Work in Progress: Assessing Motivation in Capstone Design Courses

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Abstract
Effective assessment of student learning outcomes desired by industry is required to truly impact curriculum change. As part of a National Science Foundation (NSF) project, several workshops and advisor meetings have guided the selection of outcomes and creation of the first draft of assessment instruments to measure selected outcomes. Over 1000 respondents to a variety of industry surveys, including those identified by industry representatives in the Transforming Undergraduate Education in Engineering (TUEE) workshop, identify top industry-sought outcomes as curiosity, critical thinking, teamwork, motivation, and communication. The authors selected motivation as the first outcome to address and chose the capstone design course as the first test bed. Interviews with faculty led to definition of design requirements for assessment instruments for use in capstone courses. The 2016 Capstone Design Conference workshop and a follow-on workshop at the American Society for Engineering Education (ASEE) annual conference led to the finalization of the first set of four assessments to measure student motivation. This paper describes the learning outcome selection process, assessment development process, and initial assessment instruments.

Keywords: assessment; learning outcomes; engineering education; capstone; industry; motivation

Introduction

According to voices from industry, Transforming Undergraduate Engineering Education (TUEE) Phase 1 report and The Engineer of 2020 [1,2], engineering graduates are not always demonstrating those learning outcomes needed to be successful in the workforce. The authors believe that to improve student learning outcomes requires curriculum change. But change must be directed by effective outcome assessments. As part of a National Science Foundation (NSF) funded project (DUE 1504728), the authors identified the top unmet outcomes sought by industry and created assessment instruments to support student learning and measurement of achievement.

To determine the most important learning outcomes, the authors studied previous surveys and other reports that identified the knowledge, skills, and abilities expected in engineering graduates. Sources included papers and surveys done by academic professionals and industry leaders discussing learning outcomes that should guide efforts to improve engineering education [4,5,6,7]. Due to the importance of accreditation to engineering degree programs, ABET Engineering Criteria were the starting point for creating a list of learning outcomes that are expected in engineering graduates [3]. Criteria 3a-k, student outcomes, are presented in Table 1.

Table 1. ABET Criterion 3- Engineering Student Learning Outcomes

a.	An ability to apply knowledge of mathematics, science and engineering
b.	An ability to design and conduct experiment, as well as to analyze and interpret data
c.	An ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
d.	An ability to function on multidisciplinary teams
e.	An ability to identify, formulate, and solve engineering problems
f.	An understanding of professional and ethical responsibility
g.	An ability to communicate effectively
h.	The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
i.	A recognition of the need for, and an ability to engage in life-long learning
j.	A knowledge of contemporary issues
k.	An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

In addition to ABET student outcomes, learning outcomes listed in the TUEE Phase 1 report were considered carefully because they reflect industry perspectives. Outcomes are rated by importance and by extent to which they are observed in engineering graduates [1]. Because neither ABET nor TUEE outcomes were defined in terms that are consistently interpreted, the authors developed definitions of fifteen top outcomes that encompass both ABET and TUEE's results [1,3]. The learning outcomes defined in Table 2 were used to guide additional investigation that either supported or challenged the importance of these outcomes to employers of engineering graduates.

Table 2. Student learning outcomes definitions

Outcome	**Concise Definition**
Communication	Communicates effectively and persuasively with varied audiences using both visual and auditory media
Engineering Problem Solving	Solves real-world engineering problems through careful investigation and development of solutions that prove useful for achieving goals
Project Management	Manages project tasks and human resources to accomplish established goals and objectives
Teamwork (Multidisciplinary)	Enables team effectiveness through individual contributions, collaboration, and team-building actions
Critical Thinking	Objectively analyzes and evaluates a situation and forms sound judgment
Ethical Standards and Responsibility	Demonstrates responsible actions based on ethical principles, business norms, and professional guidelines
Prioritization	Arranges tasks or objectives by order of importance in the context of competing interests
Entrepreneurship/ Intrapreneurship	Exhibits capacity and willingness to develop ideas or products into business opportunities in light of associated risks
Systems Integration	Combines component parts conceptually into a coherent whole possessing synergistic features and functions
Self-Drive & Motivation	Demonstrates intentional actions stimulated by personal energy, values, and attitudes

Cultural Adeptness	Helps people of different cultures and backgrounds belong, participate, and benefit from engineering activities
Risk Taking	Takes actions in pursuit of desirable benefits while controlling possible undesirable outcomes
Curiosity and Learning Persistence	Demonstrates a pattern of seeking new ideas and knowledge by self-motivated exploration
Economics and Business Acumen	Integrates principles of economics and business practice into engineering decision making
Engineering Fundamentals	Applies mathematics, science, and engineering principles to answer questions or solve problems

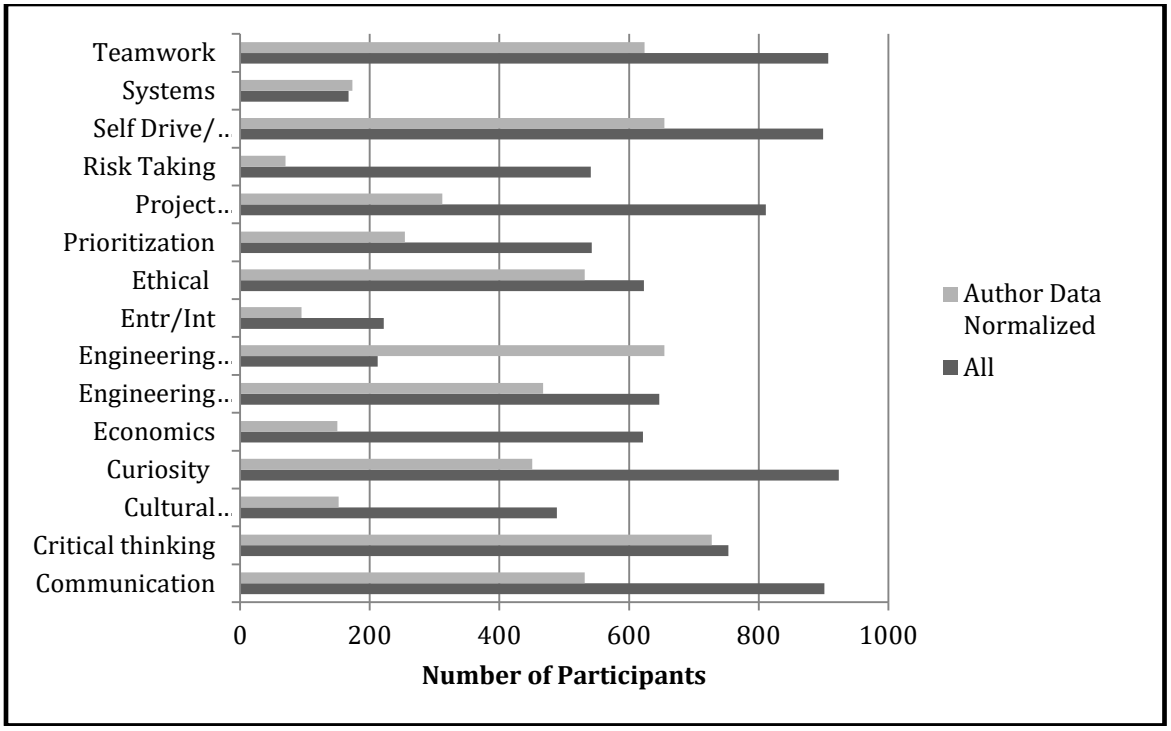
Selecting the First Learning Outcome to Address

A number of third-party surveys sought the importance of selected learning outcomes in industry. Wolfe identified the most important learning outcomes identified by MIT graduated engineers working in industry [4]. Hundley contributed a list of the top eight outcomes desired in the global engineer, based on survey data conducted with the International Federation of Engineering Education Societies [5]. McMasters and Komerath of The Boeing Company contributed another list of top outcomes according to a survey of their industry professionals [6]. Danielson and colleagues identified the important outcomes needed for mechanical engineering [7]. A compilation of data from these sources identified the top four learning outcomes as curiosity, teamwork, motivation, and communication.

To help ensure consistency of comparing similarly named outcomes from different sources, the research team sought independent data to confirm the most important outcomes. The team created its own survey using our definitions to find relative importance of the fifteen outcomes defined in Table 2. The survey was created through Qualtrics, an online survey instrument. Qualtrics provides a convenient way for participants to complete surveys on their cellular phones or computers and on their own time. Results are automatically and anonymously submitted and compiled [8]. The survey was distributed to industry representatives who serve as advisors or clients for engineering capstone programs at various universities. The survey asked industry representatives to rank order learning outcomes required for successful and productive employment. Results from eighty-nine representatives identified critical thinking, motivation, engineering problem solving, and teamwork as the top learning outcomes.

The survey results for both the literature-based research and the team's industry survey are compared in Figure 1. The authors' survey data is normalized to compare with the composite data. From this plot, the five student learning outcomes identified most frequently by industry are: curiosity/learning, teamwork, self-drive/motivation, communication, and project management.

Figure 1. Industry Surveys of Desired Learning Outcomes



In order to select the one learning outcome to address first, the team began by defining a set of user needs (factors) for assessments to be used in capstone design courses, as defined below.

- Capstone appropriate – suitable for learning and assessing in capstone course (authors and local faculty survey)
- Individual assessment – can be assessed as a performance of an individual student (author judgment)
- ABET – important to ABET accreditation (existing and proposed criteria) [3]
- Industry value – valued by industry (combined survey data)
- Institution importance – typically valued by educational institutions (TUEE 2nd workshop) [9]
- Student value – valued by students (TUEE 2nd workshop) [9]
- Industry dissatisfaction – reported by industry as lacking in graduates (TUEE 1st workshop) [1]

Table 3 shows a decision matrix used to consider each outcome in the light of these factors important to assessment in capstone design courses. A weighting for each need (1 to 5) is assigned in column two. A score indicating how well each outcome meets each need is entered with a score of 1 to 3. The basis used to help score each outcome based on a given need is noted in the factor definitions above (in parentheses). The weighted product of each score is summed for each column to calculate a total score for each outcome at the bottom of the table.

Results in Table 3 show that five outcomes scored the highest (shaded scores): teamwork, self-drive/motivation, communication, critical thinking, and curiosity/learning. After noting high ratings for self-drive/motivation by industry in Fig. 1 and realizing that motivation is generally

not assessed in capstone courses, the authors chose "motivation" as the first outcome for new assessment development.

Table 3. Selection matrix for learning outcomes for assessment in capstone course

Need or Factor	Weighting (1-5)	Teamwork	Self-Drive/Motivation	Communication	Critical Thinking	Curiosity/Learning	Engineering Problem Solving	Project Management	Prioritization	Ethical/Professional Responsibility	Engineering Fundamentals
ABET	3	3	1	3	2	3	3	2	1	3	3
Capstone Appropriate	2	3	3	3	3	3	3	3	3	2	1
Individual Assessment	5	2	3	2	3	3	2	1	2	2	2
Industry Dissatisfaction	4	2	3	3	2	2	1	3		1	1
Industry Value	5	3	3	3	3	3	2	2	1	2	2
Institution Importance	2	3	2	3	3	2	3	2	2	3	3
Student Value	1	3	3	3	3	3	3	3	3	3	3
TOTAL SCORE		57	58	61	59	60	48	46	31	46	44

Methodology for Developing Assessment Instruments

The authors defined a methodology for developing assessments for motivation by considering student and faculty needs specific to capstone design courses and a methodology for assessment development in science education. Liu's seven-step process for assessments in science education is shown below [10,11]. This methodology supports assessment validity but gives little attention to issues surrounding adoption of the new assessment, which is important for assessments to be used widely in capstone courses.

1. Identify assessment purpose and target audience
2. Define construct (topical content and levels) to be measured
3. Prepare a test specification that defines the combination of number and types of items
4. Construct an initial pool of items to be considered
5. Conduct expert review of items proposed
6. Pilot test the instrument with representative students
7. Field test the assessment instrument prototype in actual capstone contexts

Adoption research suggests that a new capstone assessment will be adopted best when it meets criteria based on the diffusion of innovation theory [12]. Rogers identifies five factors that affect adoption of innovations [13]:

- Relative advantage – value of new product (assessment) over alternatives
- Observability – ability to see impacts of the new product
- Trialability – ability to try the new product a bit at a time at low risk
- Compatibility – suitability of the new product for the environment in which used
- Complexity – perceived difficulty of using the new product

With adoption of the assessment in mind, the authors modified Liu's assessment development process by adding steps that address user needs, design requirements, and responding to preliminary feedback for the assessment. The assessment development process, with steps two and seven added, becomes:

1. Identify assessment purpose and target audience
2. Define user needs and assessment requirements
3. Define construct (topical content and levels) to be measured
4. Prepare a test specification that defines the combination of number and types of items
5. Construct an initial pool of items to be considered
6. Conduct expert review of items proposed
7. Revise instruments based on feedback
8. Pilot test the instrument with representative students
9. Field test the assessment instrument prototype in actual capstone contexts

Step 1: Assessment Audience and Purpose

Our target population is senior undergraduate engineering students engaged in team-based capstone design projects. Our goal is to develop assessments that measure outcome achievement for each student, but also can be used to identify student performance levels in topical areas within the outcome. The assessment can provide both summative performance data and assessment feedback to direct remedial actions early enough in a capstone design experience to enhance the team and project outcomes.

Step 2: User Needs and Requirements

Following common practices used in engineering design, the authors identified user needs and design requirements for the product to be developed: assessment instruments for capstone courses. Ten local capstone instructors were interviewed to identify their perceived needs for assessments used in their capstone course. Needs were then compiled and grouped, and definitions were crafted based on instructor responses. Table 4 identifies assessment user needs with definitions.

Table 4. Assessment needs and definitions

User Needs	Definition
Time-efficient	Return good value for time and effort invested
Student-valued	Provide students information they trust and value
Faculty-valued	Provide instructors information they need for the course
Program-valued	Provide programs information needed for program improvement
Employer-valued	Provide measures of student outcomes of value to employers
Competitive	Offer distinct advantages over existing assessments
Practical	Be easy to use to obtain desired measures of outcomes
Authentic	Measure knowledge, skills, and abilities authentic to the profession
Consistent	Produce scores that are consistent with student abilities

Potential design requirements for new capstone course assessments were identified from educational references and papers on assessment and pedagogy. Assessment requirements and their definitions (and possible target states) are summarized in Table 5.

Table 5. Assessment requirements definitions

Requirement	Requirement Definition	Target
Test Length	Number of questions, items, or requests to which a student must respond and a score is assigned	5-8
Test Specification	Distribution of topics and cognitive skills (and points) addressed for an outcome	Fit to capstone standard
Item Format	Types of items (selected-response, constructed-response, performance, work product) for each question	Fit to topic & cognitive level
Readability	Level of language skills and technical vocabulary required to be properly understood	Fit UG students
Specificity	Accuracy and construction of requests related to abilities, understanding, and professional skills targeted	Professional & Flawless
Fairness	Item fit to students with different background, institution, or project characteristics	Unbiased
Validity	Extent to which measurement results and interpretations are supported by empirical evidence and theoretical rationale	Trustworthy
Reliability	Extent to which measurement results are consistent and can be replicated	Consistent

The prioritization of design requirements for new capstone assessments was conducted using a needs-requirements scoring matrix shown in Table 6. User needs (column 1) are weighted by importance (column 2) based on frequency of mention by faculty. Assessment requirements are scored (1 to 9) for their alignment with each need based on the authors' knowledge of assessment and design processes (e.g. 9 indicates a high correlation between a requirement and a need). A total score for each requirement is calculated as the sum of the products of weights and requirement scores for the corresponding column. The top three requirements (shaded) are test length, test specification, and item format. This result indicates which elements of the assessment will bear the greatest importance when designing an assessment instrument.

Table 6. Needs-requirements matrix

User Needs	Weighting (1-5)	Test Length	Test Spec	Item Format	Readability	Specificity	Fairness	Validity	Reliability
Time-Efficient	5	9	3	9	1				
Student-Valued	5	3	3	9	3	3	9	3	3
Faculty-Valued	5	9	3	3	3	3	3	3	9
Program-Valued	4	3	1	1	1		3	3	3
Employer-Valued	4	3	1	1	1		3	3	3
Competitive	4	3	9	3	3	3			
Practical	4	3	9	3	1				
Authentic	3	3	3	3	1	9	3	9	3
Consistent	3	9	9	1	9	9	9	9	9
TOTAL SCORE		**189**	**161**	**149**	**89**	**96**	**120**	**108**	**120**

Step 3: Construct for Outcome

Motivation learning has multiple dimensions and progresses through successive stages of development or levels of achievement. Motivation in higher education is often described by goal orientation, task value, and self-efficacy [14]. Self-determination is also important to student motivation [15]. Assuming that motivation is best described as affective in nature, a construct is derived from an affective development taxonomy defined by five levels of achievement [16]:

> **Receive**: Learners are open to new experiences and willing to listen. They may ask, listen, discuss, or acknowledge motivational issues in their team or project, but not act on their knowledge.
>
> **Respond**: Learners react and participate actively. They may interpret, clarify, or question but not take responsibility for motivational issues they encounter in their project or team.
>
> **Value**: Learners attach values and express personal opinions. They may debate, critically evaluate, refute, or justify their own motivational positions or conditions in their project or team.
>
> **Organize**: Learners begin to develop a values system. They may formulate, defend, relate, prioritize, or compare motivational elements and their place in project and team activities.
>
> **Internalize**: Learners adopt a belief system and behave consistently within it. They may behave or influence others in concert with motivations they understand, value, and build on in teams and projects.

A construct for motivation in a capstone design project context is defined from motivational factors and levels of achievement. Motivational factors are derived from consideration of learners' values, attitudes, behaviors, interactions with others, and initiative taken to influence one's own and others' commitments and actions. For the capstone environment, three important factors in motivation are identified:

Attitudes: How the learner responds emotionally to activities, assignments, or interruptions
Behaviors: How the learner behaves visibly in activities, interactions, and challenges
Development: How the learner takes action to control and develop motivational maturity

Levels of achievement are derived from the affective development taxonomy defined above. For the capstone design project context, three levels are defined to provide a means of distinguishing change but also to simplify the determination of levels when faculty untrained in educational psychology are scoring student work. Three levels are condensed from Krathwohl's taxonomy and defined below [16].

Acknowledge (Receive): Learners identify motivations, apparent causes, and corresponding behaviors related to their teams and projects. They do not consider the need for managing motivations.
Hold & Value (Respond/Value): Learners identify values behind their motivations and defend them. They see how their behaviors relate to motivations, possibly question inconsistencies, but do not take action to manage their motivations.
Live Out (Organize/Internalize): Learners adopt, strengthen, and live out constructive motivations toward their team and work. They learn to manage and develop their motivations to benefit themselves and others.

Table 7 shows the relationship between the three motivation factors and possible actions that might evidence the three levels of achievement relevant to capstone design course contexts.

Table 7. Motivational factors and levels of achievement

Motivation Factor	Acknowledge	Hold & Value	Live Out
Motivation Attitude	Identify motivations toward project elements		
Motivation Behavior	Rate peers and self on behaviors	Compare behaviors to proficiency	Describe steps to go beyond proficiency
Motivation Development		Rate efforts in motivation development	Describe development steps accomplished

Step 4: Test Specification

A test specification was defined to distribute assessment questions across the motivation factors and levels of achievement for use in a capstone project context. Because students typically have little familiarity with motivational terminology and discussion of motivational development, questions begin with clear, tangible events and behaviors, and then progress toward issues of managing motivations.

Implementation of the motivation assessments is distributed over the duration of the capstone project (perhaps multiple courses) so that lower level questions are given first and more advance ones toward the end of the project. Some questions are repeated or sequenced to provide data that can inform and track improvements in motivational development. Table 8 shows a possible sequencing of assessment questions over the project duration.

Table 8. Test distribution over project duration

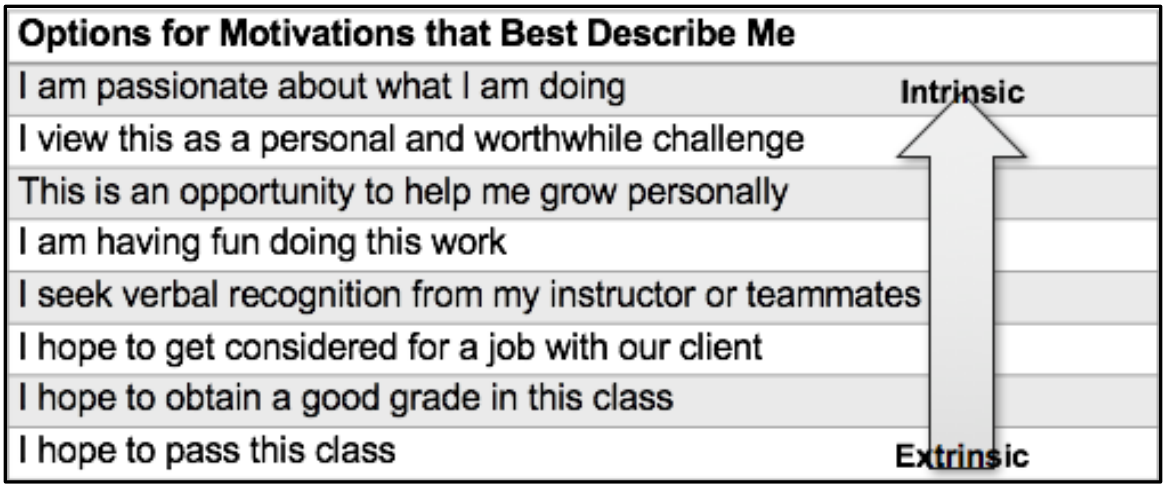
Project Stage	**Acknowledge**	**Hold & Value**	**Live Out**
Problem Definition	• Identify motivations toward project elements • Self-rate on motivation behaviors	• Rate your response to recognizing a demotivating issue	
Concept	• Identify motivations toward project elements • Self-rate and peer-rate on motivation behaviors	• Rate your response to a motivational issue	
Prototyping	• Describe an issue requiring attention to motivations • Self-rate on motivation behaviors	• Rate your response to a motivational issue	
Final Solution Hand-off	• Describe your most positive motivation • Self-rate and peer-rate on motivation behaviors	• Rate how effectively you managed your motivation	• Describe your efforts to manage motivation • Describe impacts of your efforts

Step 5: Assessment Items

Assessment items are defined to address motivation factors of attitude, behavior, and development. Some of these are more observable than others, so items must be crafted to obtain supporting evidence for claimed but unobservable positions or achievements. Assessment items for each of these factors are described below.

Attitudes. For attitudes, attention is given to students' attitudes toward projects, teams, and project clients. Items are identified that suggest extrinsic and intrinsic types of motivations. Figure 2 presents a set of eight attitude descriptors such as might be stated by students, the order indicating a range from extrinsic to intrinsic in nature. Asking students to rank the extent to which they agree with each statement or to select the statements most closely describing their feelings can serve as an indicator of their attitudes affecting motivation for their project. Asking the same question at different stages of the project can reveal how the project may be affecting student motivations.

Figure 2: Motivational attitudes assessment items



The attitude assessment is the first instrument to be administrated in the capstone course and one that can be administered multiple times to track changes. The instrument shows the type of motivation (intrinsic or extrinsic) the students identify going into and leaving the project, and how that correlates to the success of their project.

Behaviors. Behaviors reflecting motivation may be observed as students complete assignments, interact with others, and respond to challenges in their capstone projects. The authors identifed five types of behaviors that may reflect student motivations: work accomplished, supervision required, effects on teammates, taking initiative, and self-development. The set of five behaviors and five levels of the behaviors defined in Figure 3 provides a rubric for scoring students' behaviors, whether their own or those of peers. This assessment item may be used multiple times over the duration of a project to prompt thought and action about motivation-related behaviors and to track changes over time.

Figure 3: Motivational Behavior Assessment Instrument– Self-Evaluation

	Levels of Behaviors Reflecting Self-Drive and Motivation				
Behaviors	**1**	**2**	**3**	**4**	**5**
Quality & quantity of work done	☐ Delivers own work but of poor quality, incomplete, or late	☐	☐ Delivers quality work, on-time for own assignments	☐	☐ Delivers quality work on time for own assignments plus tasks beyond own
Level of supervision required	☐ Requires lots of prodding or peer pressure	☐	☐ Demonstrates self-reliance and dependability to complete own tasks	☐	☐ Takes a leadership role and helps other team members
Effect on team	☐ Has negative impact on others' work	☐	☐ Contributes effectively to the team	☐	☐ Helps team members to become or stay motivated
Taking initiative	☐ Shirks duties, avoids issues, makes excuses	☐	☐ Handles problems or hurdles as they occur (reactive)	☐	☐ Identifies problems/hurdles before negative impact on project or schedule
Self-development	☐ Demonstrates no efforts to improve performance	☐	☐ Demonstrates an effort toward personal improvement	☐	☐ Demonstrates improvement in all areas and has positive influence on others

The goal for the motivational behavior instrument is to identify students' behaviors that are influenced by their motivations and have significant impact on project success. This instrument may be used for self- or peer-assessment, providing evidence to support or counter individual perspectives on their motivations. The five levels provide discrimination that enables one to track (and hopefully drive) changes in behavior over the duration of the project.

Development. Determining a student's level of motivation development requires information about the student's realization that motivation can and should be developed and his or her ability to pursue desired motivational development. An assessment item probing this development is a self-assessment anchored by a descriptive rubric as shown in Table 9. A suggested assessment prompt for motivation development is:
Identify and name a situation you faced in your project or team that tested your motivation.
Which level--(a) Acknowledge, (b) Hold & value, or (c) Live out--best describes your handling of your motivation surrounding this situation?
Describe the actions you took to manage your motivation and handle the situation at hand.

Table 9. Rubric for motivation development

(a) Acknowledge	(b) Hold & Value	(c) Live Out
Recognized and possibly discussed your motivations related to the situation, but did not identify a plan to address your motivations	Developed understanding of your motivations, impacts, and factors affecting them, but took no identifiable action to address your motivations.	Identified opportunities for motivation development, embraced changes needed, began thoughts and behaviors to positively manage your motivations

Step 6: Expert Review

The authors obtained reviews from experts to confirm that proposed assessments will meet needs and to obtain suggestions for improvement. Three occasions were used for this review: project advisory board, Capstone Design Conference workshop (2016), and interested engineering education professionals at an ASEE focus group (2016). Each occasion and its findings are described below.

Advisory Board. The project advisory board for the NSF-funded grant was convened in advance of the Capstone Design Conference in Columbus, Ohio on June 5, 2016. A summary of the project to that date was given to the advisors ahead of time in order to use the meeting to focus more on the assessment instruments. Attending were two industry professionals and four engineering design educators. After a brief overview of the development process, the authors obtained feedback and suggestions. Principal findings are:

- Motivation is an assessment of value and not currently available in capstone courses.
- Use lay language in assessments and test it with students (e.g., summer school students or others with an incentive for careful review).
- Focus questions on motivation, not de-motivation, to avoid biasing student responses.
- Gathering self-declared assessments requires either peer or faculty confirmation or other supporting evidence to corroborate student claims.

- Ideally, assess using methods common to industry: supervisor interview of 20 minutes, probing for supporting evidence, and employee interpretation of current status and opportunities.
- Use deeper assessment, possibly face-to-face interview at mid-project and end-of-project may be best for assessing.
- Rubrics for scoring assessments may begin with a small number of levels and then progress to more levels in later administrations to give students bounds and yet allow growth.

Capstone Conference Workshop. The authors conducted a 2.5-hour workshop at the 2016 Capstone Design Conference on June 7, 2016 in Columbus, Ohio. Over 25 attendees, primarily capstone design faculty, participated actively. The authors provided an overview of the outcome selection and assessment development processes, showed draft assessment instruments, and presented possible ways to report student achievement. Throughout the workshop, participants made comments, asked questions, and provided suggestions and responded to questions. Salient feedback included:

- Timing of assessment administration may affect student responses; just prior to a major event may see very different motivations than just after the event.
- Persons who are highly motivated might affect the team either positively and negatively.
- The best data on motivation may come after the project is completed or after the student graduates and is employed.
- Rubrics need linear scales with all levels defined, avoiding AND in definitions, and using few but contrasting words to differentiate levels.
- The motivation development rubric defines levels 1 and 2 too closely.
- Peer pressure and cultural differences will affect student responses.
- Order of items to be ranked implies level, so a cloud may be better for presenting alternatives.
- Reports back to the student need to show what's most important first and be understandable to all.

Overall, motivation as a learning outcome was highly praised. The instruments were clearly works-in-progress but still were close to being ready for distribution. Some changes were made in preparation for being presented at the ASEE conference focus group.

ASEE Conference Focus Group. A mailing list for the capstone design community was used to invite people attending the Annual Conference of the American Society for Engineering Education (ASEE) to attend a focus group where they could provide feedback on motivation assessments. A group of five engineering educators met with two of the authors on June 26, 2016 in New Orleans, Louisiana. After presenting an overview of the assessment development process, attendees were invited to ask questions and provide comments.

It was suggested to gather demographic information on students to enable later analysis of assessment responses with regard to demographic differences. For the distribution of the instruments, there was concern that four administration times is too many in one year. Another suggestion was to start simpler in the beginning of the course and grow self-awareness throughout the course because these are formative instruments. Attendees provided the following additional comments:

- Motivation assessment is of interest to other institutions.
- When assessing motivation attitudes, have students check all that apply and order all items by importance; avoid overlap and use a word cloud to remove implied importance.
- On the behaviors rubric, use an even number of levels to avoid common selection of the middle level; self-development may require that students identify specific areas to develop; make rubric wording positive and action- or impact-oriented rather than self-awareness.
- On the development assessment, may need to offer other choices such as "not applicable" or "motivation was not a factor"; use statement beginning with "I . . ."
- The last assessment instrument focused on attitudes of motivation. The participants were challenged to use the instrument by assessing their attitude of motivation on attending the conference allowing multiple answers for each participant. It was suggested to let the students pick their top three attitudes. To avoid students picking what they thought was the "best" attitude in this instrument, it was suggested to randomize the attitudes and have all of the attitudes sound positive.
- Single-point rubrics may be useful for formative assessment; they engage the student and obtain more useful data than multi-point rubrics.

The feedback obtained from the workshop and focus group revealed that the assessments are:

- Assessing motivation that can be used to direct curricula change,
- Providing tools to help students grow in motivation, and
- Providing a way to communicate the motivational development of future employees—not only to identify their level and type of motivation but also to help direct career decisions based on the types of activities that motivate the student best.

Step 7. Refinement of Assessments

Feedback on proposed motivation assessments obtained from our advisory group plus two workshops led to numerous refinements of the instruments and their administration—improving assessment efficiency, effectiveness, and value. Assessment administration was reduced from four to three times in the project to fit both one- and two-semester capstone courses. A behavior assessment was added at the project end to determine if behaviors changed over the project duration. Self- and peer-assessments were refined to be administered together, reducing the number of assessments and helping students to rate themselves in context with their teammates. The new timeline for assessment administration is presented in Table 10.

Table 10. Revised timeline for assessment administration

	Assessment		
Project Stage	**1. Attitude**	**2. Behavior**	**3. Development**
Start Project	Self-assessment of attitude		
Concept Selection (mid-point of project)		Peer and self-assessment of behaviors	
Final Solution Hand-off (end of project)	Self-assessment of attitude	Peer and self-assessment of behaviors	Self-assessment of development

The assessments were refined for administration through Qualtrics. Qualtrics survey response data can be downloaded for analysis without manual data entry. Capstone course identification is achieved by directing students to unique URLs for each class, enabling analysis by discipline, project length, and other distinctions.

Attitudes. The first survey for administration is the motivational attitudes assessment. The original Part 1 included only eight attitudes ordered from extrinsic to intrinsic. With the suggestion of the multiple workshops, Part 1 of the assessment now identifies fifteen intrinsic and extrinsic attitudes relating to capstone projects that are randomized, and students are asked to choose those attitudes that most closely fit them at this point in time. An open-ended attitude option invites students to identify any unlisted attitude that fits them in this context. This option allows students to answer as honestly as possible and provides researchers information for improving the assessment in the future. In Part 2, students are asked to rank order their chosen top attitudes from most motivational to least motivational. With the help of Qualtrics, only the attitudes selected in Part 1 are displayed. Students simply rank by clicking and dragging. These results will help researchers identify motivations of students at the start of their projects, and again when the assessment is administered an additional time. Figure 6 shows a condensed version of the attitudes assessment.

Figure 4: Attitudes assessment instrument

Part 1: Check all attitudes from the following list that describe your motivation for your project.

- ■ I want to learn and grow expertise through the project.
- ❑ I have a desire to benefit other people through outputs from my project.
- ❑ I need to fulfill my capstone requirements for graduation.
- ❑ I want this project experiences to be a strong entry for my resume.
- ■ I want to work as a team in developing a design solution.
- ❑ I see this project as a worthwhile personal challenge.
- ❑ I want to earn others' recognition and appreciation for my contributions.
- ❑ I want to create a product of commercial value.
- ❑ I am eager to apply my learning to a real-world problem.
- ■ I want to accomplish work that shows my abilities to others.
- ❑ I want to prove my leadership abilities to others.
- ❑ I am eager to invest myself in a project about which I am passionate.
- ❑ Doing well in this project is a way to gain visibility with our client.
- ❑ It is important to me that I receive good grades in this class.
- ❑ I hope to create intellectual property of commercial value.
- ■ It important to me that I fulfill my obligations to team and client.
- ❑ Other attitude(s): _____

Part 2. Click and drag the items below to rank them (1 = most dominant, 2 = next, etc.)

I want to learn and grow expertise through the project.
I want to work as a team in developing a design solution.
I want to accomplish work that shows my abilities to others.
It important to me that I fulfill my obligations to team and client.

The attitude assessment is administered once at the beginning of the project and once at the end of the project. The initial distribution of attitudes and final distribution provides evidence of student motivational attitude changes as affected by their project experiences.

Behavior. The motivational behavior instrument is distributed second in the students' project experience. This assessment records students' observable behaviors toward their project, based on their own self-assessment and assessment of teammates' behaviors. This assessment combines self- and peer-assessment in one administration to achieve time efficiency.

The behavior self-assessment incorporates a single-point rubric, as was suggested based on ASEE focus group feedback and explained by Fluckiger [17]. Students are asked to reflect on each of five behaviors and determine if they believe they have achieved proficiency, then clicking on either "Not Yet Achieved Proficiency" or "Achieved Proficiency" (Table 11). Based on their choice, the student explains what they need to do to achieve proficiency or give evidence of how they have achieved proficiency for the chosen behaviors. For the highly motivated students, an optional section gives them the opportunity to explain how they plan to go above and beyond proficiency in the future.

Table 11: Motivational behavior self-assessment

Behaviors	Proficiency	Not Yet Achieved Proficiency	Achieved Proficiency
Quality & quantity of work done	Consistently delivers quality and timely work tasks to meet assignments	◯	◯
Level of supervision required	Regularly performs work tasks by demonstrating self-reliance and dependability to complete assigned tasks	◯	◯
Effect on team	Demonstrates positive and continuous actions to build effectiveness of team performance	◯	◯
Taking initiative	Reacts to and responsively handles project-related problems or hurdles to result in minimum disruption to project	◯	◯
Self-development	Through specific actions, demonstrates observable and regular efforts to improve personal performance	◯	◯

For the peer-evaluation of motivation-related behaviors, students respond to a multi-point rubric that provides behavior definitions at four levels. Table 12 provides behavior definitions that are modified based on expert feedback. Students complete Table 13 to record their ratings of teammates' behaviors (based on Table 12 definitions).

Table 12: Definition of behaviors at four levels

	Levels of Behaviors Reflecting Motivation			
Behaviors	**1**	**2**	**3**	**4**
Quality & Quantity of work done	Often does substandard work on assigned tasks	Inconsistently meets requirements on assigned tasks	Consistently meets requirements on assigned tasks	Does whatever it takes to get job done well and as expected
Level of supervision required	Often requires instructor and/or peer pressure	Occasionally needs promps and oversight to complete work	Rarely needs prompts; does work without oversight	Anticipates and performs even unstated work without prompting or oversight
Effect on team	Often has negative impact on team performance	Has neutral to negative impact on team performance	Has neutral to positive impact on team performance	Consistently has positive impact on team performance
Taking initiative	Actively avoids taking new responsibilities unless forced	When asked, generally accepts new responsibilities	When needs occur, volunteers to take new responsibility	Proactively identifies needs & takes action to meet needs
Self-development	Demonstrates no effort to learn or improve performance	Seldom demonstrates effort toward personal improvement	Often demonstrates effort toward personal improvement	Routinely achieves noticeable self-improvement that benefits the team

Table 13: Student ratings of teammates' behaviors

Rate yourself and each team member on the five areas of motivation behaviors defined above					
Area of Motivation	**Score each 1 to 4**				
	You	1	2	3	4
Quality & quantity of work done					
Level of supervision required					
Effect on team					
Taking initiative					
Self-development					

Development. The last assessment instrument administered assesses students' development of motivation maturity over the duration of the capstone project. The instrument consists of having the student describe their greatest motivational challenge and how it threatened to de-motivate them. This is followed by a multipoint rubric (see table 14) for the student to indicate for each factor which description best describes their awareness of and management of the motivational challenge they described in the first question. The assessment ends with a request for evidence of motivational development at the end of the project.

Table 14: Development assessment rubric

	Scoring			
Factor	1	2	3	4
Recognition	Was unaware of motivational threat	Slowly became aware of threat	Quickly recognized threat and named it	Saw threat coming and prepared for it
Action	Ignored or denied existence of threat	Reacted to threat but took no action	Acted to keep motivation from diving	Refocused attitudes to make required tasks align with personal values
Learning	Did not learn anything useful about motivation	Learned that motivation can affect me and my performance	Learned to take steps not to get demotivated	Learned to stay motivated even when conditions are demotivating

Step 8. Pilot Testing

Pilot testing of motivation assessments began in autumn of 2016 in six different capstone design courses at The Ohio State University. Institutional Review Board (IRB) approval was obtained and instruments were administered with the support of capstone instructors.

The Process

A request was sent to capstone faculty from each of twelve engineering departments and six instructors volunteered to be part of the study. The courses are listing in Table 14 along with a brief description of major, number of total students, and type of project. Emails were sent to all instructors with specific instructions about administering the assessment tools. They were

initially given an overview of the entire assessment process to be administered in three phases throughout the course followed by specific instructions including a link to the assessment survey for each of the three assessments. At the onset of the process, in the beginning of the course, instructors were asked to forward information to students describing the overall project. They instructed students that participation in this activity is a totally voluntary activity (per IRB requirements) but that all participants in the program would be eligible for a drawing for several cash awards at the end of the year.

Table 14. Description of Capstone Project Classes Included in Pilot Test of Prototype MTP

Class	Semesters	Discipline(s)	Students	Project Types
A	2	Multidisciplinary	66	Industry sponsored
B	1	Chemical & Biomolecular Engineering	135	Process
C	2	Biomedical Engineering	80	Product development
D	2	Integrated Systems Engineering	17	Lean 6-Sigma
E	2	Agricultural & Biological Engineering	48	Ag Process
F	2	Integrated Business & Engineering	26	Entrepreneurial

Collection and Security of Data

In order to ensure anonymity and security, all raw data is only shared with the research team. All data presented here or other public formats is anonymous and no faculty or student identities or personal information will be presented. The students' names are replaced with identifying numbers. In addition, all faculty members are identified by the type of capstone course they teach. Finally, the research team will keep hidden all information that is connected to students' personal identities for one particular class taught by one of the research team members, and he or she will have access only to survey data presented publicly. To date, full assessment data has been collected only from one one-semester capstone course. Completion of the third assessment will occur for the remaining two-semester courses at the end of spring semester 2017.

Initial Results

The original hypothesis assumed that reliable assessment of students' motivation required that each student in the class complete all three assessment instruments sequenced throughout the entire one- or two-semester course. Also, as the second and third assessments include a peer evaluation of observed motivational behaviors, it is important for team-based projects, that all team members complete this portion. While it is extremely difficult to know which teams completed these peer assessments (that data is not currently collected), it is pretty clear looking at the percentage of completions for each class in Fig. 7 that it would be only coincidental that any one team showed 100 percent completion. We may still find useful information from incomplete team peer assessments. If we show through future validation and reliability analysis that full team completion is needed, we may need to reevaluate the use of peer assessments at the team level.

One of the characteristics that affects peoples' willingness to complete surveys is the actual or perceived length and complexity of the survey. The survey tool tracks the length of time a student works on each assessment. However, the time captured shows only the time the survey

is first opened until the "complete" button is pressed. It is likely, based on the results shown in Table 15, that the average times spent are over-inflated. For example, the deviation for the second assessment tool ranges from 3.4 minutes to 30.2 minutes. Another method is required if the team needs to track actual time spent on completing the surveys. However, it is clear that the time required for the second and third assessment is significantly longer than the first. These both required textual and thoughtful written responses.

Table 15: Average Time for Each Survey for the Corresponding Course

Course:	Average time for 1st Survey	Average time for 2nd Survey	Average time for 3rd Survey
A	3 min	14 min 11sec	N/A
B	2 min 31 sec	9 min 30 sec	12min 13 sec
C	4 min 12 sec	30 min 18 sec	N/A
D	4 min 27 sec	3 min 34 sec	N/A
E	2 min 36 sec	8 min 20 sec	N/A
F	4 min	14 min	N/A

Additionally, we recorded the number of students who started but did not complete the survey. As shown in Table 16, 97% of students who started the first survey completed it, but only 81% of those starting survey two completed it. Again, pointing to the possibility of its actual or perceived complexity and time required to complete.

Table 16: Percentage of Students Who Completed each Survey

Course:	% of Students who Started & Completed the 1st Survey	% of Students who Started & Completed the 3rd Survey	% of Students who Started & Completed the 2nd Survey
A	97	80	N/A
B	91	76	85
C	98	93	N/A
D	100	67	N/A
E	94	83	N/A
F	100	88	N/A

Through initial focus groups and interviews with faculty and students, the team identified several user needs for this assessment tool (See Table 4). Based on the low level of student responses as shown in Fig. 7, it might be assumed that the tools have yet to meet the following two key needs:

- Time efficient--return good value for time and effort invested
- Student valued--provide students information they trust and value

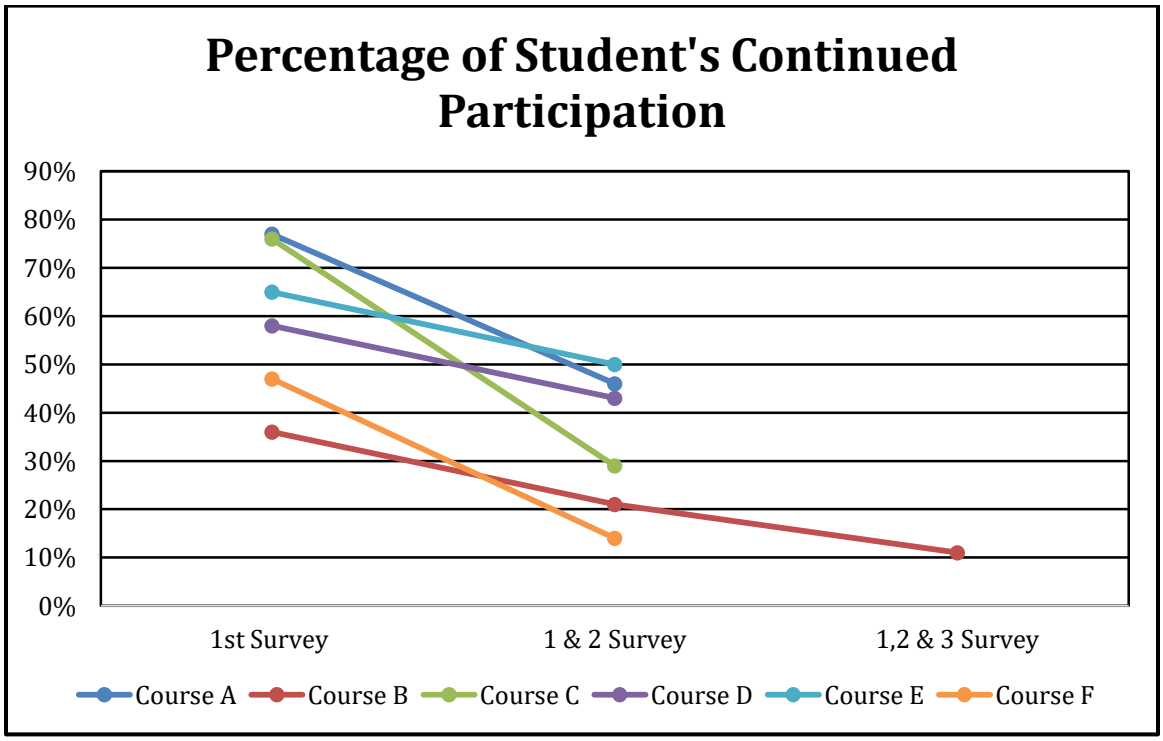
We found that in the one completed course (Course B in Fig. 7) only about 1/3 of the students completed the first survey tool and that only 1/3 of those who started actually completed all three assessments which resulted in only about 10 percent of the class completing all three

instruments. While the other five classes have yet to complete all three tools and they tend to start with higher percentage of student involvement, the trend of drop-off from the first to the second is following a similar trend.

Some of the characteristics the team will evaluate relative to this lack of participation will include:

- The consistency in which the students are directed to participate
- The effect of having to sign the (IRB) student participation agreement
- The clear "voluntary" aspect of participating as dictated by IRB
- Length of time allowed for completion allowing students to talk with other students who already completed the assessment
- Perceived or actual amount of time required to complete assessment
- The ease of completing each tool and the type of rubric (multi- versus single-point rubric)

Figure 7: Percentage of Student's Continued Participation in the Motivational Surveys



Discussion

In the coming months, the research team plans to administer the final set of third assessments and collect the remaining data from the five two-semester capstone courses. In addition, we plan to continue to analyze data received by the one-semester and two semester capstone courses. The data will help the team validate the instruments using previously defined requirements from the beginning of the assessment development. Near the end of the current semester, the team will conduct focus groups and interviews with both faculty and students from the pilot courses in order to gain feedback on the effectiveness, validity, and reliability of each of the instruments. This feedback will provide key direction to help modify the instruments before the second pilot

phase is administered next year to seven other institutions representing a diverse population and varied capstone course designs.

In addition, the team will continue to update the user needs and design requirements (Tables 4 and 5) based on the feedback from the first pilot and further interviews and focus groups of participating faculty and students.

After modification and improvement, the team will finalize the instruments and submit to IRB for approval. Finally, these improved instruments will be used at the pilot university and other partner universities that have agreed to participate. The various types of partner universities are: large public, small private all-female, small private, historically black university, etc. This will allow diversity in responses and a better picture of whether or not the user needs and requirement were met. The administration of these assessments will be more rigorous in order to increase effectiveness by reducing weaknesses with the first year's administration.

Conclusions

This paper presents the work in process of a research grant for creating effective instruments for assessing learning outcomes of engineering graduates sought by industry professionals. A rigorous process is described for engaging stakeholders in the selection of outcomes for assessment, defining needs and requirements for assessments, and developing assessment instruments that build on educational research with potential value to the profession. First version assessment instruments for motivation-related attitudes, behaviors, and development are presented and feedback from capstone design and educational research experts is discussed. Revised instruments and plans for their administration are discussed.

The inclusion of industry professionals and educational professionals has potential to produce assessment instruments of practical value and to serve as a model for future development of assessments for engineering programs. Once these instruments have been tested and proven, results from assessments will provide valuable information for students to achieve greater motivational development, instructors to better motivate and know the motivational status of their students, faculty to improve engineering curricula, and employers to expect and identify well-motivated graduates.

The authors of this paper invite feedback from the engineering education community as ongoing development and testing of motivation assessments occur. Interested collaborators are encouraged to contact the authors.

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