

Assessing Professional Skill Development in Capstone Design Courses*

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The capstone engineering design course provides students an opportunity to create a product or process as well as the opportunity to improve professional skills and workplace behaviors. The latter are often difficult to teach and assess in a project-based course. To encourage students to be aware of, to prepare for, and to engage in project-based professional skill development, the Transferable Integrated Design Engineering Education (TIDEE) consortium developed the Integrated Design Engineering Assessment and Learning System (IDEALS) that includes course materials, assessment instruments and companion scoring rubrics that target professional development. In the IDEALS assessment instruments, professional skills include professional responsibility and an ability to pursue lifelong learning related to twelve specific abilities/attributes that are technical, interpersonal, and individual in nature. The IDEALS professional skills assessments consist of a progression of two formative assessments (Professional Development Planning and Professional Development Progress) and one summative assessment (Professional Development Achieved) that are used to prepare for, monitor, and summarize student professional development during the capstone course. A companion instructional module and scoring rubric is provided with each assessment instrument in an instructor-friendly web-based format that helps the instructor guide student development. The professional skills assessment instruments were piloted at six colleges and universities throughout the United States that differ with respect to size, geographic location, student demographic, and public or private status. The results of these pilot implementations, inter-rater agreement studies, student perceptions, and faculty perceptions of the assessment instruments are included in this paper. Results indicate that use of the instruments is perceived by students as value-added within the capstone program, are perceived by instructors as helpful in monitoring student growth as well as in program assessment, and show sufficient scoring consistency for reliable use.

Keywords: formative assessment; summative assessment; program assessment; professional skills; lifelong learning; professional development

1. Introduction

Capstone engineering design courses are often the setting for the development and refinement of many of the complex, nontechnical skills required to be a high-performing engineer. These skills are also reflected in program accreditation standards. For example, ABET requires engineering programs to demonstrate that their graduates understand professional and ethical responsibility as well as recognize the need for and demonstrate the ability to engage in lifelong learning. However, because professional development skills are complex and multifaceted, they are challenging to assess. The Transferable Integrated Design Engineering Education (TIDEE) consortium has addressed this challenge by developing the web-based Integrated Design Engineering Assessment and Learning System (IDEALS) that can be used to provide feedback to students about their performance in developing skills for professional practice as well as teamwork, design process, and solution assets [1–3]. Results from these same assessments can be aggregated for purposes of program assessment [4, 5].

To date, both teamwork and professional development assessments have been piloted in programs represented by the authors of this paper. Results from implementing and testing a web-based version of the teamwork assessments have been previously discussed and been shown effective at bridging the gap between educational theory and classroom practice in capstone engineering design courses [2, 3, 5]. Three assessments are now being tested which examine professional development in technical, interpersonal, and individual attributes important to personal and project needs, workplace behaviors, and the ways of being of a reflective practitioner. A web-based implementation is again used to allow instructors to deploy the assessments in a manner that supports student reflection, is sustainable, and minimizes non-value-added activity. This paper provides references to comparable efforts, a description of three IDEALS professional development assessments (Professional Development Planning, Professional Development Progress, and Professional Development Achieved), results of deploying these assessments in capstone design courses over the past several years as well as student and faculty perceptions of the assessments, and some data on the reliability of the instruments.

2. Literature review—assessment of professional skills in engineering

Professional development skills include a breadth of topics deemed relevant by industry and academic sources. Davis et al. [6] surveyed fifty professionals

from various disciplines (biological and environmental, civil, chemical, electrical and computer, geological, mechanical, and petroleum engineering) and backgrounds (academic and industry) to provide guidance on the preferred skills of new engineering employees. Topics in the areas of teamwork, ethical behavior, and communication were deemed essential in addition to technical competence. Professional skills are some of those most highly valued by employers [7], but teaching and assessing professional skills have typically been a challenge in academic settings [8]. Traditional educational measures of quality do not necessarily align with or predict professional performance and demand new approaches to learning the relevant skills [9]. Additionally, focusing on the development of these skills is typically unappealing to the students involved [10] because it is seen as a distraction from technical content.

Several researchers have developed approaches to assess professional skills where students first presented with a scenario, respond to the scenario, and instructors score the response. McMartin et al. developed a scenario-based method and accompanying rubric to assess engineering practices, teamwork, and problem solving [11]. Ater Kranov et al. developed a method for directly assessing professional skills with respect to a given scenario during a session where student work is scored at the conclusion of one hour using a given rubric [12]. Shuman et al. focused specifically on ethical behavior by creating and validating a scoring rubric for assessing student ethical behavior through analysis of written responses to three dilemmas [13, 14].

Some researchers developed assessment techniques that measure professional skill development through typical classroom activities. Cady et al. assessed professional skills along with other ABET outcomes using a survey that queried students' engagement in engineering courses [15]. McCowan and Knapper explored integrated methods for including social and environmental awareness of students within the typically, highly constrained engineering curriculum [16]. Williams explored the use of portfolios for capturing student work to document achievement in ABET learning outcomes [17]. Briedis used rubrics to assess lifelong learning, global and societal context of the engineering profession, and contemporary issues from classroom activities with a focus on sustainability [18]. Mourtos mapped lifelong learning skills to elements of engineering courses and used student responses to course tests and surveys to measure lifelong learning [19].

Web implementation is an essential feature of any assessment intended for wide adoption. Web-based implementation offers potential for digital handling

of student and instructor responses, which facilitates information sharing among team members and multiple instructors. Data from multiple respondents can also be compiled and analyzed to identify similarities, differences, and trends. Peer feedback to students can be kept anonymous to other students. Loughry et al. developed an assessment of team member effectiveness [20] and implemented a web-based method using these assessment tools [21, 22]. The TIDEE consortium also presented a web-based method for assessing student teamwork during capstone projects [3], and a similar web framework was used for assessing professional skill development.

3. IDEALS professional development assessments

IDEALS professional development assessments were developed as part of a package of assessments for capstone design courses [1]. The IDEALS professional development assessments consist of three formative assessments (Professional Development Planning, Professional Development Progress, Professional Responsibility Formation) and one summative assessment (Professional Development Achieved). A description of the Professional Responsibility Formation assessment is not included in this paper and can be found in [23]. The other three professional development assessments form a sequence through which the students can plan, monitor, and reflect on achievements throughout the capstone experience while receiving feedback from an instructor on the accuracy of their perceptions and the quality of their reflections.

Topics addressed in the IDEALS professional assessments are derived from the areas of interest expressed within the survey of engineering professionals by Davis et al. [6] and from comparable industry reports [24]. These include a desire for

lifelong learning. The result of this investigation was the identification of the twelve professional development abilities/attributes shown in Table 1. Table 1 divides the abilities/attributes into three major areas—technical, interpersonal, and individual—and includes definitions of each ability/attribute. These abilities/attributes anchor the IDEALS professional development assessments. Each of the three assessment instruments and corresponding scoring rubrics are described in this section and complete versions of the assessment, scoring rubric, and encompassing lesson plan can be found online [1].

3.1 Professional development planning assessment instrument

The goal of the Professional Development Planning activity is for students to begin processing their capstone project activities with respect to professional development attributes, develop an objective and plan for achieving growth in a specific area of professional development, and begin taking ownership of their own development as will be necessary in a professional environment. Students begin the Professional Development Planning assessment activity by rating the importance of the twelve professional abilities/attributes (Table 1) with respect to the student's personal and project success. Students use a three point scale where a rating of low indicates that the attribute is not relevant to the project or to their personal and professional life, a medium rating indicates that the attribute is moderately important to the project or the student's personal and professional life, and a rating of high indicates that the attribute is very important to the project or the student's personal and professional life. Subsequently, students rate their own perceived abilities in each of the twelve areas on a three-point scale. A low rating indicates that they exhibit little of this ability/attribute, lack confidence, and may be

Table 1. Twelve professional development abilities/attributes and accompanying description

Professional Development Ability/Attribute and Description

Technical

- Analyzing information:** Applying methods/tools of analysis to understand and predict conditions.
- Solving problems:** Formulating, selecting, and implementing actions for optimal outcomes.
- Designing products:** Producing creative, practical products that bring value to varied stakeholders.
- Researching questions:** Investigating, processing and interpreting information to answer important questions.

Inter-personal

- Communicating:** Receiving, processing, sharing information in many forms to achieve desired impact.
- Collaborating:** Working with a team to achieve collective and individual goals.
- Relating inclusively:** Valuing and sustaining a supportive environment for all knowledge and perspectives.
- Leading others:** Developing shared vision & plans; empowering to achieve individual & collective goals.

Individual

- Practicing self-growth:** Planning, self-assessing, and achieving goals for personal development.
 - Being a high achiever:** Delivering consistently high quality work and results on time.
 - Adapting to change:** Being aware and responding proactively to social, global, and technological change.
 - Serving professionally:** Serving with integrity, responsibility and sensitivity to individual and societal norms.
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stagnant in it; a rating of medium indicates that the student exhibits a moderate level of this ability/attribute; while a high rating indicates that the student exhibits strength in this ability/attribute, is fully capable, and could help others improve it. Students then identify an ability/attribute from the list of twelve (Table 1) that is both important for their project and that requires further development to enhance the project team's success. Students are then asked to briefly describe how the shortcoming might or has negatively impacted their project or team, steps they can take to achieve growth in this area, and what evidence will tell them that they have achieved growth in this area.

Instructors provide feedback to the student based on their responses in the Professional Development Planning assessment. In addition to the student's work, instructors are provided a rubric (Table 2) that aligns with the three elements of the student's written work (their documented understanding of the potential and actual impacts of the noted shortcoming, the plan to achieve growth in this area, and the approach for measuring successful growth). The rubric allows the instructor to rate the student responses as one of five levels of achievement (novice, beginner, intern, competent, and expert) in each of the three areas, corresponding to a score of 1 to 5. Additionally, the instructor can add written comments based on the student work in the assignment or in the project.

3.2 Professional development progress assessment instrument

The goal of the Professional Development Progress assessment activity is for students to provide an update on the planned improvement specified in the Professional Development Planning activity. In this assessment activity, students first select the area of improvement that was typically identified in the Professional Development Planning activity. Students briefly describe the steps they have taken to achieve the targeted professional development, some specific evidence of the impact of their professional development to-date, and additional steps that they will take to achieve the targeted professional development.

The instructor is provided a rubric (Table 3) that aligns with the student writing assignments in the activity, and students are scored by the instructor on their progress to date (steps taken), the quality of their evidence of progress, and the quality of their newly planned steps. The rubric again features five levels of achievement in each area and instructors can leave additional comments for the student in a text box.

3.3 Professional development achieved assessment instrument

The Professional Development Achieved assessment is the summative assessment that follows the

Table 2. The scoring rubric used by instructors for providing feedback in Professional Development Planning

	Novice	Beginner	Intern	Competent	Expert
Understanding impacts	Unable to state proper impacts of the shortcoming.	Vague statement of impacts; weak understanding.	Acceptable statement of impacts; moderate grasp.	Clear statement of impacts; good comprehension.	Clear explanation of impacts; insightful comprehension.
Plan to achieve growth	No plan presented or plan unrelated to stated goal.	Vague plan given; little potential to reach stated goal.	Usable plan defined; moderate potential to reach stated goal.	Valuable plan given; good potential to reach stated goal.	Excellent plan; highly likely to reach stated challenging goal.
Evidence for growth	No clues about evidence of successful growth.	Vague allusion to evidence for successful growth.	Reasonable types of evidence for desired personal growth.	Clear statements of suitable evidence for successful growth.	Clear, measurable, suitable criteria for successful growth.

Table 3. The scoring rubric used by instructors to provide feedback in the Professional Development Progress activity

	Novice	Beginner	Intern	Competent	Expert
Steps taken	No action taken or action unrelated to stated goal.	Vague action taken; little relevance to stated goal.	Useful actions taken; moderate relevance to stated goal.	Valuable actions taken; relevance to stated goal.	Strategic actions taken; high value to challenging goals.
Evidence for growth	No mention of evidence of successful growth.	Vague allusion to evidence of successful growth.	Reasonable types of evidence of desired personal growth.	Clear statements of suitable evidence of successful growth.	Clear, quantitative, suitable evidence of successful growth.
Additional steps	No plan presented or plan unrelated to stated goal.	Vague plan given; little potential to reach stated goal.	Usable plan defined; moderate potential to reach stated goal.	Valuable plan given; good potential to reach stated goal.	Excellent plan; highly likely to reach stated, challenging goal.

Table 4. The scoring rubric used by instructors to provide feedback in the Professional Development Achieved activity

	Novice	Beginner	Intern	Competent	Expert
Growth description	Minimal or irrelevant description of growth.	Vague description of growth.	Reasonable description of growth.	Clear description of growth.	Rich, in-depth description of growth.
Proven value	No relevant evidence of value to project or person.	Vague evidence of value project or person.	Some evidence of value to project or person.	Strong evidence of value to project or person.	Insightful evidence of value to project or person.
Future development	No idea of future development.	Vague idea of future development.	General idea of future development.	Concrete idea of future development.	Transferable insightful idea about future development.

Professional Development Progress and/or Professional Development Planning assessments. This activity allows assessment of student achievement in professional development over the duration of the project and elicits future value of the professional development to the student. Students are again presented the twelve professional development abilities/attributes and are asked to rate their change in perceived importance of each ability and their change in perceived performance in each ability. The rating scale consists of three levels—decreased, no change, and increased. A decreased rating indicates that the student perception of importance or performance decreased significantly over the duration of the project. A rating of no change indicates that the student perception of the importance or performance has not changed significantly since the start of the project. An increased rating indicates that the student perception of importance or performance increased significantly since the start of the project. Students then identify the ability in which they experienced the most significant personal growth throughout their project and describe how they have grown in this ability, how that growth has proven valuable to the project, and how the growth experienced has prepared them for future professional development. The student's written reflections are scored by the instructor using the rubric shown in Table 4. Students can also receive written comments and suggestions for improvement from the instructor.

3.4 Web-based support

The IDEALS assessments have been implemented in a secure, web-based environment [1] that supports varied uses of the assessments in different course settings. The site contains assessment instruments, instructor and student interfaces, data archives, data processing, reporting functions, and companion instructional modules. The instructor specifies the assignment by indicating which students are to receive the assignment, if it is to be completed by individuals or by teams, the due date for student completion of the assignment, and the

due date for instructor feedback. Students complete the assignments inside or outside of class, depending upon the instructor's approach to integrating it with class instruction.

Students complete the professional development assessment assignments and receive feedback from the instructor online. Instructors are prompted to use a web-implemented version of the scoring rubrics shown for each of the professional development instruments and are provided comment boxes for writing additional feedback. The web system automates data compilation for instructor and student viewing. The assessment cycle is complete when students log back into the system to read feedback from the instructor. Researchers can anonymously access data transferred between students and instructors. Information maintained by the system can be used for grading, prompting instructor feedback, planning individual or team interventions, making adjustments to formal class sessions, and preparing documentation for curriculum review and accreditation. Additionally, the web system administers post-assessment surveys to instruct students about assignment quality and value. Researchers can use this information for testing the assessment instruments and for answering educational research questions.

4. Implementation and testing methodology

4.1 Implementation

The web-based TIDEE professional development assessments were pilot tested by engineering design educators at six institutions during the 2008–2009 and 2009–2010 academic years. Institutions differed with respect to size, location, student demographic, and public or private status. Each participating institution—Washington State University, University of Idaho, Seattle University, Rose-Hulman Institute of Technology, Smith College, and LeTourneau University—provided data from one or more of the assessments. Implementation of the professional development assessments varied by

institution and by instructor during the pilot testing, including the number and types of professional development assessments used and when the assessments were deployed. This approach ensured that a range of facilitation strategies would be employed to test the instruments in representative capstone design courses. 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 assessments. Briefings included discussion of the intent of the assessments, possibilities for their use in class, anticipated benefits from the assessments, and how to access and use the web-based system. In order to encourage participation, collaborating faculty were given flexibility in choosing which assessments they would use and in what term they would use the assessments. Stipends were provided as incentives for fulfilling commitments to administer assessments 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 (3–9 members). Two instructors used all three assessments in one course while other instructors used a subset of the three assessments. Both online and hard-copy versions of the assessment were used, but only online results are reported.

4.2 Testing methodology

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

4.2.1 User satisfaction surveys

User satisfaction was explored for both students and instructors involved with the professional development assessment activities. After the assessment assignment 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 development assessments. Only instructors evaluated the summative professional development assessment (Professional Development Achieved). 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.

4.2.2 Inter-rater agreement study

To provide an estimate of scoring consistency for the professional development assessments, 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 development assessments. Initial rate training included a review of the assessments and corresponding performance criteria, practice scoring of student work, score comparisons across raters, and time for discussion and justification of scores [25]. 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 [26]. Once sufficient under-

standing 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 each instrument.

5. Results

5.1 Professional development planning

A total of 261 students rated the importance and individual level or performance in each ability/attribute. Figure 1 shows the results of student rating of the importance of professional attributes/abilities. *Being a high achiever* received the most ratings of high importance while *relating inclusively*, *practicing self-growth*, and *adapting to change* received the most ratings of low importance. Figure 2 shows the results of student perception of their own level of performance in each of the professional attributes/abilities. *Serving professionally*, *solving problems* and *collaborating* received the

most ratings of high importance while practicing *self growth*, *designing products*, *leading others* and *adapting to change* received the most ratings of low importance. Students most frequently indicated that an area that is important for their project and that requires further development to enhance the project team's success was *communicating* (16.1% of respondents) while the least frequently cited was *servicing professionally* (1.5% of respondents) (Fig. 3). Faculty rating of students' written work in the Professional Development Planning assessment is shown in Table 5, where 238 pieces of student work were scored. The scoring used the rubric in Table 2. Students performed above the intern level in describing the impact of their selected area for improvement while they performed below the intern level in describing a plan for achieving growth as well as in describing evidence that what will result from achieving the growth.

5.2 Professional development progress

A total of 200 students provided and wrote about an

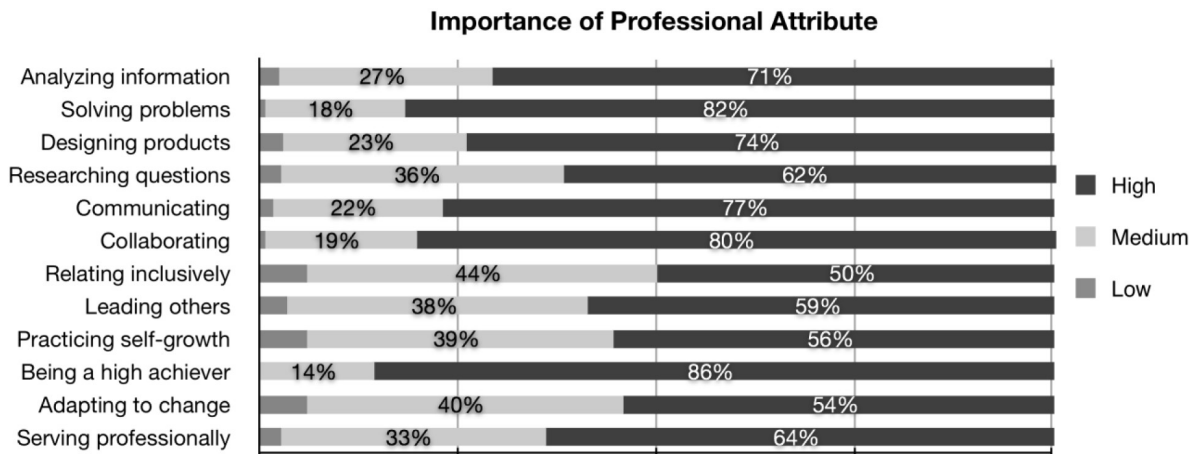


Fig. 1. The student rated level of importance of each professional ability/attribute (n=261).

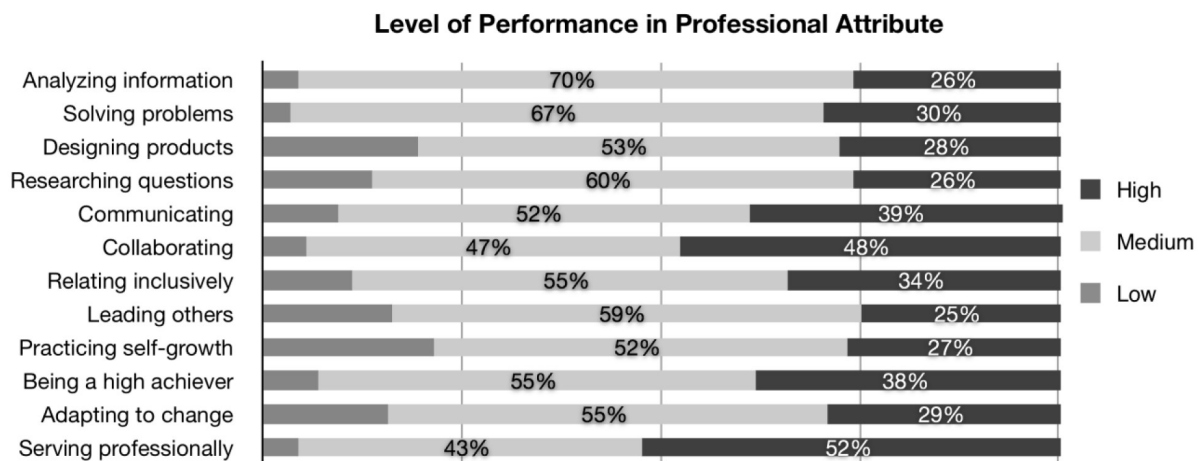


Fig. 2. The student rated level of self performance in each professional ability/attribute (n=261).

Student Selected Area for Growth: Planning

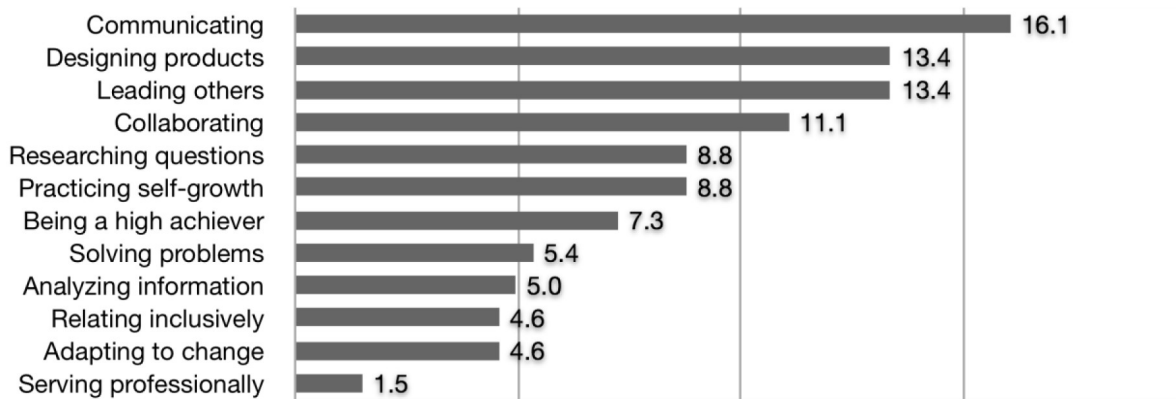


Fig. 3. Percentage of students that noted an ability/attribute as important for their project and that requires further development to enhance the project team's success (n=261).

Table 5. Instructor scoring of student written work in the Professional Development Planning exercise (n=238)

	Instructor ratings	
	\bar{X}	SD
Understanding impacts	3.4	0.9
Plan to achieve growth	2.9	0.9
Evidence for growth	2.7	1.0

Table 6. Instructor scoring of student written work in the Professional Development Progress exercise (n=200)

	Instructor ratings	
	\bar{X}	SD
Steps taken	3.3	1.0
Evidence for growth	2.9	1.1
Additional steps	2.7	1.1

area of growth in progress. Figure 4 shows the frequency of student responses to the area of growth in Professional Development Progress. *Communicating* (24% of respondents) was most frequently cited as the area of professional development in progress while *serving professionally* (0.6% of respondents) is least frequently cited as the area of professional development in progress. Faculty rating of students' written work in the Professional Development Progress assessment is shown in Table 6. The scoring was performed with the rubric in

Table 3. Students performed on average at an intern level when describing the steps that they have taken to achieve growth while they performed at less than an intern level when describing evidence that their growth has impacted project performance and when describing the additional steps that they will take to achieve the targeted development.

5.3 Professional development achieved

A total of 228 students performed the Professional Development Achieved assessment activity. Figure

Student Selected Area for Growth: Progress

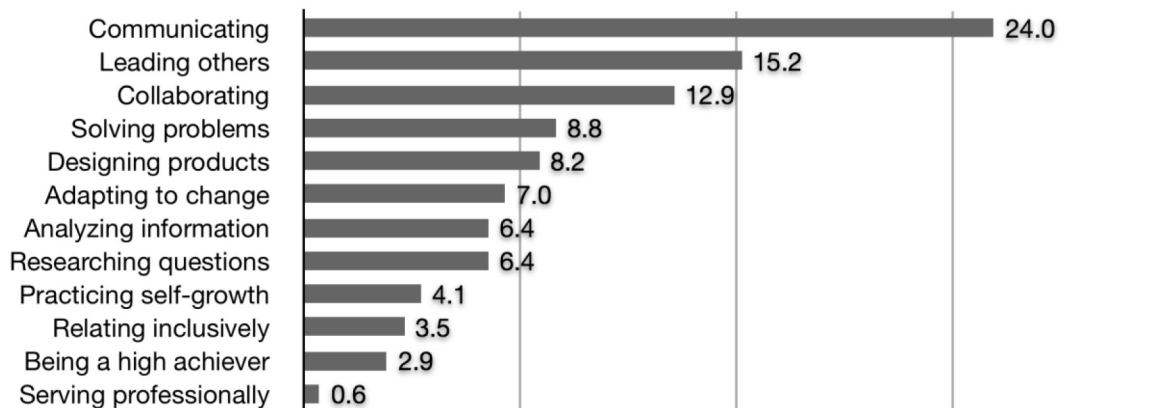


Fig. 4. Percentage of students that noted an ability/attribute was most significant in their growth mid-project (n=200).

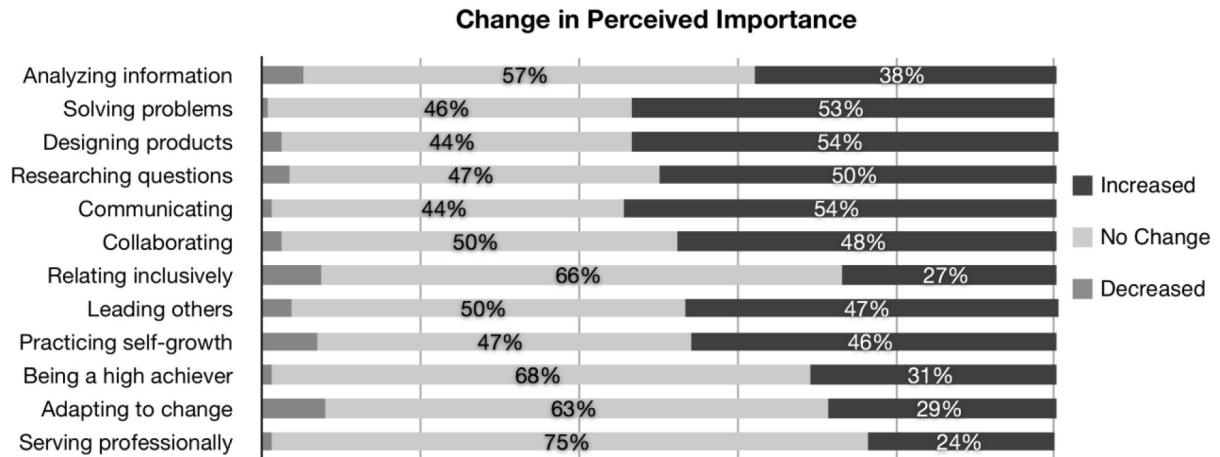


Fig. 5. Student indicated change in perceived importance of each professional ability/attribute (n=228).

5 shows the results of student rating of their change in perceived importance of each professional attributes/abilities. *Communicating*, *designing products*, and *solving problems* received the most ratings of increased importance while *relating inclusively*, *practicing self-growth*, and *adapting to change* received the most ratings of decreased importance. Figure 6 shows the results of student rating of their change in perceived performance of each professional abilities/attributes. *Designing products*, *collaborating*, and *solving problems* received the most ratings of increased performance while *collaborating* also received the most ratings of decreased performance. Figure 7 shows that students most frequently indicated the area of most significant growth was *collaborating* (15.4%), *communicating* (14.5%), *leading others* (13.2%), and *designing products* (12.7%) while the least frequently cited were *serving professionally* (2.2%), *being a high achiever* (2.6%), *relating inclusively* (3.1%), and *analyzing information* (3.9%). Faculty rating of students'

written work in the Professional Development Achieved assessment is shown in Table 7. The scoring was performed using the rubric in Table 4, where scores were on a scale of 1 to 5. Students performed on average above an intern level in all written portions of the assessment including describing the professional growth, how the growth has proven valuable to the project, and how the experience has prepared the students for future development. An above average example of student work and accompanying instructor feedback is included in Fig. 8 to provide an example of student/faculty interaction enabled by the assessment.

5.4 User satisfaction survey results

User satisfaction was measured from post-assessment surveys of instructors and students. Tables 8 and 9 indicate the number of faculty and students participating in these surveys. Both surveys used the 5 point Likert scale described in section 4.2.1.

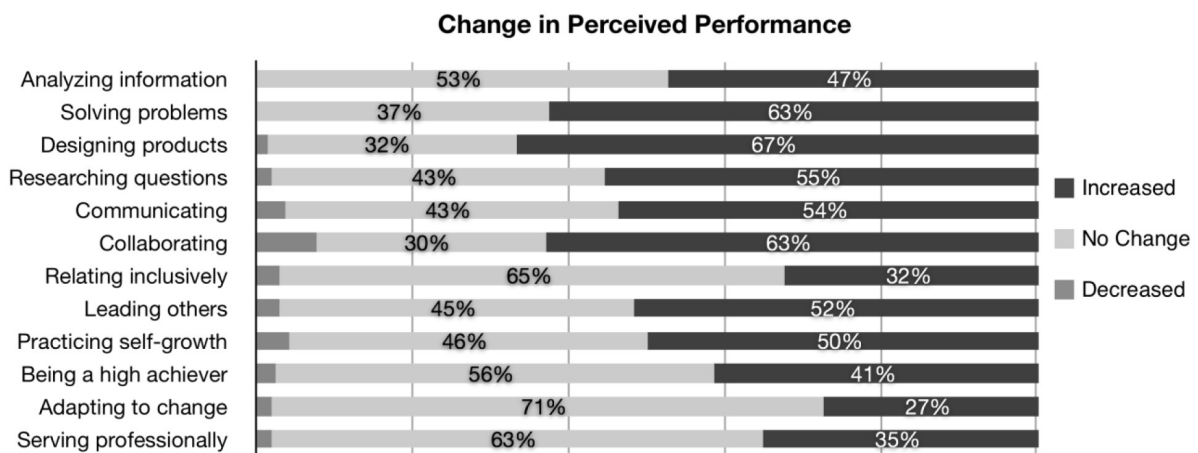


Fig. 6. Student indicated change in perceived performance of each professional ability/attribute (n=228).

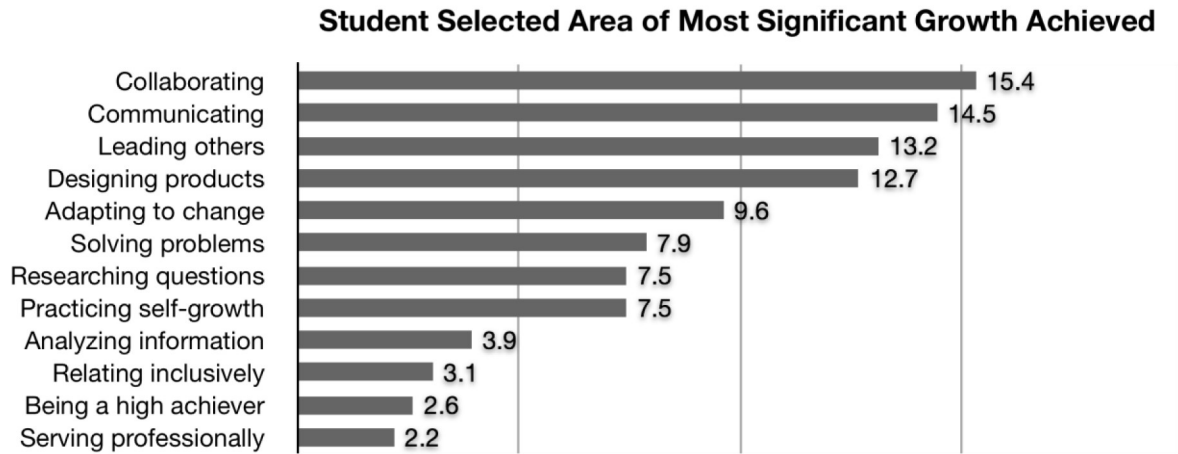


Fig. 7. Percentage of students that noted an ability/attribute as most significant growth achieved near the end of their project (n=228).

Table 7. Instructor means and standard deviations for scoring Professional Development Achieved (n=179)

	Instructor ratings	
	\bar{X}	SD
Growth description	3.4	0.6
Proven value	3.2	0.8
Future development	3.4	0.8

5.5 Inter-rater agreement results

Comparing ratings given by different raters for the same student work provides insight about the con-

sistency with which the assessment gives feedback to students. Table 10 presents results by different combinations of rater pairs for the four raters scoring Professional Development responses. 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 ten of the twenty scores they separately gave to student responses on the Professional Planning assessment. Their scores then differed by 1 point on nine additional student responses and they differed by 2

Area of most significant personal growth
Leading others

Describe how you have grown in this ability.
"During the first semester, I ended up doing the majority of the work because I didn't allocate enough work to other group members... by the end of first semester, I was burned-out because of all of the work I was doing and the other team members wanted to have more responsibility over certain areas of the project. It was at that time I realized that this IS a TEAM project. I was taking too much control and I needed to trust in my fellow team members."

Discuss how your growth in this ability has proven valuable (to you or your project).
"I realized that I needed to work WITH the other team members' strengths. For TEAMMATE1, that was giving him tasks that involved prototyping and hands-on-building... Once each team member had a specific area that they were they expert in, team productivity went through the roof!"

Describe how this growth experience has prepared you for future professional development.
"This experience will help me in the future because it has prepared me to work with others that don't approach engineering in the same way I do. I will need to be open to trying different methods so that the number and quality of design solutions is maximized. It is important for a team leader to recognize the strengths of each team member and utilize them throughout the project..."

Instructor feedback
I agree that your growth as a leader was the primary area of accomplishment that I recognized in your work this semester. You have enabled your teammates to achieve at levels that they would not have reached on their own...

Fig. 8. An example of student work and instructor scoring from the Professional Development Achieved assessment.

Table 8. Results of the instructor survey on accuracy and value of Professional Development Planning and Progress

	Professional Development Planning (n=13)		Professional Development Progress (n=7)		Professional Development Achieved (n=17)	
	\bar{X}	SD	\bar{X}	SD	\bar{X}	SD
How effective was the assessment in identifying areas where students or teams were struggling?	3.4	1.0	2.9	1.1	3.0	1.0
How effective was the assessment in identifying areas where students or teams were excelling?	2.0	0.8	3.3	1.0	3.9	1.1
How helpful was the assessment in guiding remedial instruction or other interventions?	3.4	0.6	3.6	1.0	3.0	0.9
How helpful was the assessment in guiding the generation of important feedback?	3.6	0.7	3.4	0.5	3.4	0.9
How confident are you that the resulting scores are accurate (trustworthy) representations of student performance?	3.1	0.6	3.3	0.5	3.3	0.9

Table 9. Results of the student survey on accuracy and value of Professional Development Planning and Progress

	Professional Development Planning (n=25)		Professional Development Progress (n=23)	
	\bar{X}	SD	\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?	3.8	0.9	4.1	0.9
How valuable to you personally was the assignment and feedback for increasing your overall understanding of the topic addressed?	3.6	1.1	3.7	1.0
How valuable to your team was the assignment and feedback for increasing your overall project success?	3.0	1.0	3.4	1.0

Table 10. Rater pair number (and percent) for each scoring difference

Professional Development Planning							
Difference	Rater Pairs*						Mean
	1-2	1-3	1-4	2-3	2-4	3-4	
0	10 (50%)	8 (40%)	12 (60%)	6 (30%)	8 (40%)	10 (50%)	9.0 (45%)
±1	9 (45%)	11 (55%)	6 (30%)	14 (70%)	11 (55%)	8 (40%)	9.8 (49%)
±2	1 (5%)	1 (5%)	2 (10%)	0	1 (5%)	1 (5%)	1.0 (5%)
±3	0	0	0	0	0	1 (5%)	0.2 (1%)
±4	0	0	0	0	0	0	0.0
Professional Development Progress							
Difference	Rater Pairs*						Mean
	1-2	1-3	1-4	2-3	2-4	3-4	
0	6 (30%)	12 (60%)	12 (60%)	4 (20%)	7 (35%)	11 (55%)	8.7 (43%)
±1	12 (60%)	6 (30%)	7 (35%)	14 (70%)	11 (55%)	9 (45%)	9.8 (49%)
±2	2 (10%)	2 (10%)	1 (5%)	2 (10%)	2 (10%)	0	1.5 (8%)
±3	0	0	0	0	0	0	0.0
±4	0	0	0	0	0	0	0.0
Professional Development Achieved							
Difference	Rater Pairs*						Mean
	1-2	1-3	1-4	2-3	2-4	3-4	
0	8 (40%)	10 (50%)	9 (45%)	15 (75%)	11 (55%)	8 (40%)	10.2 (51%)
±1	10 (50%)	7 (35%)	9 (45%)	5 (25%)	9 (45%)	10 (50%)	8.3 (41%)
±2	2 (10%)	3 (15%)	2 (10%)	0	0	2 (10%)	1.5 (8%)
±3	0	0	0	0	0	0	0.0
±4	0	0	0	0	0	0	0

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

points on the one remaining piece of student work. Averaging the point differences across assessments for each rater pair, 45.8% were in exact agreement, 48.1% differed by 1 point, 5.8% differed by 2 points, and 0.2% differed by 3 points.

6. Discussion

The reported work has limitations including a small sampling of data, the subjectivity of making ratings, and non-uniformity in assessment implementation and faculty facilitation. Faculty collaborators were given maximum flexibility for implementation to gain their buy-in and participation, but it is clear that the specifics of implementation and facilitation of assignments are important variables in determining the overall validity of this assessment instrument. Factors affecting successful implementation included: (1) timing of the assessment, (2) preparation of instructors and students, and (3) implementation of specific activities associated with the assessment. McCormack et al. [4] reported preliminary data on types of responses obtained from students and practical issues to be considered for effective implementation of this and similar assessments. The TIDEE group has recently developed instructional modules associated with each of the professional development assessments that provide a lesson plan outline for a single class period, a facilitation guide for instructors, and activity sheets for students.

The interpersonal abilities/attributes in Table 1 were consistently the most frequently cited for planned areas of growth, growth in progress, and growth that was achieved by students. The interpersonal attributes of *communicating*, *collaborating*, and *leading others* were among the top 4 most frequently cited attributes in Professional Development Planning and were the 3 most frequently cited attributes in Professional Development Progress and Achieved. Undoubtedly these attributes are highly visible to students in an open-ended, project and demand student attention from the inception of the capstone project through the conclusion.

The individual abilities/attributes in Table 1 were the least frequently cited attributes of planned growth, growth in progress, and growth achieved. *Serving professionally* was consistently the least frequently cited attribute. It is speculated that students interact with and see their impact of their designs on society infrequently in capstone courses. Interestingly, *adapting to change* increased substantially in the frequency of citations between the planning activity and the progress and achieved activities. Seemingly, the ever-changing nature of an open-ended product demanded that students alter plans and activities. For a student that is in a

large project for the first time, this type of change is likely not anticipated. *Collaborating* received the most ratings in both increased and decreased perception of performance during the Professional Development Achieved assessment. This might be attributed to the fact that students grew more accurate perceptions of their own collaborative ability, which may be worse than originally thought. It also might be attributed to a diversity of good and bad team experiences throughout the capstone project.

Instructor scoring of student work showed that the quality of the work was on average below the intern level in the Professional Development Planning and Professional Development Progress assessments and above the intern level for the Professional Development Achieved assessment. Results confirm instructor intuition that students struggle to make quality statements looking forward for purposes of planning and measuring future results while they are more successful at analyzing past events. By the Professional Development Achieved assessment, students have likely benefited from having experienced an entire planning and execution cycle in professional development. Whether students can transfer what they have learned about professional skill development and associated behaviors to the professional workplace is an open question. What can be said is that students receiving these assessments have become more aware of the importance of professional development and are more reflective about their skill development in the context of a capstone design course. Further research is needed to better understand the possible transfer of professional skill development from undergraduate education to the professional workplace.

While faculty scoring has some variability, the inter-rater reliability data in this paper suggests that minimal training in use of scales gives consistent results. Importantly, 93.9% of scores were within one score level while at least 45.8% of responses (instructors and teaching assistants) were the same. These initial rater agreement data suggest that Professional Development assessments can be scored reliably by individuals that receive minimal training.

In the post-assessment survey, student ratings of the formative professional development assignments increased across all factors from planning through progress. The students viewed the assessments as somewhat accurate to mostly accurate. The student perception of value to the individual and team increased from the professional Development Planning assessment to the Professional Development Progress assessment. These increases may be attributed to a student's improved aware-

ness of the importance of professional skills throughout a large project experience that approximates professional practice. The two lowest scores in the instructor survey are observed in identifying areas in which students excel in Professional Development Planning (2.0) and identifying areas in which students were struggling in Professional Development Progress (2.9). This may represent a discrepancy between performance (both high and low) that instructors observed in day to day project interactions and what some students actually wrote about when completing the assessment. It is important to remember that data captured by these assessment instruments is just a snapshot in time. This underscores the importance of properly preparing students through classroom activities preceding administration of the assessments, insuring that student motivation is high and that sufficient time is allocated for a complete response [4]. In several surveys, instructors mentioned that the ranking portion of the activity (H, M, L, etc.) was less valuable than the written component of the exercise. This is likely true, but there seems to be value in having students read the definitions and process the list of professional abilities/attributes before progressing with the assessment. This enables students and instructors to build a common vocabulary for professional development discussions and for the students to be prompted on abilities they might write about.

One program engaged in the professional development assessments used results from two elements from the Professional Development Planning and Professional Development Achieved assessments, along with corresponding instructor scoring, to measure achievement in program outcomes. The data obtained, along with the program targets are shown in Table 11. For element 1 in Table 11, 'Students will identify an important ability/attribute that needs further development and state impacts if ability/attribute is not developed,' the program set two levels of achievement. The program hoped that 90% of their students could progress from novice to beginner or higher. Furthermore, the program

hoped that 50% of their students could progress from novice to competent or higher. The program results indicate that the targets were exceeded for element 1. The program was able to exceed the established targets for elements 1 and 2 but was not able to achieve the targeted higher performance for attributes 3 and 4. For example, 98% of students achieved a rating of beginner or higher for element 4, 'Students will outline future development,' however, only 4% reached a level of competent or higher. Because of these results, the program is implementing changes to stimulate higher performance in elements 3 and 4.

The same program surveyed their advisory board (all practicing engineers or managers) about the importance of professional development planning, in general, and the use of the professional development planning, progress, and achieved methodology for measuring outcomes. The six advisory board members present unanimously supported the importance of professional development planning, in general, and the measurement approach being used in particular. In the discussion following the presentation they reported that their companies require a yearly plan and self-reflection that was often tied to either raises or promotions. It was the consensus that individuals who displayed higher levels of self-reflection and planning typically received more promotions and/or raises. Furthermore, they indicated that the employees who did not plan or self-reflect often stayed in the same position or at the same salary level. Through this dialog, the advisory board gave evidence that the IDEALS Professional Development assessments have content validity.

Finally, in an effort to gain input from practicing capstone design professionals, the IDEALS team offered a short course at the 2010 Capstone Design Conference. At the end of the workshop attendees were given a survey about the assessment instruments and corresponding teaching modules. The results are shown in Table 12. The attendees overwhelmingly supported the potential of the IDEALS assessments and modules to promote skill develop-

Table 11. An example of student performance and program targets in professional development using the IDEALS professional development assessments

Element	Program Targets	Student Performance	Target Met
Students will identify an important attribute/ability that needs further development and state impacts if attribute/ability is not developed.	90% Beginner or higher	92% Beginner or higher	Yes
	50% Competent or higher	62% Competent or higher	Yes
Students will develop a plan to improve this attribute/ability.	90% Beginner or higher	92% Beginner or higher	Yes
	50% Competent or higher	55% Competent or higher	Yes
Students will state evidence that demonstrates improvement of the attribute/ability.	90% Beginner or higher	99% Beginner or higher	Yes
	50% Competent or higher	10% Competent or higher	No
Students will outline future development.	90% Beginner or higher	98% Beginner or higher	Yes
	50% Competent or higher	4% Competent or higher	No

Table 12. Survey results from 2010 Capstone Design Conference on potential of IDEALS

Question	Yes	No	Maybe
Based on what you have seen in this short course, do you believe that the IDEALS assessments and modules would promote skill development among your students?	21	0	1
Based on what you have seen in this short course, do you believe your students would find the IDEALS assessments and modules engaging?	13	4	5
Based on what you have seen in this short course, do you believe that the evidence produced from the IDEALS web-based system would be useful for ABET documentation of Criterion 3i (recognition of the need for and an ability to engage in lifelong learning) for your program?	20	1	0

ment and present evidence that is useful in documenting lifelong learning for program accreditation. The participants were more tentative in their belief that their students would find the IDEALS assessments and modules to be highly engaging. First-hand experience using IDEALS assessments and modules in the classroom, beyond seeing these for the first time in a conference workshop, is likely to rectify these apprehensions.

7. Conclusion and future work

This paper examines the rationale for the IDEALS professional development assessments, explains performance tasks associated with each assessment, describes scoring rubrics for each assessment, and presents results to-date for both the formative and summative assessments. Preliminary findings support the use of the IDEALS assessments to assist students in planning and assessing their status in professional development. Student feedback indicates that they were engaged in the assessment process, found value in the assessment activities, and believed the instructor feedback to be accurate. Instructors found that the assessments were helpful in providing actionable feedback to the students, and inter-rater agreement in scoring student work was sufficiently consistent across instructors. These results show that the IDEALS professional development assessments and course materials hold promise as professional development tools for capstone students and as the basis for program assessment. The best indicator of the benefit of the IDEALS professional development assessments would be feedback from graduates in the first few years after graduation. At some point the TIDEE team hopes to begin collecting such longitudinal data.

The TIDEE team is continuing to gather data from professional skills assessments at multiple institutions. Data will be analyzed independently and across the progression from Professional Development Planning, Professional Development Progress, and Professional Development Achieved. The TIDEE group is currently refining curriculum modules that support the use of TIDEE assessments.

These contain course materials and lesson plans intended to prepare teams or individuals for more successful design experiences and to help instructors better integrate TIDEE assessments into project courses. The effects of these modules will be measured in terms of the quality of results witnessed in instructor scoring as well as student and instructor feedback through post activity surveys.

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