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Contextualizing Professionalism in Capstone Projects Using the IDEALS Professional Responsibility Assessment*

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Professionalism, which includes engineering ethics, is recognized as a valued topic in industry and education but it is difficult to teach and assess. This paper presents a web-based professional responsibility instrument and accompanying rubric, which is used to assess student understanding and skill in analyzing areas of strength and opportunity surrounding a professional responsibility issue associated with the student's design project. Students completing the assessment most frequently rated work competence as both highly important and an area of team strength while issues of sustainability were least frequently cited. The scored results of this assessment revealed that students were moderately effective at relating issues of professional responsibility to situations within their projects as well as addressing them in a responsible manner. In a post-assessment survey, students and faculty rated the assessment as somewhat accurate to mostly accurate. An inter-rater agreement study of the assessment showed that scorers were on average within one level of difference on the scoring rubric 97% of the time. Results of administering the assessment in a capstone course can be easily packaged and presented as part of a program accreditation self-study.

Keywords: assessment; professional responsibility

1. Introduction

Engineering capstone design courses present the opportunity for authentic assessment of teamwork, professional, and design skills. Assessment of these complex skills is best performed in a situation similar to that in which they will be used [1, 2]. However, many capstone design faculty are uncertain about how to develop and assess these skills [3], and any attempt to provide authentic project-based

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activities is subject to resource constraints. Thus, class activities often fall short of the goal of realistically assessing professional skills. In response, the Transferable Integrated Design Engineering Education consortium (TIDEE), a team of design faculty from several institutions [4], created and is testing the web-based Integrated Design Engineering Assessment and Learning System (IDEALS) that is targeted towards use during capstone design projects. Past TIDEE papers focused on the instruments and testing results from teamwork [4] and professional development [5] and established the framework for presenting these results. In particular, this paper focuses on the assessment tools and curriculum elements for developing professional responsibility within the context of the student design project. This paper highlights the instrument and supporting curriculum, the results of testing from 2008–2010, feedback from surveys on the instruments, and the packaging of results for program assessment.

2. Literature review—professional responsibility

Professional responsibility and ethics are core components of ABET accreditation where outcome 3f [6] states that students will attain 'an understanding of professional and ethical responsibility.' Herkert [7] defines professional responsibility as the 'moral responsibility arising from special knowledge possessed by an individual (p. 164).' Unfortunately, literature on teaching or assessing student achievement in professional responsibility is not available. To inform the creation and use of a professional responsibility assessment, the TIDEE consortium surveyed the state of engineering ethics learning in various curricula and the impact of this education. From this information and with guidance from professional codes of conduct, TIDEE formed the Professional Responsibility assessment and accompanying curriculum.

Stephan [8] noted that in 1999, only about one in four undergraduate engineering institutions offered ethics-related courses while the remainder embedded the instruction in other courses such as the capstone experience. More recently, Lattuca, et al [9] report that chairs and faculty indicate increased attention on professional responsibility and ethics in response to EC2000. One instructional method employed is the use of case studies to present students with ethical situations and as the seeds for discussion. Harris et al. [10] supported the use of case studies as the best method that they observed for learning engineering ethics because they expose students to ethics in technical situations, engage students in ethical analysis, and show that some ethical situations are ambiguous and are handled differently by experts. Harris et al. [11] stated that cases could be focused on aspirational or preventative action, microethics considerations or macroethics [7, 12], and could be extended or abbreviated.

Ethics texts often use case studies as the framework for learning about ethics in practice. However, Newberry [13] warns that instruction in engineering ethics may be 'superficially effective' because students view the ethics work as an academic exercise. Newberry states that students lack the emotional investment in the ethics exercises and often find it difficult for them to be intellectually involved because of their inexperience in manipulating relevant 'facts, rules, and logic'. Yadav and Barry [14] developed a categorization of case studies for teaching engineering ethics and concluded that an empirical study is still needed to show the usefulness of case studies. Johnson et al. [2] note that assessment of complex skills is best performed not in a simulation, but in situations most similar to those in which they can be applied. Additionally, after a review of 42 ASEE conference papers from 1996-1999 that featured methods such as theoretical grounding, service learning, and case studies, Haws [15] suggested that 'real' experiences were the most effective way to learn about engineering ethics. Furthermore, Pritchard [16] argues that ethical considerations must include synthesis portions of the design process.

3. Instrument description

A key feature of the professional responsibility assessment is the contextualization of ethical responsibility to the student's project. Students can easily identify ethical challenges in an exaggerated sense, but it is the practice of identifying the key professional issues closely related to their capstone design project that defines achievement in professional responsibility. To complete the assessment online, students first identify the importance (High, Medium, Low) of each of seven areas of professional responsibility within the context of their project. The enumeration of these professional responsibility areas is shown in Table 1. Students then identify their current level of performance (High, Medium, Low, N/A) in each area of professional responsibility in the context of their project. Table 1 also includes a mapping of each identified area of professional responsibility to the NSPE fundamental canons [17]. It is important to note that the professional ethical canons are a subset of the seven areas of responsibility. These canons do not address the important issue of sustainability, even though sustainability is referenced in the

Table 1. The seven areas of professional responsibility in the assessment instrument

Area of responsibility	Definition	NSPE Canon
Work Competence	Perform work of high quality, integrity, timeliness, and professional competence.	Perform services only in areas of their competence; Avoid deceptive acts.
Financial Responsibility	Deliver products and services of realizable value and at reasonable costs.	Act for each employer or client as faithful agents or trustees.
Communication Honesty	Report work truthfully, without deception, and understandable to stakeholders.	Issue public statements only in an objective and truthful manner; Avoid deceptive acts.
Health, Safety, Well-Being	Minimize risks to safety, health, and well-being of stakeholders.	Hold paramount the safety, health, and welfare of the public.
Property Ownership	Respect property, ideas, and information of clients and others.	Act for each employer or client as faithful agents or trustees.
Sustainability	Protect environment and natural resources locally and globally.	
Social Responsibility	Produce products and services that benefit society and communities.	Conduct themselves honorably, responsibly, ethically, and lawfully so as to enhance the honor, reputation, and usefulness of the profession.

professional obligations and discipline specific codes (e.g. ASCE, AIChE, ASME, and IEEE).

Next, students identify an area of professional responsibility that is both important to their project and for which they have demonstrated a moderate or high level of proficiency in the context of their project. Students are then asked to briefly describe what this responsibility means to their project, the ways that they have demonstrated the responsibility in their project, and specific impacts on their project that they have observed. Finally, students identify an area of professional responsibility that is important to their project but has seen a relatively low level of application to-date. Students briefly describe the possible impacts of this opportunity and an action plan to better fulfill the responsibility in their project.

Instructors use the rubrics in Tables 2 and 3 to score the corresponding written student work that is captured online. Scoring is performed using a Likert scale of 1–5 (Novice, Beginner, Intern, Competent, Expert). The instructor also has the option to leave additional written comments for the student in the online form.

4. Curriculum support

To support the assessment of professional responsibility outside of class, a set of in-class and pre-class activities (modules) were developed and used to prepare students with the ultimate goal of increasing student learning. Key elements of the curricular module include a pre-class reading assignment in which students familiarize themselves with the

Table 2. Rubric used by instructors to score the written student work related to the demonstrated strength

	Novice	Beginner	Intern	Competent	Expert
Understanding of responsibility	Misunderstood or unable to explain elements of it; no reference to codes.	Little understanding; few elements fit the responsibility; vague reference to codes.	Moderate grasp of responsibility; some reference to codes; some relevant detail.	Credible grasp of responsibility; good use of relevant codes and examples.	Impressive grasp; insightful description, use of codes & examples.
Effective demonstration of responsibility	Strength not used or not used well; no impacts cited.	Strength used casually, passively; obscure impacts.	Strength used fairly well; not purposeful; some good impacts.	Strength used well, purposefully; clear positive impacts.	Strategic use of strength; impressive documented impacts.

Table 3. Rubric used by instructors to score the written student work related to the opportunity for improvement

	Novice	Beginner	Intern	Competent	Expert
Understanding of opportunity	Vague description of opportunity; does not see benefits; no reference to codes.	Weak description of opportunity; implies benefits; vague reference to codes.	Okay description of opportunity; vague benefits; some reference to codes.	Good explanation of opportunity; good definition of benefits & reference to codes.	Superb explanation of opportunity; insightful on benefits & relevant codes.
Plans to capitalize on opportunity	No plan or unclear; unreasonable to implement.	Vague plan or weak plan; difficult to implement.	Reasonable plan; may be possible to implement.	Clear, strong plan; reasonable to implement well.	Impressive plan; likely embraced by all and implemented.

National Society of Professional Engineers (NSPE) code of ethics as well as their discipline's ethical codes (ASME, IEEE, etc.). In addition, an in-class, active-learning exercise is included in which groups of inter-team students identify subsets of professional issues on their individual projects corresponding to the NSPE canons and then report their findings to the class. Ethics test cases are also provided as an in-class warm-up for ethical discussions. Instructors use the lecture period to familiarize students with the professional responsibility assessment instrument, which is completed by students post-class. If it is the first IDEALS web-based assignment, instructors can spend time familiarizing students with the assessment website and process.

5. Implementation details

The professional responsibility assessment was pilot tested by engineering design educators at four institutions during 2008–2010. Institutions differed with respect to size, location, student demographic, and public or private status. Implementation of the professional responsibility assessment varied by institution and by instructor during the pilot testing, including the number of times the assessment was used and when the assessment was deployed. Participating capstone design faculty, who were not part of the TIDEE development team or consultants to the project were briefed by their local TIDEE project representative prior to using the assessment. Briefings included discussion of the intent of the assessment, possibilities for its use in class, anticipated benefits from the assessment, and how to access and use the web-based system. Stipends were provided as incentives for fulfilling commitments to administer the assessment and provide requested data.

Students in the targeted capstone design classes represented a broad set of disciplines, including engineering (bioengineering, mechanical engineering, electrical engineering, civil and environmental engineering, chemical engineering, agricultural and biological engineering, materials engineering, and general engineering), business (marketing, management information systems, entrepreneurship, and accounting), and sciences (mathematics, physics, chemistry). Project types included client-sponsored, student-initiated, design competition, entrepreneurial, service learning, and international development. Additionally, project duration varied (one semester, two semesters, two quarters, three quarters) and team size varied greatly (3–9 members). Both online and hard copy versions of the assessment were used, but only online results are reported.

6. Testing methodology

In addition to compiling results from multiple professional responsibility assessment administrations from 2008–2010, the professional responsibility assessment was evaluated using multiple methods to determine if the instrument and companion scoring rubrics were useful, usable, and desirable for the primary users—students and instructors. A survey was conducted with students and instructors who participated in assessment and scoring activities respectively to gather user insights on the instrument accuracy and value. Additionally, inter-rater agreement in use of the scoring rubrics was computed.

After the assessment was completed by students and scored by the instructor, a brief questionnaire was administered to students and instructors asking for feedback regarding their perceptions of the usefulness and accuracy of the formative professional responsibility assessment. The questionnaire for students contained three items that asked students to rate:

(a) their perceived estimate of the accuracy of instructor feedback,
(b) personal value derived from using the assessment instrument, and
(c) added-value the assessment provided to their project work.

The questionnaire for instructors contained five items that asked instructors to rate:

(a) effectiveness at identifying areas in which students struggle,
(b) effectiveness at identifying areas in which students excel,
(c) helpfulness at guiding remedial instruction and intervention,
(d) helpfulness at guiding important feedback, and
(e) confidence in the accuracy of the score.

Response items for both surveys were based on a 5-point Likert scale with the following anchor labels: (5) very accurate/very valuable, (4) mostly accurate/generally valuable, (3) somewhat accurate/somewhat valuable, (2) mostly inaccurate/little value and (1) very inaccurate/no value.

To provide an estimate of scoring consistency for the professional responsibility assessment, a small inter-rater agreement study was conducted. For this study, two faculty members and two graduate students scored the same student work to determine scoring agreement. These four individuals were given training in the use of the scoring criteria for rating student responses to the professional responsibility assessment. Initial rater training included a review of the assessment and corresponding perfor-

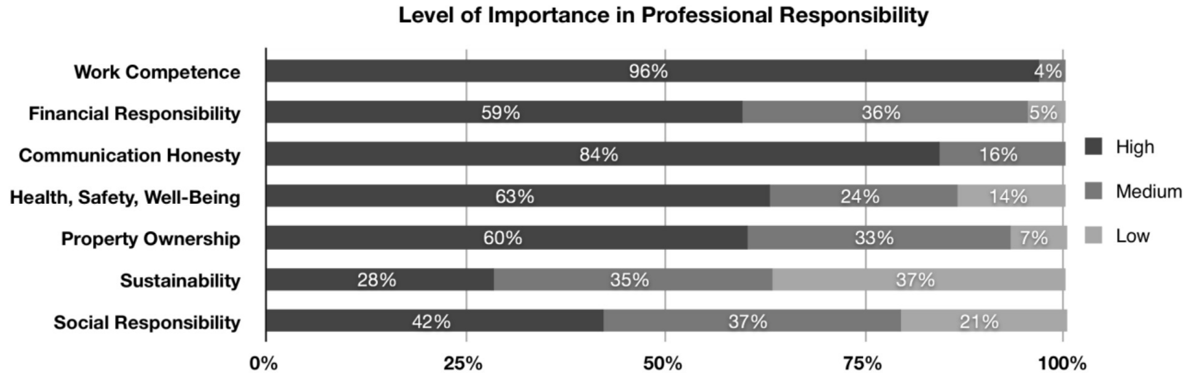

Fig. 1. Student self reported level of importance in professional responsibility areas.

mance criteria, practice scoring of student work, score comparisons across raters, and time for discussion and justification of scores [18]. Rater training also included a review of common errors/biases associated with scoring of student performance, including leniency, central tendency, strictness, contrast effect, and halo [19]. Once sufficient understanding of the scoring criteria and its application was obtained, the four scorers independently scored work from a sample of 20 students, whose work represented a cross-section of performances. Percent agreement statistics were computed for the overall scoring with the professional responsibility instrument.

7. Results

One hundred sixty-one students at a subset of the TIDEE institutions reported their perceived level of importance of the seven areas of professional responsibility. Ninety-six percent of students rated that work competence was highly important while 37% of students reported that sustainability had a low importance. The complete set of student results is shown in Fig. 1.

For self-assessment, students felt that they performed at a high level in terms of honest communication (76%) while they reported a low level of performance in terms of supporting sustainable design (12%). The results from 161 respondents are shown in Fig. 2. Students reported that sustainable design was most frequently not applicable to their project (34%).

Students were asked to identify an area in which the team demonstrated professional responsibility, describe their understanding of the opportunity for improvement, and how they have effectively demonstrated the responsibility. The frequency of times identified as the professional responsibility demonstrated is shown in Table 4. Table 4 also contains the identification frequency for opportunities in professional responsibility improvement. Work competence was most frequently cited as the area of professional responsibility demonstrated and opportunity for improvement. This is likely because of the students' ease in evaluating quality in this area. The typical undergraduate engineering education is technically focused, and the student's proficiency in technical competence related to the project would be easiest for them to assess based on experience. Sustainability and social responsibility were least frequently cited as the areas of responsibility

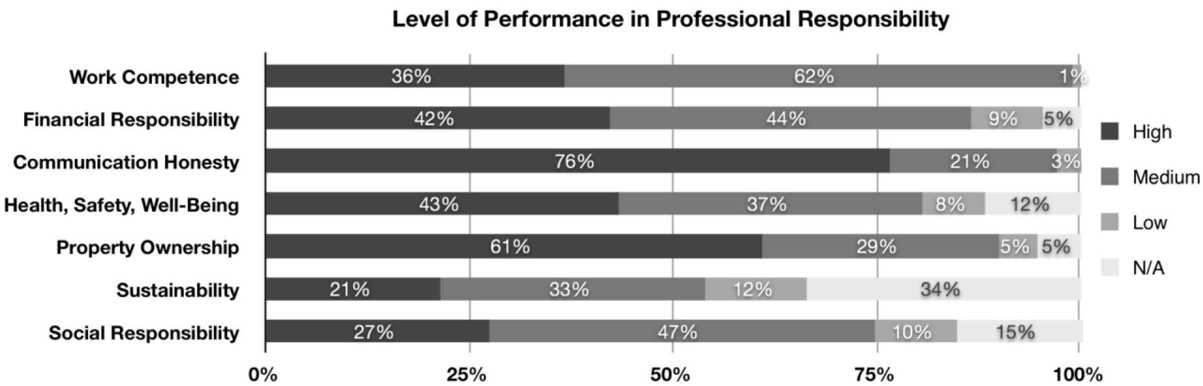

Fig. 2. Student self reported level of performance in professional responsibility areas.

Table 4. Student identified areas of professional responsibility demonstrated and opportunity for improvement

Area of responsibility	Professional responsibility demonstrated	Professional responsibility opportunity for improvement
Work competence	36%	25%
Financial responsibility	16%	22%
Communication honesty	26%	9%
Health, safety, well-being	7%	12%
Property ownership	7%	9%
Sustainability	4%	12%
Social responsibility	4%	10%

demonstrated which is again, likely in part due to the student's inability to recognize issues of sustainability and social responsibility.

The summary of faculty scoring of 161 pieces of student work is shown in Table 5. The faculty scores showed that students performed at intern levels in all areas and scored lowest at developing plans to achieve improvement. The scoring results are not unexpected because students typically perform better at identification tasks and worse at synthesizing planned action.

Comparing ratings given by different raters for the same student work provides insight about the consistency with which the assessment gives feedback to students. Table 6 presents results by different combinations of rater pairs for scoring samples of the professional responsibility assignments. Cells in the table present (by rater pairings) the number and percent of ratings that differed by 0, 1, 2, 3, and 4 points (on a 5-point scale). For instance, raters 1 and 2 (both capstone design instructors) agreed on seven of the twenty scores they separately gave to student responses on the professional responsibility assessment. Their scores then differed by 1 point on eleven additional student responses and they dif-

Table 5. Faculty scoring of student submissions to the professional responsibility assessment (n=161)

	Understanding of professional responsibility	Effective demonstration of responsibility	Understanding of opportunity for improvement	Plans to capitalize on improvement
Average	3.8	3.6	3.6	3.3
Standard deviation	0.7	0.8	0.8	0.9

Table 6. Rater pair number (and percent) for each scoring difference

	Rater pairs*						
Difference	**1–2**	**1–3**	**1–4**	**2–3**	**2–4**	**3–4**	**Mean**
0	7 (35%)	11 (55%)	4 (20%)	8 (40%)	14 (70%)	9 (45%)	8.8 (44%)
±1	11 (55%)	9 (45%)	15 (75%)	12 (60%)	6 (30%)	10 (50%)	10.5 (53%)
±2	2 (10%)	0	1 (5%)	0	0	1 (5%)	<1 (3%)
±3	0	0	0	0	0	0	0
±4	0	0	0	0	0	0	0

* Raters 1 and 2 are previous capstone design instructors. Raters 3 and 4 are engineering teaching assistants.

Table 7. Results of the faculty, post-assessment survey (n=23)

Professional responsibility (n=23)	$\bar{X}$	SD
How effective was the assessment in identifying areas where students or teams were struggling?	3.7	0.6
How effective was the assessment in identifying areas where students or teams were excelling?	3.9	0.8
How helpful was the assessment in guiding remedial instruction or other interventions?	3.6	0.7
How helpful was the assessment in guiding the generation of important feedback?	3.9	0.7
How confident are you that the resulting scores are accurate (trustworthy) representations of student performance?	4.0	0.7

Table 8. Results of the student, post-assessment survey (n=10)

Professional responsibility (n=10)	$\bar{X}$	SD
Based on the scores and feedback you received, how accurate of a picture do you feel the instructor painted of your or your team's performance?	3.7	1.5
How valuable to you personally was the assignment and feedback for increasing your overall understanding of the topic addressed?	3.4	1.0
How valuable to your team was the assignment and feedback for increasing your overall project success?	3.0	0.9

fered by 2 points on the two remaining pieces of student work.

8. User feedback

Twenty-three faculty members completed the post-assessment survey shown in Table 7. Participating faculty indicated that they perceived the results as mostly accurate and the assessment process generated valuable feedback. Ten student participants completed the post-assessment survey and the results are summarized in Table 8. Students rated the feedback as somewhat accurate to mostly accurate while they perceived the personal value greater than the assessment's value to the project. Not all faculty and students that participated in the assessment completed the survey. For reasons of anonymity, survey result data was not associated with participant data, which includes the home institution and discipline. The student and faculty surveys were completed online to facilitate data gathering.

A post-assessment discussion with a subset of faculty that implemented the professional responsibility curricular module and assessment revealed several insights. Interviewees stated that the curricular module and assessment didn't necessarily provide direct value to project deliverables, but proved to be valuable to the development of individual students. They also reported that the assessment seemed that it could be used in an a la carte basis, but timing in the project, sequencing with other assessments, and getting students familiar with the online system were all key factors for success. In their opinion, the assessment definitely benefited from setup and discussion during a class period (in-class curriculum). They also noted that using the provided faculty materials and outline required approximately thirty minutes of preparation.

9. Packaging for program assessment

The results of the professional responsibility assessment can be packaged as part of an ABET self-study report addressing criterion 3f. The program assessment report begins with a description of the assessment instrument and its use such as that described in section 3 of this paper. The department then identifies targets for student achievement on faculty scored work and subsequently analyzes the quality of student work as rated by instructors using the accompanying rubric. If the measured levels of student performance fall below the established targets, the report can outline corrective action that will be taken. In addition to reporting student scores on the written elements of the professional responsibility assessment (similar to Table 5), the department can also report on other information gathered from assessments using materials similar to Figs. 1 and 2 and Table 4.

10. Conclusions

This paper outlines the professional responsibility assessment as well as the results of using it at a diverse set of universities, the participants' opinions of the assessment, and the results of an inter-rater agreement study related to the assessment. The IDEALS professional responsibility assessment attempts to achieve realism and student emotional investment by asking students to establish 'case studies' from within the context of their capstone design projects. This highlights the ever present nature of professional responsibility in engineering by requiring students to identify the dilemmas in their project that are likely not as dramatic as many textbook case studies, but more relevant. The early findings showed that an 'intern' rating of student work was deemed accurate by both students and instructors alike and scoring results could be packaged as accreditation data. The reported work has limitations that include small sampling of data, the subjectivity of making ratings, and non-uniformity in assessment implementation. Factors affecting successful implementation included timing of the assessment, preparation of instructors and students, and implementation of specific activities associated with the assessment. The curriculum materials attempt to mitigate variations in quality due to differences in student familiarity with professional responsibility and canons. Supporting curriculum materials can be used to guide delivery of the material in a single lecture. Future work is required to measure the effectiveness of the curricular material. These results show that the IDEALS professional responsibility assessment and course materials hold promise as tools for developing and assessing the professional responsibility related skills of capstone students and as the basis for program assessment. The best indicator of the benefit of the IDEALS professional responsibility assessment would be feedback from graduates in the first few years after graduation. At some point the TIDEE team hopes to begin collecting such data.

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