1,302 courses.

The survey questions used to answer the research questions posed in this study were the same on both surveys, just presented in a different order on the survey. The survey presented a list of 19 ESI topic options and asked individuals to indicate which of the topics they taught in their courses. Topics included:

- Bioethics
- Engineering and poverty
- Engineering code of ethics (e.g. NSPE)
- Engineering decisions in the face of uncertainty
- Environmental protection issues
- Ethical failures / disasters

- Ethical theories
- Ethics in design projects
- Nanotechnology ethics
- Privacy and civil liberties
- Professional practice issues
- Responsible conduct of research
- Risk and liabilities
- Safety
- Social justice
- Societal impacts of engineering and technology
- Sustainability and/or sustainable development
- War, peace, and/or military applications of engineering
- Other topic(s) related to social and ethical issues (identify)
- No topics related to the societal impacts of technology or ethics

The instructors who indicated one or more ESI topics were then asked to “think about the ONE course in which you believe you most effectively teach engineering and/or computing students about the societal impacts of technology and/or ethics.” They were asked to name the course and select one of four descriptors for the course (required undergraduate, elective undergraduate, required graduate, elective graduate). Undergraduate courses were asked to provide an additional descriptor (e.g. first year introductory, full course on ethics). The survey taker was then asked to indicate the methods used to teach ESI in the course, selecting all that apply from among 16 options. These ESI teaching methods included:

- Case studies
- Engineering design
- Examples of professional scenarios
- Guest lectures (e.g., philosophers, social scientists)
- Humanist readings
- In-class debates and/or role plays
- In-class discussions
- Lectures
- Moral exemplars
- Problem solving heuristics

- Project based learning
- Reflection as an assignment
- Service-learning, community engagement, and/or learning through service
- Think-pair-share
- Videos, movie clips
- Other(s) [fill in]

This was followed by a prompt to identify all of the methods that were used to assess the outcomes from ESI instruction, selecting from among the following ten options:

- Group-based written assignment
- Individual critical and/or personal reflective essays
- Individual homework assignments where questions have fairly straight forward right and wrong answers (similar to Fundamentals of Engineering type questions)
- Individual homework assignment, essay, and/or papers that are graded with a rubric
- Individual standardized assessment method (DIT, EERI, ESIT, or similar)
- Survey
- Team rating
- Test and/or quiz questions
- Other (describe)
- Do not assess these learning outcomes

Finally, individuals were asked “in general, how satisfied are you with your ability to assess the outcomes and societal context and/or ethics instruction in this course”, with rating options on a Likert-type scale from 1 (very dissatisfied) to 7 (very satisfied). Individuals were then given the opportunity to describe a second course where they taught ESI to engineering and/or computing students. The survey concluded with a series of demographic items. The ESI assessment methods, ESI teaching methods, and ESI topics were binary variables (yes/no). Statistical tests and data modeling were conducted in SPSS version 24.

IV. RESULTS

A. *RQ1. ESI Assessment Satisfaction*

Satisfaction with ESI assessment varied across the respondents, as shown in Figure 1.

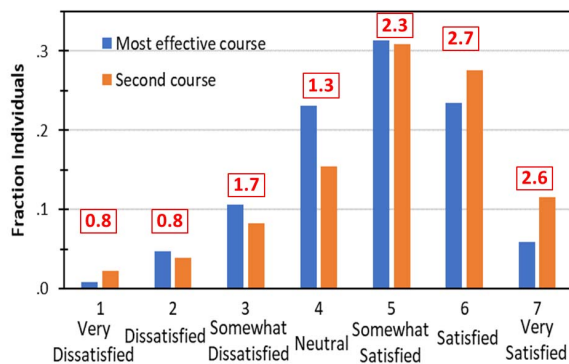


Figure 1: Range of ESI assessment satisfaction responses with number of assessment methods used by level of satisfaction.

Most respondents were somewhat satisfied (5 out of 7) with their ability to assess the outcomes of ESI instruction in their course.

The total number of assessment methods (from among 9 options) that respondents indicated they used in the courses where they believed that they were the most effective for ESI education varied from none (not assessed) to 8, with a median of 2. There was a moderate relationship between the total number of ESI assessment methods used and satisfaction with ability to assess ESI teaching outcomes in the course as indicated in Figure 1. For example, those who rated their satisfaction with assessment as 1 and 2 used an average of 0.8 ESI instructional assessment methods in their course; those rating their assessment satisfaction as 6 used an average of 2.7 ESI assessment methods.

It appeared that those willing to report an “other” ESI assessment method likely found that method particularly meaningful. “Other” ESI assessment methods written in by those who rated their assessment satisfaction at 6 or 7 were:

- Student oral presentations (some were specifically noted to be group oral presentations, in other cases unclear; rubrics mentioned in many cases; n=24)
- Project work (rubrics commonly mentioned and/or feedback from clients or communities; n=18)
- Student contributions to class discussion (rubrics mentioned for some; n=8)
- Online blog posts / discussion board contributions (n=3)

Individuals also wrote-in “other” responses that the research team considered to be encompassed within the eight assessment method options provided. For example, one comment was “peer assessment of contributions to group assignments”, which was the intent of the “team ratings” option. Another wrote “self-reports via survey”, which should have been included under the “survey” option. Term papers and written reports (n=10) were expected to be included among individual homework assignments graded with a rubric or group-based written assignments. Thus, the nomenclature used on the survey itself may have been interpreted differently by various respondents.

The results imply that using about three different methods to assess student learning of ESI is a best practice, and that the strongest methods may be a unique fit to particular instructor goals. Among those satisfied or very satisfied with ESI assessment (6 or 7) in the course where they believed they were most effective in ESI education (n=332), the most commonly used assessment methods were individual homework assignment, essay, and/or papers that are graded with a rubric (55%) and individual reflective essays (52%). Rubrics were also mentioned in the “other” assessment write-in responses (n=10). The team-based assignments may often be project or group reports.

B. RQ2. Assessment Methods Compared to Course Types

For Research questions 2-4, courses were only included in the analysis when instructors were satisfied with their ability to assess the ESI course learning outcomes in order to assist other instructors who would like to adopt results that were satisfactory for instructors. There were 810 courses described by 698 individuals where the satisfaction level with the ability to assess the outcomes of ESI instruction was at least somewhat (rated 5 or higher).

Research Question 2 addresses both the average number of assessment methods used by course type and the assessment tools most frequently used represented as a percentage. Results (summarized in Table I) indicated that graduate level courses were the most frequently described type of course. Full ethics courses include the largest average number of assessment methods while capstone design courses included the fewest. This is logical given differences in the percentage of these courses that focuses on ESI. Full ethics courses also had the highest consensus on choice of assessment method with 81% choosing individual reflective essays as the assessment tool.

Across all 810 course types the most common assessment methods were individual homework graded with a rubric (50%) and individual reflection (47%); these methods were the most frequently used in the majority of course types. Individual homework assignments graded with a rubric were the least common in capstone design (35%). Individual reflections were much less commonly used in engineering/engineering science courses (33%). Group-based written assignments were the most commonly used in design-focused courses beyond the first-year (and also used in 48% of first year design courses). Test/quiz questions were used in 44% of all course types, but only the most prevalent in first-year introductory courses.

ESI assessment methods that were not used as frequently included individual homework assignments with fairly straight-forward right/wrong answers (most prevalent in engineering / engineering science courses at 26% vs. 19% among all courses), team ratings (most common in capstone design at 34% vs. 18% among all courses), surveys (most common in first year design at 23% vs. 13% among all courses), and individual standardized assessment methods (most common in ethics courses at 8% vs. 2% among all courses).

TABLE I. MOST FREQUENTLY USED ASSESSMENTS FOR ESI COURSE TYPES

Course Type	N courses	Most Frequently Used Assessment Method		
		Avg # assmt methods	Assessment Method	% Using Assessment Method
Graduate-Level	181	2.5	Individual Homework Rubric	50
			Individual Reflective Essays	50
Capstone Design	133	2.2	Group-based Written Assignment	51
Eng/Eng Science, Sophomore-Junior	123	2.3	Individual Homework Rubric	54
Design-Focused, Sophomore-Senior	111	2.5	Group-based Written Assignment	50
First Year Introduction	86	2.5	Test/Quiz Questions	52
Professional Issues	85	3.0	Individual Homework Rubric	69
Ethics	48	3.4	Individual Reflective Essays	81
HSS	40	3.1	Individual Homework Rubric	80
First Year Design-focused	31	2.6	Individual Homework Rubric	55
			Individual Reflective Essays	55
Other	28	2.3	Individual Reflective Essays	50

C. RQ3. ESI Assessment Methods Compared to Teaching Methods

Different teaching methods might target different levels of knowledge, reasoning, or attitudes about ESI, and different assessment tools are likely to align better with these goals. Results are presented for the ESI assessment tool most frequently used by instructors in Table II.

The most frequently used ESI teaching method, case study, was most often paired with the use of individual reflective essays as an ESI assessment method. The individual reflective essay was also the method most strongly associated with the largest number of teaching methods. Notably, individual standardized assessment tools such as the ESIT were not the most frequently used tools for any method with these standardized tools only used by 14 respondents.

For assessment methods that were not as commonly used overall, better alignment with some teaching methods was observed. Individual homework with right/wrong answers aligned primarily with problem solving heuristics (27%), team ratings aligned with service-learning (35%), and text/quiz questions aligned with lectures (54%), videos/movies (54%), and problem solving heuristics (53%).

TABLE II. MOST FREQUENTLY USED ASSESSMENTS FOR ESI TEACHING METHODS

Teaching Method	N Using Teaching Method	Most Frequently Used Assessment	
		Assessment Method	% Using Assessment Method
Case Study	586	Individual Reflective Essays	53
		Individual Homework Rubric	53
Discussion	582	Individual Reflective Essays	54
		Individual Homework Rubric	54
Lecture	559	Individual Homework Rubric	55
		Test/Quiz	54
Professional Scenarios	500	Individual Homework Rubric	55
		Individual Reflective Essays	54
Design	347	Group Written Assignment	51
		Individual Homework Rubric	49
Project Based Learning	347	Group Written Assignment	58
Video, movie clip	265	Individual Reflective Essays	62
		Individual Homework Rubric	59
Guest Lectures	262	Individual Reflective Essays	60
Reflection as an Assignment	250	Individual Reflective Essays	77
Debate / role plays	209	Individual Reflective Essays	70
Problem Solving Heuristics	133	Individual Reflective Essays	64
		Individual Homework Rubric	62
Think-Pair-Share	122	Individual Reflective Essays	69
Service Learning	119	Individual Reflective Essays	61
		Group Based written assignment	57
Humanist Readings	105	Individual Reflective Essays	80
Moral Exemplars	91	Individual Reflective Essays	68

D. RQ4. Do ESI assessment methods vary by ESI topics?

Among the individuals satisfied with their ESI assessment, the type of assessment tools used differed somewhat based on what ESI topics were taught (See Table III). The most frequently taught topic that was associated with an assessment tool was professional practice issues taught by 562 respondents and associated with individual reflective essays as an assessment tool. Similar to the previous section on ESI teaching methods, individual reflective essays were most frequently the strongest associated tool across topics. Here

TABLE III. MOST FREQUENTLY USED ASSESSMENT METHODS FOR ESI TOPICS

ESI Topic	N Teaching Topic	Most Frequently Used Assessment	
		Assessment Method	% Using Assessment Method
Professional Practice Issues	562	Individual Homework Rubric	52
Societal Impacts of Technology	529	Individual Reflective Essays	55
Code of Ethics	455	Individual Reflective Essays	53
Ethical Failures	451	Individual Reflective Essays	55
Safety	451	Individual Homework Rubric	52
Engineering Decisions Under Uncertainty	450	Individual Reflective Essays	53
Sustainability/Sustainable Development	438	Individual Homework Rubric	54
Ethics in Design	402	Individual Reflective Essays	53
Safety	385	Individual Homework Rubric	52
Risk & Liabilities	351	Individual Homework Rubric	53
Environmental Protection	350	Individual Homework Rubric	55
Responsible Conduct of Research	293	Individual Reflective Essays	52
Ethical Theories	265	Individual Reflective Essays	63
Engineering & Poverty	175	Individual Reflective Essays	67
Social Justice	211	Individual Reflective Essays	66
Privacy & Civil Liberties	148	Individual Reflective Essays	66
War, Peace, and/or Military Applications	105	Individual Reflective Essays	63
Bioethics	83	Individual Reflective Essays	63
Nano-technology Ethics	52	Test/Quiz Questions	56

again, standardized assessment tools were not the most frequently chosen tool for any topic.

There were a number of assessment methods that were not commonly used in general (and not shown in Table III), but were somewhat more prevalent among individuals who taught particular ESI topics. Group-based written assignments were used by 50% of those who taught poverty-related issues and among 47% of those who taught ethics in design and risk and liabilities. Team ratings were used as an ESI assessment method among 26% of those who taught poverty-related issues and 24% who taught about war, peace, and/or military applications. Individual homework assignments with right/wrong answers were used by 25% of those who taught nanotechnology ethics and 23% of those who taught bioethics and environmental protection issues. Surveys were used to assess ESI instruction among 23% of those who taught

nanotechnology ethics. Individual standardized assessment methods were not commonly associated with any of the ESI topics; the highest was 5% of those who taught bioethics and 4% of those who taught ethical theories.

V. DISCUSSION

It is important that appropriate and robust methods are used to assess the outcomes of ESI education of students. These methods are likely to vary based on the specific learning goals for ESI education within the course, including the levels of knowledge, skills, or attitude outcomes. This research identified assessment methods for ESI that are more frequently used among those satisfied with their ESI instruction as well as specific assessment tools most often paired with specific ESI course types, teaching methods and ESI topics. However, a limitation in the results is that the majority of individuals used multiple ESI teaching methods and multiple ESI assessment methods in their courses, therefore individual associations are confounded. Similarly, the survey only identified ESI topics that an individual taught in any course setting. Thus, ESI assessment methods within a particular course may or may not be used to assess student learning related to a specific ESI topic. Binomial logistic models were used to account for confounding factors when identifying associations between ESI assessment methods and ESI topics and teaching methods (data not shown). However, presenting the results in that manner was believed to be confusing to many readers.

A. Patterns Across Results

One pattern apparent across results is that there are few instructors (n=14) using standardized ESI assessment tools. This may result from lack of knowledge of available tools or the desire to customize tools to specific teaching methods and topics. This lends increased weight to the notion of instructors' desires to customize ESI assessment tools to their specific learning goals in various courses.

Another pattern demonstrated a different number of assessment tools used on average in different course types with full courses on ethics applying the most assessment methods. This could indicate that assessment of ethics has varying importance in different types of courses.

A third pattern apparent across results is the high frequency of individual reflective essays across multiple ESI teaching methods and topics. However, reflections as an assessment method should not be viewed as uniformly strong. Among 343 courses using one or more ESI assessment methods where instructors were neutral or unsatisfied with assessment, individual reflections were the most commonly used assessment method (used in 38% of the courses). In 57 courses using individual reflection for ESI assessment, instructors were dissatisfied with their ability to assess ESI (rated 3 or lower on Likert-type scale). Thus, the quality of reflection prompts and methods used to assess these open responses vary significantly. Novices should seek out effective reflection prompts and assessment methods. While these may need to be adapted to specific courses and goals, creating

these without careful consideration is not guaranteed to be satisfactory. Instructors who would like to delve deeper into the construction of reflective tools and view an example targeting service learning should see this reference [10].

Similar cautions are associated with using individual homework graded with a rubric for assessment of ESI learning. This was the most prevalent ESI assessment method in the 810 courses where individuals were satisfied with their ESI assessment (used in 404 courses) and the second-most prevalent method of ESI assessment in courses where assessment satisfaction was neutral or dissatisfied (35% of 343 courses using 1 or more ESI assessment methods). There were 53 courses where rubrics were used to assess individual homework assignments (and potentially additional methods) that were dissatisfied with ESI assessment. Again, both the quality of the assignment itself and the nature of the assessment rubric may vary. Those instructors desiring to learn more about validity in rubric construction should investigate this reference [11].

Previous research also indicates that individuals likely differ in the level of ESI assessment that they believe to be adequate and satisfactory. For individuals with modest expectations for ESI learning sophistication among their students, finding satisfactory assessment methods might be comparatively simple. Some individuals may be satisfied with students being able to correctly answer multiple-choice type questions similar to those on the NCEES Fundamentals of Engineering Exam. Others may wish students to develop sophisticated moral and ethical reasoning abilities in complex situations with diverse societal and environmental impacts. Assessing these deeper learning outcomes is likely to pose greater challenges. Different opinions on the robustness of ESI assessment quality by ESI educators has been identified in other research [12].

B. Implications and Future Research

The implications of these results include the idea that divergent ESI assessment methods are used more or less frequently by ESI instructors depending on applications of different ESI teaching methods, course types, and topics. These results could be useful to new ESI instructors or current ESI instructors who are interested in finding out about the assessment practices of colleagues. This can be especially important for instructors who are the only person to teach ethics at their institution.

Given the results indicating desire to customize assessment tools, future investigation should explore the motivations behind these choices. Research questions could explore whether instructors are happy implementing self-designed tools or whether instructors might benefit from workshops and other trainings to teach the development and validation assessment tools. Future research for the present investigation includes plans to explore additional workshops in these areas after piloting an ESI assessment training at an ASEE regional conference [13].

Future research could also explore the low reported usage of standardized ESI assessment tools. Validated assessment tools imply considerable investment in their development. If research results indicate low motivation to use these validated tools, perhaps future investment in their development should be curtailed. Future research could also explore the impact of revised ABET outcomes on the development of ethics assessment tools. For the authors of the current paper, future research will be focused on qualitative interviews of ESI instructors.

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