AC 2012-4389: INTEGRATED DESIGN ENGINEERING ASSESSMENT AND LEARNING SYSTEM (IDEALS):

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Integrated Design Engineering Assessment and Learning System (IDEALS):
Piloting Teamwork and Professional Skills Development Instructional Materials

Abstract

National and global engineering challenges require preparation of engineering graduates with strong technical, personal, and interpersonal abilities. For reasons of resource efficiency and consistent preparation, engineering programs would benefit from well-developed, integrated instructional materials and assessments that effectively motivate and facilitate development of professional skills vital to engineering practice. The purpose of this paper is to summarize the work of a National Science Foundation funded project team that created and pilot tested instructional modules for teamwork, professional development (self-directed learning), and professional responsibility. The modules and associated assessments are known as the Integrated Design Engineering Assessment and Learning System (IDEALS). The modules, available online to authorized instructors, include pre-class assignments, in-class exercises, and post-class assessment assignments. Pilot testing has shown that instructors in diverse settings are able to use full sets or selected modules in a skills area to achieve and assess desired professional skills learning outcomes.

Introduction

Many national leaders feel that the economic viability of the US hinges upon our ability to prepare engineers to compete favorably in a rapidly changing global economy.[1, 2] Proponents of economic development and advocates for social consciousness call for engineering graduates who bring more diverse perspectives to the profession and who are better able to address the grand challenges of the twenty-first century.[3]

What are the knowledge, skills, and behaviors needed by engineering graduates to succeed in a rapidly changing world? Industry has presented its lists of desired attributes.[4] The National Academy of Engineering has defined attributes needed by the engineer of 2020.[5] Notable among desired abilities are to: communicate effectively across disciplines and cultures, collaborate to create practical and innovative solutions, anticipate and adapt to change, and learn from experience.[6, 7] We must teach students to learn from and innovate amid engineering design and problem-solving challenges and to use reflection to make new discoveries, gain deeper understanding of problems, and find better solutions.[8]

Engineering design courses provide opportunities to develop many important professional abilities. Commonly cited design learning outcomes include teamwork, design competence, and other professional skills, including reflective practice. When students practice professional skills in project-based communities of professional practice with real project stakeholders, this context for learning and assessment can yield authentic professional skills and authentic assessment results.[9-12]

Engineering educators have developed a number of assessments for use in design projects to document and improve student achievement.[13-23] In earlier work, authors of this paper developed a set of fifteen assessments for capstone engineering design courses, now part of the Integrated Design Engineering Assessment and Learning System (IDEALS).[18] The IDEALS assessments address many of the desired attributes for engineers, while also supporting capstone engineering design learning (individually and as a team) and solution development (process and product). The validity of these assessments is grounded in a nationally established assessment framework, cognitive research on design learning, and classroom testing at seven diverse institutions.[18, 24-28]

During the period 2008-2010, data were gathered to pilot test the validity of IDEALS teamwork and professional development assessments. Results (reported elsewhere) indicate that both students and instructors found the assessments moderately accurate and useful for informing learning and for evaluating achievement.[25, 27, 28] The manner in which the assessments are facilitated appears to affect student attitudes, the quality of assessment results, and the validity of the assessments.[29, 30]

This paper will describe the development and pilot testing of IDEALS modules (instructional materials plus assessments) that were created to support student learning and to improve the effectiveness of assessments.

IDEALS Assessments

IDEALS assessments are built upon modern principles of learning and assessment.[31, 32] They push students to think about and explain their knowledge, discuss their performance with peers, apply their learning to professional challenges, refine previous knowledge, analyze their own learning processes, and extend learning to new situations. Assessments reinforce definitions of learning targets and provide feedback on a student's progress toward these targets. Each family of assessments (i.e., sequence of assessments in one area of skills performance) defines principles upon which to build new learning, facilitates improved learning, and finally documents learning achieved at a specific point in time.

Formative and summative assessment assignments use different assessment instruments. The formative assessments typically begin by asking students to consider factors important to the performance of interest and to rate themselves and/or teammates on achievements, motivating students and establishing performance expectations. Students are then asked to explain their understanding of strong performances and to propose ways to improve weaker performances. Assessments are scored using a rubric based on important elements of student performances. When students receive feedback tied to important elements of desired performance, this information helps them improve their understanding and future performances.

IDEALS assessments are summarized in Tables 1, 2 and 3, showing the types of questions and the factors used to score the performances for teamwork, professional development, and professional responsibility, respectively. The full assessments and their feedback templates (including scoring rubrics) are available at http://ideals.tidee.org.

Table 1. Teamwork Assessment Questions and Performance Factors

Assessment	Assessment Questions	Performance Factors
Team Contract	• Rate importance of 12 listed team processes to your team's productivity • Prepare a team contract that defines operating procedures for your team to be productive and to build strong teamwork	• Roles and responsibilities • Team relationships • Joint achievements • Member contributions • Team information management
Team Member Citizenship	• Rate importance of 12 listed types of member contributions • Rate each member on these contributions • Identify relative value contributed by each member • Describe a strength of each member • Suggest an improvement for each member	• Member relative contributions • Understanding of contribution strength and benefits • Understanding of desired improvement and necessary steps
Teamwork in Progress	• Rate importance of 12 listed team processes and process effectiveness • Describe use of the team's contract • Identify successes, challenges, and contract changes needed to improve performance • Submit revised team contract	• Contract use • Team process successes • Team process challenges • Team contract refinements • Contract match with needs • Contract written quality • Contract usability
Teamwork Achieved	• Rate changed importance of 12 listed member contributions • Rate each member on these contributions • Identify relative value contributed by each member • Summarize a noteworthy contribution of each member • Describe an effective team process • Describe your teamwork learning and its impact	• Peer ratings of contributions • Contribution summaries • Member benefits to team • Team process description, value and applicability • Teamwork learning achieved, process, and application

Table 2. Professional Development Assessment Questions and Performance Factors

Assessment	Assessment Questions	Performance Factors
Professional Development Plan	• Rate importance of and level of performance for 12 listed types of abilities/attributes • Identify 3 abilities needing further development • Define a plan to develop one ability	• Need for development • Development plan • Evidence needed for success
Professional Development in Progress	• Identify 3 abilities of attempted development • Explain development in an area attempted • Explain plan for a new area of development	• Old development motivation, actions, impact, refinement • New development need, plan, impacts expected
Professional Development Achieved	• Rate importance change, performance of 12 abilities • Explain professional development achieved • Explain learning about process of professional development	• Professional development achievement and impacts • Professional development learning and transfer

Table 3. Professional Responsibility Assessment Questions and Performance Factors

Assessment	Assessment Questions	Performance Factors
Professional Responsibility Formation	• Rate importance & level of proficiency for 7 listed professional responsibilities in project • Describe high proficiency in a responsibility • Describe how to enhance your project through better fulfillment of a responsibility	• Understanding and fulfillment of a professional responsibility • Understanding of opportunity and plan to show responsibility
Professional Responsibility Achieved	• Identify changes in perceived importance & level of proficiency for 7 professional responsibilities in project • Describe a professional or ethical challenge and how handled in your project • Evaluate handling of a challenge, pose better way in light of professional codes • Discuss envisioned challenge of following professional codes in future	• Appreciation, performance trends for a professional responsibility • Performance when facing a professional challenge • Understanding of a professional responsibility • Broader impacts of professional responsibility in future

IDEALS Modules

IDEALS modules include student activities and instructor facilitation guides. Some modules support specific learning outcomes, while others have more general purposes. Completed modules are posted on the IDEALS project website (http://ideals.tidee.org) for download by project personnel or other authorized users.

General Modules

General modules include an instructor's guide and additional resources for pre-class, in-class, and/or post-class assignments, but they do not have defined assessments. General modules prepare students for other IDEALS assignments or for broader application of IDEALS learning. The purposes of each general module are shown in Table 4.

Table 4. Resources for General Modules

Module Name	Purpose
IDEALS Introduction	• Motivate and guide students to engage in reflection, learning, and assessment • Introduce students to mechanics of online IDEALS assignments
Design Context	• Introduce students to engineering grand challenges • Challenge students to develop attributes desired in successful engineers
Transferring Knowledge	• Help students recognize value of professional skills to their future • Prepare students to "sell" themselves on their strong professional skills

Teamwork Modules

Table 5 shows the structure of modules for the teamwork skills area and the student-directed resources provided to support each module. The first three modules include pre-class and in-class

activities to prepare students for the post-class formative assessment. The fourth (summative) assessment does not include substantive readings or in-class activities. Examples of student work and instructor feedback are provided for each assessment to aid in setting realistic expectations. Students complete the IDEALS assessments online, and they receive feedback online.

Table 5. Resources for Teamwork Modules

Module Name	Activities (from Instructor's Guide)	Student Resources
Team Contract	*Pre-class*: Form teams; prompt students to consider what makes a good team *In-class*: Discuss requirements for effective teams; begin draft of a team contract *Post-class*: Complete (as a team) IDEALS **Team Contract** formative assessment; review feedback from instructor	#1: Team Contract Parts #2: Sample Bylaws Template #3: Team Test Cases
Team Member Citizenship	*Pre-class:* Read ref #3 and #4 *In-class*: Discuss readings, methods, and principles for giving/receiving feedback (ref #2, 5, 6) *Post-class*: Complete (individually) IDEALS **Team Member Citizenship** formative assessment; review peer and instructor feedback	#1: Assessment Examples for Scoring #2: IDEALS Assessment Cycle #3: SII Method for Assessment Reporting #4: Mindset for Assessment #5: (Sloan) Giving and Receiving Feedback #6: (McGill) Strategies for Giving/Receiving Feedback
Teamwork in Progress	*Pre-class:* Review Team Contract; read ref #1 and complete worksheet *In-class*: Discuss ref #2 relative to Team Contract; identify revisions to contract *Post-class*: Complete (as a team) IDEALS **Teamwork in Progress** formative assessment; review instructor feedback	#1: Team Contract Review Worksheet #2: Team Situation Worksheet
Teamwork Achieved	*In-class:* Examine, clarify assignment *Post-class:* Students (individually) complete IDEALS **Teamwork Achieved** summative assessment; review instructor feedback	

Professional Development Modules

Table 6 summarizes modules, activities, and student resource materials for the IDEALS Professional Development modules. The first module asks students to conduct inventories of their preferences and attitudes as a basis for needs that may be addressed by individual professional development. In-class discussions with teammates help students modify their understandings of development needs to guide their professional development. The second formative assessment prompts student reflection on progress and on needs of the team that may reveal needs for professional development, spurring individuals to more effective development efforts. The final (summative) assessment asks students to explain their development process and to give evidence of their advancements in professional development.

Table 6. Resources for Professional Development Modules

Module Name	Activities (from Instructor's Guide)	Student Resources
Professional Development Plan	*Pre-class*: Conduct personal inventories of preferences and/or skills; complete worksheet #1 *In-class*: Discuss members' inventory results, complete team summary in worksheet #2; discuss member opportunities for development; review expectations for assignment *Post-class*: Complete (individually) worksheet #3, IDEALS **Professional Development Plan** formative assessment; review feedback from instructor	#1: Professional Development Plan: Inventories #2: Professional Development Plan: In-Class Worksheet #3: Professional Development Plan: Post-Class Worksheet
Professional Development in Progress	*Pre-class:* Consider progress on professional development *In-class:* Discuss new and continuing project needs for professional development *Post-class:* Complete (individually) **Professional Development in Progress** formative assessment; review instructor feedback	#1: Professional Development in Progress: Pre-class Activity #2: Professional Development in Progress: In-class Activity
Professional Development Achieved	*In-class:* Discuss expectations for assignment *Post-class:* Complete (individually) **Professional Development Achieved** summative assessment; review instructor feedback	

Professional Responsibility Modules

Table 7 presents a summary of Professional Responsibility module activities and student resources. The first formative module, Professional Responsibility Formation, causes students to examine the ethical and professional responsibilities associated with their project and to identify actions to better fulfill these responsibilities. The second module, a summative assessment, documents students' understanding, processes, and achievements in Professional Responsibility.

Table 7. Resources for Professional Responsibility Modules

Module Name	Activities (from Instructor's Guide)	Student Resources
Professional Responsibility Formation	*Pre-class*: Review codes of ethics for relevant fields *In-class*: Discuss engineering codes (ref #1) and professional responsibilities and their application to project (ref #3); complete worksheet #2 *Post-class*: Complete (individually) IDEALS **Professional Responsibility Planning** formative assessment; review feedback from instructor	#1: NSPE Code of Ethics #2: Engineering Ethics Worksheet #3: Professional Responsibility Examples
Professional Responsibility Achieved	*In-class:* Discuss assignment and expectations *Post-class:* Complete (individually) IDEALS **Professional Responsibility Achieved** assessment; review instructor feedback	

The impact of IDEALS professional skills modules depends upon the effectiveness of module implementation. What is proper implementation depends upon several considerations. First,

assignments that are confusing or seem irrelevant to students do not receive serious attention, so students learn and achieve less. Low motivation also causes assessment results to be less valid. On the other hand, assignments that require too much administrative time and do not aid grading, student learning, and program accreditation will receive less serious attention from faculty. Any negative responses from students or faculty may lead to discontinuation of IDEALS module use, depriving students and faculty of potential benefits from effective use of the modules.

Module Implementation

IDEALS professional skills modules were developed in 2009-2010 and implemented in different capstone design courses for pilot testing during 2010-2011. To capitalize on the many different modules, the flexibility in which modules may be used, and the diversity of collaborating institutions, instructors at each institution selected and implemented modules based upon their own preferences and course constraints. Engineering disciplines that implemented modules include mechanical, electrical, aerospace, civil and environmental, computer science and engineering, biological and agricultural, and bioengineering. Participating institutions included public and private doctoral and master's granting institutions, HBCU, all-women institution, and a technical institute. Student projects spanned a variety of interdisciplinary and discipline-specific design projects— ranging from competitions to industry-sponsored projects and from entrepreneurial to humanitarian in nature. Thus, this pilot testing provides a broad sampling of conditions that will inform future development and testing of the IDEALS modules.

The modules used by engineering faculty at the seven collaborating institutions varied markedly. Some instructors used modules in only one skills area, while some used modules in two or three areas. Some used all modules in a skills area; others did not. Some used modules in their entirety, while others used primarily the assessment part of the modules. Thus, the instructors selected and used the modules in ways that best fit their needs and goals for the design course, which models the practices one would expect when IDEALS modules are used by the engineering community.

Evaluation Methods

Modules were evaluated in a variety of ways that included normal classroom use. Data gathered from students included their responses to assessment questions and to follow-up questions on the value of the assignment, time spent on the assignment, accuracy of its portrayal of their knowledge, and instructor scoring of their responses. Instructor scores of student assessment responses were also available. A separate evaluation was made of inter-rater agreement among faculty and graduate students who scored assessment responses. Thus, classroom-based evaluations focused on the assessment part of modules, not the entire module.

Faculty were interviewed to gather first-hand perspectives on IDEALS modules they had used. These were capstone design instructors from collaborator institutions, most of whom have intimate knowledge of the modules, philosophy and theory behind the modules, and how to use modules in a capstone design course. Each had used a subset of modules and resources available for the modules they implemented. Instructors responded to a prescribed set of questions

administered by telephone interviews. Their responses were transcribed and checked for accuracy before finalized.

Former students were interviewed via telephone approximately five months after finishing their IDEALS module experiences the previous academic year. Many were employed or in graduate school at the time of their interviews. These former students were invited by capstone faculty to participate in the interview (and offered an incentive gift card); those agreeing to participate were included in a pool from which four were selected from each of the seven schools. A graduate student conducted the interviews by: (a) sending students interview questions and copies of assessments they had completed in their class, (b) interviewing at times convenient to the interviewee, and (c) sending transcribed responses to interviewees to confirm their accuracy.

Evaluation around Classroom Use of Assessments

Data from the Team Member Citizenship assessment gave valuable insights about student and faculty perceptions.[25] Mean student responses to the importance of various member contributions suggest that students view a list of twelve team member contributions as moderate to high in importance for team success. Individual appraisal of self and peer contribution to the team were usually rated as 'good' to 'very good.' As expected, mean self-ratings of performance of the contributions tended to be higher than mean peer ratings of the same contributions.[33] In addition, students' explanations of member strengths and areas to improve provided insights into ways the Team Member Citizenship assessment fit expectations. Faculty rating of students' written explanations of member strengths and coaching for improvement provided additional evidence that the assessment provides results as expected. Faculty from all institutions tended to give higher scores for the member strength assessment item responses than for the coaching of improvement items. Data seemed to match the intuitive perception of expected student performance, in that students will perform better in reporting observations and struggle when asked to demonstrate higher level critical thinking needed to coach improvements.

Initial inter-rater agreement data provided tentative information about scorer agreement, suggesting that the Team Member Citizenship assessment can be scored reliably by individuals receiving basic scoring training.[34] Averaging the point differences for the six rater pairs, 45% were in agreement, 52% differed by one point, and 3% differed by two points. User satisfaction was indicated by viewing student and instructor rating summaries. Out of 62 respondents, 38 students (61%) perceived instructor feedback as very accurate or mostly accurate, 30 students (48%) found the exercise to be personally very valuable or generally valuable, and 27 students (44%) found the exercise to be very valuable or generally valuable to the team. Additional student comments (n=25) offered insight into the personal value derived from the assessment experience and provided some suggestions for improving the activity.

Professional Development Module Evaluation

Students participated in three professional development assessment activities: Professional Development Plan, Professional Development in Progress, and Professional Development Achieved. Results of the assessment activities indicated that students better achieve targeted

professional development that benefits themselves and their team's project.[27] A total of 261 students rated the importance and their own level of performance on attributes and abilities necessary for professional development planning. "Being a high achiever" received the most ratings of high importance for planning, while "relating inclusively," "practicing self-growth," and "adapting to change" received the most ratings of low importance. The majority of students indicated high levels of self-performance for "serving professionally" and "collaborating." Further, "communicating" was most often selected by students as the ability or attribute important to their project that required further development to enhance the team's success.

Similarly, "communicating" was most frequently cited as the area of professional development in progress (24% of respondents, n=200). "Serving professionally" was the least frequently cited area of professional development in progress (0.6% of respondents). Further, faculty scoring of student performance indicated students performed on average at an intern level when describing the steps that they have taken to achieve growth. Faculty ratings also indicated that students performed at less than an intern level when describing evidence that their growth has impacted project performance and when describing the additional steps necessary for achieving the targeted development.

Results from the Professional Development Achieved assessment activity (n=228) indicated that students rated "communicating," "designing products," and "solving problems" to be of increased importance as the project progressed, while "relating inclusively," "practicing self-growth," and "adapting to change" received the most ratings of decreased importance. Students gave the most ratings of increased performance over the project duration to "designing products," "collaborating," and "solving problems," while "collaborating" also received the most ratings of decreased performance. Further, the four primary areas in which students indicated most significant growth were "collaborating" (15.4%), "communicating" (14.5%), "leading others" (13.2%), and "designing products" (12.7%). The least frequently cited areas of growth were "serving professionally" (2.2%), "being a high achiever" (2.6%), "relating inclusively" (3.1%), and "analyzing information" (3.9%). Faculty scoring of student achievement indicated that students performed on average above an intern level in all written portions of the assessment including describing the professional growth, how the growth had proven valuable to the project, and how the experience had prepared them for future development.

Post-assessment questionnaire feedback from students and faculty indicated that instructors effectively integrated teamwork and professional development instruction and assessment for added value in the design project classes. Thirteen instructors and twenty-five students completed a post-assessment survey following the Professional Development (PD) Plan activities, while seven instructors and twenty-three students completed a survey following the Professional Development in Progress activities. In addition, seventeen instructors completed a post-assessment survey following the Professional Development Achieved activities. Analysis of instructor responses indicated that all three assessments were effective in identifying areas where students or teams were struggling, and these were helpful in guiding interventions and in providing useful feedback. The PD Progress and PD Achieved assessments were more effective in identifying areas where students or teams were excelling. Analysis of student responses indicated that the scores and feedback they received on the planning and progress assessments accurately reflected their performance and the performance of their team. In addition, students

found the assignment and feedback valuable for increasing their overall understanding of the topic addressed and for increasing their overall project success.

Professional Responsibility Module Evaluation

The first professional responsibility instrument (formerly Professional Practice assessment) and associated rubric were developed to assess student understanding and skill in analyzing areas of strength and opportunity surrounding a professional responsibility in a student's design project. The professional responsibility (PR) assessment was evaluated using multiple methods to determine if the instrument and companion scoring rubrics were useful, usable, and desirable for 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. In addition, an inter-rater agreement study was performed, and students and instructors completed a brief follow-up questionnaire, offering feedback about their perceptions of the usefulness and accuracy of the formative professional responsibility assessment.

Ninety-six percent of students (n=161) rated that (of seven areas of professional responsibility) "work competence" was highly important while 37 percent of students reported that "sustainability" was of low importance to their project. For self-assessment, students felt that they had performed at a high level in terms of "honest communication" (76%) while they reported a low level of performance in terms supporting "sustainable design" (12%). "Work competence" was most frequently cited as an area of professional responsibility demonstrated well and as an opportunity for improvement. "Sustainability" and "social responsibility" were least frequently cited as the areas of responsibility demonstrated, likely due in part to the student's inability to recognize issues of sustainability and social responsibility in their project. Faculty scores showed that students performed at intern levels in all parts of the assessment and scored lowest at developing plans to improve in their demonstrated professional responsibility.

Inter-rater agreement provided insight about the consistency with which the assessment gave feedback to students. On average, 44 percent of raters were in full agreement, 53 percent differed by one point, and 3 percent differed by two points. The post-assessment survey indicated that faculty perceived the results as mostly accurate and that the assessment process generated valuable feedback. In addition, students indicated that the feedback was somewhat accurate to mostly accurate, and they perceived the personal value of the professional responsibility assessment to be greater than the assessment's value to the project. Not all faculty and students who participated in the assessment completed the survey. Post-assessment discussion with the subset of faculty who implemented the professional responsibility curricular materials and assessment offered additional insights that the professional responsibility assessment results can be packaged as part of an ABET self-study report addressing Engineering Criterion 3f.

 Faculty Interview Evaluation Results

Faculty interviews were conducted in two ways: individual interviews and a group interview. Individual IDEALS collaborator interviews were planned for ongoing data collection from October 2010 through January 2011. Individuals were asked thirteen questions at the completion of each module, after they had given feedback to students. Results showed that the modules

properly support the associated assessments, both from a student perspective and from a faculty perspective.[26] Instructors also indicated that the modules add value to capstone project work and that the supplementary resources were adequate. They agreed that the modules aligned well with course outcomes, project learning, and assessment activities. Most agreed that there is suitable consistency between modules in their structure and implementation, and that modules can be used effectively on a stand-alone or ala carte basis to meet program needs. Instructors remarked that most module protocols were consistent and organized. Finally, they indicated that value gained from using modules was adequate to justify the time they and their students invested.

A whole-team interview was conducted with IDEALS project collaborators during a team teleconference on July 18, 2011. First, faculty mentioned that the progression of modules provided built-in check points for monitoring student work as the course progressed. Because faculty received few student questions about module specifics, they believed that students completed the modules with few problems. Faculty also perceived that students liked the tasks associated with the professional development module and engaged readily in these activities when they understood how personal information was being used to advance their own performances. Based on conversations with students, faculty believed that students learned important concepts from the modules. Faculty felt strongly that students gained significant knowledge and skills from the IDEALS module completion experience.

Alumni Interview Evaluation Results

A total of 28 former capstone design students (alumni) from seven institutions completed the IDEALS follow-up interview. Interviews were conducted by telephone, with the exception of two which were completed via email for reasons of proximity. Prior to each interview, alumni were sent interview questions and assessment instruments they had completed while in their capstone course. During the interview, alumni were asked to comment on the overall value gained from the IDEALS instructional activities and the assessments, the aspects of the IDEALS modules that were of greatest value to them, the degree to which the IDEALS modules helped them learn to think and act like a professional and to produce a high quality design solution, and the ways in which the IDEALS modules have been useful in life after the capstone design course. Interview notes were taken by the caller and sent to participants immediately after the interview to ensure that participants' comments were captured accurately. After all interviews were completed, data were aggregated and analyzed for themes and for influences.

The majority of alumni interviewed indicated that they gained moderate value overall from the IDEALS instructional activities and assessments. The modules were valuable in both team building and professional growth. Both the activities and assessments were helpful in identifying their strengths and weaknesses and in providing them feedback from other students and instructors. Some alumni found modules useful for learning better ways to communicate with their teammates. They agreed that IDEALS was valuable in providing them opportunities for professional development that benefitted them later, such as in building cover letters and resumes. Some alumni found less than moderate value in the IDEALS modules; they felt that the assessments and activities were busy work or that they were repetitive and a waste of time. In

sum, alumni found the overall value of the IDEALS modules (activities and assessments) to be moderate.

By far, alumni found the assessments to be the most valuable part of the IDEALS module, followed by class discussions and readings. "Assessments really forced you to look at yourself and look at how you're working from day one through the end of the program, and also having professor feedback so you know what you think you're doing is actually how you're coming across." Members' assessments of other members helped students see that people had different perceptions. Several mentioned that the greatest value was in the reflection process. The majority of alumni indicated that modules were moderately helpful in their learning to think and act like a professional. Examples of how IDEALS modules had helped students included: completing industry performance evaluations, setting goals, conducting self-evaluation and assessment, emphasizing teamwork, creating a team contract, using self-reflection to "review one's own approach", understanding team member personality traits and being able to identify which person is best suited to help solve problems at-hand, knowing how to act in meetings, examining how a team functions at different levels, reflecting on how to be a better leader, having stronger professionalism, interacting professionally with a liaison or advisor, not dwelling on "petty human idiosyncrasies," understanding the importance of clearly defined roles and responsibilities, portraying ideas, communicating better, writing peer-evaluations, and learning teamwork in a group environment.

Alumni interviewees varied in their ratings of the degree to which the IDEALS modules helped them produce a high quality design solution. Six of them indicated that the modules were of no help, two of little to no help, seven of little help, two little to moderate help, eight of moderate help, and three of great help. Many suggested the benefit gained was more indirect, in the form of team communication and the necessary steps leading to the design solution. One participant summarized: "I don't know if they increased the quality of the final design, but they made it easier to get to that end result; made it smoother for teammates. The team members grew more as professionals than we would have without the IDEALS modules, even though this specific design may not have greatly benefited from it." Others intimated that IDEALS was helpful in teaching professional development, communication, and leadership skills. Thus, the IDEALS modules indirectly helped students produce a high quality design solution.

Almost unanimously, IDEALS alumni interviewees found the professional development (PD) assessments and activities to be most useful in professional life after their capstone design course. Aspects of the PD modules that were useful included: identifying strengths and weaknesses, self-reflection, setting goals, communication skills, negotiation, networking, writing professionally, establishing clearly defined responsibilities and prioritizing, and building group skills. Some indicated that the modules helped them in job interviews, in actual job performance, in summer internships, in communicating with their superiors, in working with human resources personnel for performance reviews, and overall in how they presented themselves professionally to others. One alumnus commented, "I was better prepared in my current job to set my own goals and have them be specific, measureable, attainable, and reasonable after going through this process." Another said, "It just has given us the tools to continue that sort of personal development and knowing it is something you have to set a goal for; it's not something that's

just going to happen." In sum, alumni felt the Professional Development Plans were most beneficial in their life after the capstone design course.

What were impacts of differences in the ways that modules were used? Statistical analyses were conducted using SPSS 17.0 to determine correlations between the ways in which modules were used (implementation factors) and the alumni ratings of impact of the modules used. Alumni rated modules on three items: overall value gained from the modules, how much modules helped students learn to think and act as a professional, and how helpful the modules were in producing a high quality design solution. Implementation factors included: (a) number of modules used, (b) number of full modules (pre-class, in-class, and post-class parts) used, (c) number of teamwork modules used, (d) number of professional development modules used, and (e) number of professional responsibility modules used. Results of the statistical analysis that showed significant correlations are summarized in Table 8.

Table 8. Correlations (*r*) between Implementation Factors and Module Impacts

Implementation Factor	Ratings of Impacts	Correlation
No. of modules	Overall value gained	$r=.379$, $p<.05$
No. of modules	Helped to think and act as professional	$r= .427$, $p<.05$
No. of full modules	Helped to think and act as professional	$r = .450$, $p<.05$
No. of teamwork modules	Overall value gained	$r=.473$, $p<.05$
No. of teamwork modules	Helped to think and act as a professional	$r=.426$, $p<.05$

The **number of modules** implemented was significantly correlated with overall value gained from the modules and with how the modules helped students' to think and act like a professional. The number of **full modules** used was significantly correlated only with how much the modules helped students learn to think and act like professionals. Negative but statistically insignificant correlations occurred between the number of full modules used and both the overall value gained from the modules and the degree to which modules helped produce a high quality design solution—suggesting that too much module work distracted from skills learning and project success. The use of teamwork modules gave students significant value and helped them think and act like professionals. The professional development and professional responsibility modules, used sparingly by faculty, did not show significant correlations with impacts on project work or other perceived benefits.

Conclusions and Recommendations for Future Work

IDEALS modules were developed for the purpose of supporting effective learning and accurate assessment of achievements of professional skills. The structure of pre-class, in-class, and post-class components of modules gives students prerequisite knowledge, exposure to classmate perspectives, and an opportunity to articulate targeted performance and understanding. Additionally, sequential use of modules in a skills area give students repeated exposure to a topic, multiple sources of feedback, and opportunities to reflect on past performances and understandings— all of which deepen learning. Because these modules are situated in a design project context, learning and assessment are connected to a professional environment that increases motivation and authenticity in learning. Importantly, the IDEALS modules create

opportunities for learning and assessment of professional skills as a natural part of design projects in an engineering curriculum.

IDEALS assessment results and feedback from students and instructors give evidence that the modules support learning of professional skills— some of which benefit the students' current project work and others that are valuable in future professional work environments. It appears that the number of modules used in a course must be adequate to produce the desired impact but not so numerous as to distract significantly from project work. The use of full modules (pre-class, in-class, and post-class parts) helps develop professional thinking and action in students.

The diverse conditions under which IDEALS modules were tested supports the concept that modules are transferable to most engineering capstone design courses. Modules were used in courses with projects lasting one semester, two semesters, two quarters, and three quarters. Instructors using IDEALS modules followed relatively similar design processes but with a wide range of design reviews, presentations, and milestones. Instructors chose varied modules to complement their design project assessments and to align with their learning objectives. The fact that significant impacts of modules were demonstrated with such varied implementation strategies speaks positively for the transferability of modules to different course contexts. Earlier work showed that facilitation of modules contributes to students' motivation, so future research should investigate effects of facilitation on the learning outcomes of interest.[29, 30] Overall, more data is required to replicate implementation conditions so that results can be stated with greater certainty.

Acknowledgements

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