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Assessment Instruments for Engineering Ethics Education: A Review and Opportunities

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Abstract

Assessment plays an important role in education, and there is no exception in engineering ethics education. However, although there have been efforts to evaluate students' learning in engineering ethics classrooms, relatively limited efforts have been made to utilize valid and reliable assessment instruments to evaluate students' achievement of learning objectives in engineering ethics education. It may be partly due to the limited number of instruments specifically designed for engineering ethics education. In this paper, we report our review of the papers that have reported the development and validation study of assessment instruments for engineering ethics interventions. We searched for papers published in representative journals and conference proceedings in the field of engineering education and engineering ethics. As a result, eight different assessment instruments specifically designed for engineering contexts have been found. We found that the majority of the papers reported an individual-level assessment instrument, which aims at measuring individual students' qualities or characteristics. We also found a change in the trend in the subject of the assessment instrument. While the early efforts in developing assessment instruments focused mostly on assessing engineering students' reasoning skills, more recent publications introduce assessment instruments designed for measuring students' attitudes or qualities related to broader societal considerations, such as social responsibility and community engagement, as well as diversity and inclusion and social justice considerations. Based on the review, we briefly discuss opportunities in the new assessment instrument development effort.

Introduction

Assessment plays an important role in education and has been emphasized within the community of engineering education research [1]. There has been no exception in engineering ethics education. To evaluate the effectiveness of engineering ethics interventions, engineering educators have utilized various assessment strategies. Based on their review of the literature, Hess and Fore [2] identified that engineering educators have utilized both quantitative and qualitative strategies to evaluate the effectiveness of their educational interventions: Some common quantitative assessment strategies included collecting student perceptions of the effectiveness of the educational interventions through course evaluation surveys. Some common qualitative assessment strategies included collecting students' course evaluations which have their reflections on learning gains.

However, although there have been such efforts to evaluate students' learning, relatively limited efforts have been made to utilize valid and reliable assessment instruments to evaluate students' achievement of learning objectives in engineering ethics education. The Defining Issues Test (DIT) has been used for some empirical studies to assess students' general moral reasoning skills [3]-[5], but it has not been properly contextualized in engineering contexts [6]. Therefore, studies to develop and validate assessment instruments for engineering ethics education interventions are necessary to better assess students' learning outcomes.

Indeed, to fulfill these needs, there have been studies to develop assessment instruments. This paper aims to provide a common ground for engineering ethics researchers about existing assessment instruments in engineering ethics and identify potential opportunities in new assessment instrument development. We reviewed papers that reported the development and validation study of assessment instruments for engineering ethics interventions, published in representative journals and conference proceedings in the field of engineering education and engineering ethics. Based on the review, we discuss opportunities in the new assessment instrument development effort.

Review of Engineering Ethics Assessment Instruments

We searched for literature that introduced the development and validation study of assessment instruments for engineering ethics education, from two engineering education journals (*Journal of Engineering Education* and *International Journal of Engineering Education*), one engineering ethics-related journal (*Science and Engineering Ethics*), and the proceedings of the ASEE (American Society for Engineering Education) conference, the largest and representative conference for engineering education. We did not include *Advances in Engineering Education* in our search, considering the scope of the journal that focuses more on disseminating innovative engineering education practice.

For the *Journal of Engineering Education*, we initially searched for articles that include the keywords, (ethics OR social responsibility) AND (assessment) AND (validation) anywhere in the article published between 2000-2023. The initial search resulted in 158 articles but after screening the articles with titles and abstracts, 7 articles remained as potentially relevant papers that report a study of development and validation of an assessment instrument for any ethics-related learning outcomes (broadly defined, including professional skills). Among those, only one paper [7] reported an instrument (Engineering Professional Responsibility Assessment Tool (EPRA)) that was specifically designed for assessing the outcomes of engineering ethics and social responsibility education, so we decided to introduce their study in this paper.

For the *International Journal of Engineering Education*, we used a very similar procedure and searched for articles that included the keywords, (ethics OR "social responsibility") AND (assessment) AND (validation) anywhere in the article. Since there was no function to set the publication date on the journal website, every article published since 1991 was included in the search results. After screening the articles with titles and abstracts, eight articles remained as potentially relevant papers, and those articles were all published after 2000. Among those, two papers reported newly developed instruments for ethics-related outcomes with validity evidence: Hess et al. [8]'s Civic-Minded Graduate Scale (CMG) and Rambo-Hernandez et al. [9]'s Valuing

Diversity and Enacting Inclusion in Engineering Scale (VDEIE). We introduce those studies in this paper.

For the journal *Science and Engineering Ethics*, we searched for articles published between 2000-2023 with the keyword "engineering ethics assessment instrument." We used a different search strategy because the scope and audience of the journal were different from the other journals and the conference proceedings we explored for this paper. The initial search showed 229 articles, and after screening the articles with titles and abstracts, five articles remained. While reviewing the five articles more carefully, we excluded two articles because they reported measures specifically designed for research ethics [10],[11]. Finally, we found only three articles (two of which are for the same measure) reporting newly developed instruments for ethics-related outcomes with some validity evidence: the Engineering and Science Issues Test (ESIT) [12] and an assessment instrument for students' ethics case analysis in bioengineering contexts [13],[14]. We introduce them in this paper.

For the *Proceedings of the ASEE Annual Conference*, we searched for the articles with keywords (ethics OR social responsibility) AND (assessment OR scale OR instrument OR survey) AND (validation OR development) in the title published between 2000-2023. We limited our search to title-based because too many articles (28,043 articles) showed up when we did not limit our search to title-only: we thought the search function did not perform the screening task properly because many irrelevant papers were also included in the results. The initial search generated 18 articles, and after screening the articles with titles and abstracts, nine articles remained. Among those, five articles reported newly developed instruments for ethics-related outcomes with validity evidence: Two of them introduced Engineering Ethical Reasoning Instrument (EERI) [15],[16]; one was for providing additional validity evidence of EPRA [17]; one was for Engineering Social Justice Scale (ESJS) [18]; and one was for an ethics survey based on a four-domain development diagram (4DDD Ethics Survey) [19]. We introduce all four instruments in this paper.

Table 1 summarizes the literature analysis process, and we will introduce a total of eight instruments in chronological order of the publication.

Table 1. Overview of the literature analysis process

Title of Journal or Conference Proceedings	Initial Search	Title & Abstract	Final Included*
Journal of Engineering Education	158	7	1
International Journal of Engineering Education	558	8	2
Science and Engineering Ethics	229	5	3
Proceedings of the ASEE Annual Conference	18	9	5

*Some articles reported the same instrument, therefore the sum of the number of final included articles from each journal or conference proceedings is bigger than the instruments introduced below.

Engineering and Science Issues Test (ESIT)

ESIT was created by Borenstein and his colleagues [12] to assess the effectiveness of ethics education in science and engineering, especially in fostering engineering and science students' moral reasoning skills. The test presents ethical dilemma cases relevant to science and engineering contexts and asks students to engage with a series of questions. Similar to the DIT-2, the ESIT scores the prevalence of Kohlbergian post-conventional thinking within students' answers (P-score), as well as the presence of Kohlbergian post-conventional thinking and absence of pre-conventional thinking (N2-score).

The authors suggest that the ESIT can measure the effectiveness of ethics education, as they performed validation studies considering participants' ethics education (those who have and have not had it previously). However, as the authors suggest, the validity of the ESIT still requires extensive testing in a variety of institutional contexts, and with a much broader range of participants - gender, age, and cultural background. The authors also found that the way of distributing the test (written form vs online) influenced the study findings. Participants who took the test in the written form had more improvement in responses to the test compared to those who took the test online. The authors suggest that this difference in improvement could be further explored with more research on ethics assessment and ethics pedagogy.

Engineering Ethical Reasoning Instrument (EERI)

Zhu and colleagues [15] created EERI to measure moral decision-making in design projects. The EERI is based on Kohlberg's moral development theory and relies on micro and macro ethics in engineering. Similar to DIT-2 and ESIT, EERI is also a scenario-based assessment instrument: The instrument presents design scenarios that were adapted from students' design projects and asks students to select the action that they would most likely take in the situation. After students make a decision, they are also asked to rate a series of items how important each item was in making their decision.

The authors utilized a mix-method approach to validate the instrument. The EERI instrument went through several iterations, the last version was administered to more than 800 participants. The estimated reliability of the ratings across the six scored scenarios was from 0.72 to 0.85 with the exception of one of the scenarios (estimated reliability of 0.565). To validate the EERI and the model of the relationship between individual moral reasoning and team ethical climate [20], Zhu and colleagues conducted a qualitative study with 51 semi-structured interviews and non-participatory observations with participants in four engineering programs. Discourse and thematic analyses were used to analyze the data from semi-structured interviews and non-participatory observations. The authors then converted the qualitative findings to quantitative results. The findings reveal evidence of three different stages of moral development probed in EERI [15]. In addition, the qualitative data offered more insights into the participants' ethical decision-making process.

Pinkus et al.'s Ethics Case Analysis Instrument

Pinkus et al. [13] developed an assessment instrument that can assess engineering students' moral reasoning, specifically in bioengineering contexts. The assessment instrument evaluates how students utilize five higher-level moral reasoning skills (HLMRS) when they analyze ethics case studies: 1) in framing issues, applying professional/technical knowledge, 2) viewing the problem from multiple perspectives, 3) moving flexibly among multiple different perspectives, 4) utilizing analogous cases, and 5) employing *methods of moral reasoning,* defined by the authors with three distinct components (labeling, defining, and applying), in conducting analysis. In assessing students' case study analysis, while evaluators qualitatively assess the first four skills and assign one of the binary answers of yes or no, for the last skill, the outcome of the assessment is what the authors called a Methods of Moral Reasoning (MMR) proportion, which is defined as the ratio of applying to the sum of labeling, defining, and applying.

This instrument was not designed following the standard practice of instrument development [21], which means, for example, the instrument was not designed to be able to conduct factor analysis for validity evidence. However, Pinkus and her colleagues reported a sensitivity study and inter-rater reliability study of the instrument in a separate paper [14], to provide validity and reliability evidence of their instrument. Through the sensitivity study, they checked whether the instrument is sensitive to changes in students' learning over the course of teaching bioengineering ethics in the semester of their study, and through the inter-rater reliability study, they evaluated whether independent coders agree with each other's assessment results.

Engineering Professional Responsibility Assessment (EPRA)

Canney and Bielefeldt [7] developed an instrument called EPRA to measure undergraduate engineering students' social responsibility attitudes. The EPRA is particularly designed to help educators evaluate the effectiveness of curricula interventions that are developed to study the change in students' views of social responsibility. The EPRA went through several iterations, and the final version of the EPRA included 50 items each of which measures one of the three realms: 1) personal social awareness, 2) professional development, and 3) professional connectedness. The personal social awareness realm includes three dimensions: awareness, ability, and connectedness. The professional development realm includes three dimensions: base skills, professional ability, and analyze. The professional connectedness realm includes two dimensions: professional connectedness and costs-benefits. Each item is rated on a 7-point Liert scale (1 = strongly disagree and 7 = strongly agree).

To establish the validity and reliability of the instrument, the authors utilized a multimethod approach through expert feedback, structural equation modeling, multidimensional item response theory, and convergent evidence of validity and evidence of reliability using ordinal alpha [7]. Especially for the quantitative analyses, the final EPRA was distributed to more than 1,000 students, and these analyses indicate the appropriateness of the EPRA to measure social responsibility attitudes in engineering students – the original alpha offers evidence of acceptable to good reliability for the instrument dimensions. The multidimensional item response theory analysis suggests varying levels of difficulty for students and the MIRT shows a strong model fit.

Four Domain Development Diagram (4DDD) Ethics Survey

Canney and his colleagues [19] developed a survey based on Vanasupa and others' 4DDD, which guides educators' instructional design for them to consider cognitive, psychomotor, affective, and social dimensions of learning to foster students' holistic development [22]. Canney and his colleagues developed an instrument that consists of six constructs each of which can be mapped onto the four domains and measure: students' 1) interest in ethics, 2) perceptions of the value of ethics education, 3) feelings of autonomy in the class activities about ethics, 4) relatedness with their classmates, 5) perceptions of their own competence related to ethics, and 6) systems thinking related to ethics. Each construct is measured with 4-6 items, therefore a total of 33 items are included in the survey. Each item is rated on a 7-point Likert scale (1 = strongly disagree and 7 = strongly agree).

Canney et al. [19] is a work-in-progress paper that has been relatively recently published in the ASEE conference proceedings. The authors calculated Cronbach's alphas, which supported the internal consistency of each construct for the instrument, and conducted confirmatory factor analysis which suggested weak evidence of the theorized internal structure and further refinement studies.

Civic-Minded Graduate Scale (CMG)

Hess and his colleagues [8] did not develop a new instrument for engineering ethics assessment but started from an existing instrument, titled CMG*,* which was designed to measure the qualities of civic-minded graduates of higher education. The original version of CMG includes 30 items and covers three domains of civic engagement - knowledge, skills, and dispositions - each of which consists of four distinct elements. Survey-takers respond to each item with a 9-point Likert-type scale (1 = strongly disagree, 9 = strongly agree). Based on the existing measurement model, Hess and his colleagues conducted a confirmatory factor analysis to check whether the same factor structure holds in science and engineering student populations and found the original model does not fit the data well. Therefore, they conducted additional principal component analysis and confirmatory factor analysis to obtain validity evidence of the measure with the population and science and engineering students.

A distinct factor structure from the original measure emerged from the data, suggesting a five-factor model: 1) valuing community engagement, 2) confidence in building skills, 3) civic knowledge and skills, 4) empathic interpersonal communication, and 5) civic intention and obligations. The first factor, *valuing community engagement*, measures one's sense of personal calling or desire to serve the betterment of the community. The second factor, *confidence in building consensus*, measures one's confidence in their ability to engage with others in dealing with complex social issues. The third factor, *civic knowledge and skills*, measures one's knowledge and skills necessary to deal with community issues. The fourth factor, *empathic interpersonal communication*, measures one's propensity to listen to others and try to build consensus on controversial issues in interpersonal contexts. The fifth factor, *civic intention and obligations*, measures students' intentions to engage in the political process.

In fact, this measure has not been written specifically for engineering contexts. However, we decided to introduce this measure in this paper because the paper provides strong validity evidence for the engineering student population. As the authors also pointed out in their paper, civic engagement has not been a popular topic in engineering ethics education. However, as engineers' collective social responsibility towards the broader society has become more emphasized among the engineering education community [23], a measure to assess individual engineers' civic-mindedness may be able to be used as a proxy of students' learning in the topic of macroethics.

Valuing Diversity and Enacting Inclusion in Engineering Scale (VDEIE)

Rambo-Hernandez et al. [9] developed an instrument that measures engineering students' attitudes toward diversity and their intentions to enact inclusion in engineering contexts. The instrument was designed to measure two constructs related to valuing diversity (fulfill a greater purpose, serve customers better) and two constructs related to enacting inclusion (challenge discriminatory behavior, promote a healthy work environment). For the two constructs related to valuing diversity, each item completes the following statement, "Engineers should value diversity in order to…," and for the two constructs related to enacting inclusion, each item completes the following statement, "While working on a team, I…" Each item is rated on a 7-point Likert Scale (1 = strongly disagree, 7 = strongly agree).

The authors administered four rounds of survey and conducted exploratory and confirmatory factor analyses and longitudinal measurement invariance tests with the data. The results suggested stable evidence of the factor structure of the instrument.

Engineering Social Justice Scale (ESJS)

Lutz and Peuker [18] modified an existing instrument named Social Justice Scale (SJS), developed by Torres-Harding et al. [24], to develop their own ESJS. The original SJS consisted of 24 items for measuring four aspects of one's social justice orientation: attitudes, perceived behavioral control, subjective norms, and behavioral intentions. For the modification, they first changed some wording of the original SJS scale to better fit the scale into the engineering contexts and distributed the survey to the first-year and transfer students. For each item, students answered on a 7-point Likert scale (1 = strongly disagree and 7 = strongly agree). With the collected data, they conducted two rounds of exploratory factor analyses and identified three underlying factors. The first factor reflected the items of the two constructs in the original measure, *attitudes* and *behavioral intentions*. The second factor reflected the *subjective norms* construct of the original measure. The third factor reflected the *perceived behavioral control* construct of the original measure, although the factor contained only two items.

Similar to Canney et al. [19], Lutz & Peuker [18] is a work-in-progress paper that has been relatively recently published in the ASEE conference proceedings, so the authors presented only preliminary validity evidence of the instrument. The authors' follow-up studies will report the updated ESJS instrument.

Synthesis and Opportunities

Based on our literature review, we identified eight assessment instruments specifically designed for engineering ethics education and introduced them in the previous section. We found that three of the eight instruments have been designed to measure engineering students' moral reasoning (ESIT, EERI, and Pinkus et al.'s ethics case analysis instrument); two have been designed to measure engineering students' attitudes towards social responsibility and qualities for civic engagement (EPRA and CMG); and two have been designed to specifically cover topics like diversity and inclusion and social justice (VDEIE and ESJS). Those seven instruments (ESIT, EERI, Pinkus et al.'s ethics case analysis instrument, EPRA, CMG, VDEIE, and ESJS) have been specifically designed as an individual-level assessment instrument to examine individual students' characteristics or achievement of learning outcomes of ethics interventions.

While the majority (seven out of eight) were individual-level assessment instruments, there was also one instrument (4DDD ethics survey) that was specifically designed to examine the qualities of a course as a course-level assessment instrument. Considering the fact that there have been relatively limited efforts to develop course-level and curriculum-level assessment instruments, educators could consider developing new instruments that can assess the qualities of ethics instruction or curriculum while complementing the 4DDD ethics survey.

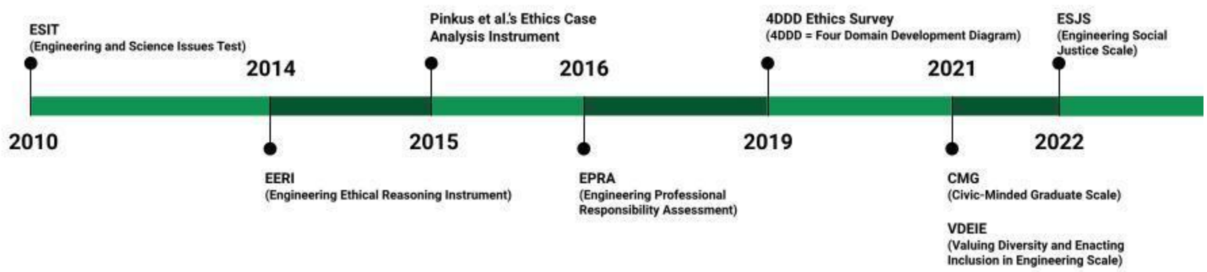

Figure 1. Timeline of the Ethics Assessment Instrument Publication

Figure 1 shows the timeline of publication of the papers that reported ethics assessment instruments. The timeline shows an interesting change in trend around the topic of assessment over time: The first three instruments published in the years 2010, 2014, and 2015 were all about assessing one's reasoning ability, reflecting the fact that teaching reasoning has been the primary focus of engineering ethics education for a while [25],[26]. Then instruments for assessing engineering students' attitudes towards and qualities for addressing the themes like broader social responsibility or community engagement have been developed and published in 2016 and 2021 respectively, aligning with the endeavors to broaden the scope of engineering ethics to include macroethics [23]. Also, the two most recent publications in 2021 and 2022 cover the topics of diversity and inclusion and social justice, reflecting the recent efforts to promote diversity, equity, and inclusion (DEI) in engineering education and practice.

While many new instruments can be developed and validated for engineering ethics education, researchers can find a clear opportunity in developing instruments for assessing students' learning of one of the most frequently discussed topics in engineering ethics education - professionalism and codes of ethics [27]. To fill this gap, researchers can focus on the concept of *moral identity*, a construct for one's self-definition especially organized around a set of moral traits [28]. It has been considered a significant predictor of a person's moral behavior [29], but has been rarely studied in engineering education contexts. Although there are some existing measures for moral identity in general, as far as we know, there is no measure specifically designed for professional moral identity of engineers. Therefore, developing an assessment instrument that can measure professional moral identity of engineers could be helpful.

Conclusion

In this paper, we introduced the papers that reported the development and validation study of assessment instruments for engineering ethics interventions. Then we synthesized previous efforts in developing such assessment instruments and identified opportunities for future study. We first search for papers published in representative journals and conference proceedings in the field of engineering education and engineering ethics. We reviewed papers published in the *Journal of Engineering Education, International Journal of Engineering Education, Science and Engineering Ethics*, and the *Proceedings of the ASEE Conference* and found eleven papers that met our criteria and reported eight different assessment instruments. Based on the review, we found that the majority of the papers reported an individual-level assessment instrument, which aims at measuring individual students' qualities or characteristics. We also found a change in the trend in the subject of the assessment instrument. While the early efforts in developing assessment instruments focused mostly on assessing engineering students' reasoning skills, more recent publications introduce assessment instruments designed for measuring students' attitudes or qualities related to broader societal considerations, such as social responsibility and community engagement, as well as diversity and inclusion and social justice considerations.

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