Application of Indirect and Direct Measures for Student Teamwork Outcome Assessment within an Undergraduate Civil Engineering Curriculum

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Introduction

Teamwork is a crucially important professional proficiency that engineering students need to develop during their undergraduate educational program of study. An effective engineering undergraduate curriculum needs to offer ample opportunities to obtain functional teamwork skills, develop personal interaction proficiencies, and demonstrate essential levels cognitive development in preparation to successfully serve as contributing members of productive multidisciplinary teams. An ability for graduates to function on multidisciplinary teams is identified by ABET as one of eleven student outcomes in the a-k list that engineering programs need to adopt in preparing graduates to attain program educational objectives. Additionally, the American Society of Civil Engineers (ASCE) Body of Knowledge (BOK) identifies nine professional outcomes, including teamwork, as a subset of 24 overall outcomes that establish cognitive criteria for knowledge, skills and attributes required by graduates to begin successful civil engineering careers. Criteria identified for teamwork require students to function effectively as a member of an intra-disciplinary team. This cognitive level of achievement satisfies the learning criteria threshold for Bloom's Taxonomy 3, Application, as students would demonstrate an ability to apply learned concepts in familiar and unfamiliar situations.

This paper describes teamwork activities occurring within the civil engineering curriculum at The Citadel that map to assessment of the Department's adopted teamwork outcome. An array of teamwork assignments and activities are provided throughout the curriculum extending across all four years of the undergraduate coursework including: Introduction to Civil Engineering (CE 103) Surveying (CE 205), Geomatics (CE 208), Surveying Lab (CE 235/239), Highway Engineering (CE 302), Geotechnical Engineering Lab (CE 402), Introduction to Geotechnical Engineering (CE 409), and Capstone Design (CE 432). Teamwork assignments in these courses include: laboratory teams, problems solving sessions, homework assignments, class presentations, exam preparation exercises proposal preparation, design projects, and design project presentations. Course-based Embedded Indicator results, Department Senior Exit Survey data, and student perception data of teamwork effectiveness will be evaluated and compared. Results will be useful in providing evidence-based measures of how a curriculum is performing on this crucially important profession skill outcome. Findings are intended to be of interest to other institutions working to adopt and refine effective educational methods and assessment criteria for support of teamwork outcomes. This paper will demonstrate use of multiple direct and indirect measures to create evidence-based assessment results and comparisons.

Background

Student perception surveys have been piloted effectively to assess engineering classroom learning activities for a variety of instructional applications including outcomes assessment[1]. Additionally student perceptions surveys have been applied successfully to evaluate professional skills such as measuring student proficiencies and understanding of ethical issues and professional responsibility[2]. Furthermore, adopted assessment procedures have been successfully applied using Senior Exit Surveys to assess student outcomes through a comprehensive and integrated approach using both direct and indirect measures[3]. Understanding students through perception surveys is useful to improving engineering pedagogy as a means of providing insight into student development occurring during their engineering education[4].

Embedded indicators are widely accepted as an effective means of assessing student achievement as compared to adopted performance standards[5]. Use of course-based embedded indicators, detailed grading rubrics, and graded student performance scores compared to department standards provide a well-founded method for conducting meaningful assessment[6]. Comparisons between direct and indirect assessment measures can be extremely useful in allowing additional insight into student learning[7]. It is widely considered desirable to include multiple direct and indirect tools to serve as the foundation of an effective assessment and continuous improvement process for evaluating adopted outcomes. This approach can provide useful evaluation evidence for specific outcomes and allow broad analysis of the overall course curriculum[8].

Data provided in this paper provides a comparison of multiple methods to assess teamwork activities occurring within the civil engineering curriculum supporting assessment of student performance for the Department's adopted teamwork outcome. Students are provided with a variety of structured teamwork assignments, exercises and evaluation methods extending across all four years of the undergraduate coursework. Evidence-based assessment methods supporting the development of teamwork competencies are summarized along with data evaluation trends and comparisons providing insight into student performance and outcomes attainment.

Civil Engineering Curriculum Teamwork Activities

The undergraduate civil engineering curriculum includes a total of eight courses with a specific focus on teamwork, beginning with Introduction to Civil Engineering (CE 103) in the freshman year and culmination with Capstone Engineering Design (CE 432) in student's senior year. Characteristics of teamwork assignments specific to each of these courses are summarized in Table 1. Additionally method of team formation and range of student team size is also indicated. With regard to team formation determined through CATME team creation and management software, Comprehensive Assessment of Team-Member Effectiveness, developed through NSF grant funding[9], uses student entered descriptive data to create teams through objective routines and is generally viewed by students as an improvement to traditional team formation approaches.

Student Perception Survey

A student perception survey was administered by faculty, within a classroom setting, to a total of 159 undergraduate civil engineering students, including freshmen (n=47), sophomores (n=37), juniors (n=34) and seniors (n=41). The survey instrument, informed consent, and survey protocol were developed in accordance with the university's Institutional Review Board (IRB) requirements and received IRB approval prior to implementation. Data was collected during Fall Semester 2016. Questions were focused on obtaining student perception responses pertaining to team formation, collaboration, leadership, conflict resolution, teamwork skills, and learning objectives. Managing conflict when working in teams are crucial skills students need to develop and it is imperative professors provide feedback and foster development of student skills so inevitable conflicts can follow a constructive path to resolution[10]. See Table 2 for survey questions and definition of 1-5 Likert scale responses. In administering the survey instrument, each course included in the teamwork outcome thread was identified by number, title, and brief summary of the teamwork exercise to ensure students clearly understood which particular aspect of the course they were being asked to evaluate.

Table 1. Summary of Teamwork Activities in Civil Engineering Curriculum

Course	Teamwork Activity	Team Formation	Team Size	# of Teams
CE 103, Introduction to Civil Engineering	Entry level engineering projects including a water quality test, bridge design simulation, and site development layout plan	Self Selected	2-4	6
CE 205, Surveying	In-class problems on survey leveling, traversing, and area calculations, via competitions, or team board solutions	Assigned	2-3	10
CE 235, Surveying Laboratory	Surveying crews collect and analyze field data collected through leveling, distance measurement, traversing, and construction staking	Self Selected	4	4
CE 208, Geospatial Representation	Create presentations on GPS Satellite Systems including US NAVSTAR, US OCX, Russian GLONASS, European GALILEO, and Indian. Team presentations are peer evaluated and ranked for effectiveness.	Self selected	3-4	7
CE 239, Geomatics Laboratory	Surveying crews collect and analyze field data collected by traversing, planimetric mapping, topographic surveys, and GPS position surveys.	Self selected	4	4
CE 302, Highway Engineering	Design a two-lane highway extending through rural rolling terrain, with design elements including horizontal alignment, vertical alignment, cross sections, drainage, earthwork and construction deliverables.	Assigned	2-3	9
CE 409, Geotechnical Engineering	In class problems solving, exam preparation exercises, crossword puzzles, and jeopardy quizzes on analysis of soil properties and fundamentals of soil mechanics.	Assigned	3-4	8
CE 432, Capstone Engineering Design	Alternatives analysis, permit application submittal, design deliverables and presentation of findings to a professional panel for a highway interchange project, currently under design in the local area.	CATME	4-5	11

Table 2. Survey Instrument for Student Perception of Teamwork in Civil Engineering Courses

Student Self-Assessment	**Likert Scale**
1.) The means used for student team formation were effective.	1 2 3 4 5 0
2.) My team worked in a positive collaborative manner	1 2 3 4 5 0
3.) I provided leadership in completing team assignments.	1 2 3 4 5 0
4.) My team had to address conflict to complete team assignments.	1 2 3 4 5 0
5.) Teamwork activities were effective in learning teamwork skills.	1 2 3 4 5 0
6.) Teamwork activities were effective in learning course material.	1 2 3 4 5 0
Likert definitions: 1=strongly disagree, 2=disagree, 3=unsure, 4=agree, 5=strongly agree, 0=cannot rate	

Student Perception Survey Data and Analysis

Student perception of teamwork assignments, occurring across all four years of the civil engineering curriculum, was analyzed and compared using survey data to better understand differences corresponding with various teamwork performance characteristics. Courses surveyed by academic year include: one freshmen course, three sophomore courses, five junior courses, and eight senior courses. Students were asked to evaluate all courses they had completed, or were presently enrolled. Mean student scores were determined for student responses using 1-5 Likert scores, after which numeric values were converted to percentages for ease of comparison, based on percent of the five-point scale. Additionally standard deviation was similarly converted to percent for simplicity in equitable comparison across a range of investigative perspectives. Survey results for all civil engineering teamwork courses aggregated by academic year are summarized in Figure 1. In evaluating student responses to the six questions posed regarding course specific teamwork perceptions, some insightful and beneficial trends were apparent, relevant to outcome assessment and continuous improvement. It should be noted data collected reflects different student populations, time frames and class environments, however, are believed to be comparable based on a similar and consistent student stream in each succeeding year.

Regarding the need for teams to address conflict, aggregated student perspective by academic year, increased from 70% freshman year to 79% senior year. This upward trend corresponds with more challenging and rigorous teamwork design projects, as student progress through the curriculum. Understandably, expanded assignment complexity is frequently accompanied by increased team conflict and is often associated with more demanding design tasks or projects.

Surprisingly student perception for all five other teamwork performance characteristics trended down from freshman to senior year. This unexpected finding can possibly be attributed to initial optimism of freshman students diminishing over time as the ups and downs, and hard lessons of rigorous academic learning takes a toll on student's positive outward views and contemplative perspectives. This trend was most surprising with respect to effectiveness of student team formation as student perception decreased from 88% to 78%. Means to improve team formation such as CATME were implemented, yet when aggregated, seniors have lower perceptions than freshman students. When asked if the student provided leadership in completing team

assignments, student perception undulated between 87% and 82%. When asked if teamwork activities were effective in learning teamwork skills, student perception decreased from 92% to 83%. When asked if teamwork activities were effective in learning course material, student perception decreased from 91% to 85%. Lastly when asked if the team worked in a positive collaborative manner, student perception decreased from 93% to 81%. These unforeseen pervasive negative teamwork trends could collectively suggest that accumulated difficult team projects, situations and experiences adversely influence perceptions of senior students in retrospect. However, these challenging, demanding and sometimes frustrating lessons, would likely result in civil engineering students who are better prepared to solve real world problems and enter professional practice, where all work is conducted in teams.

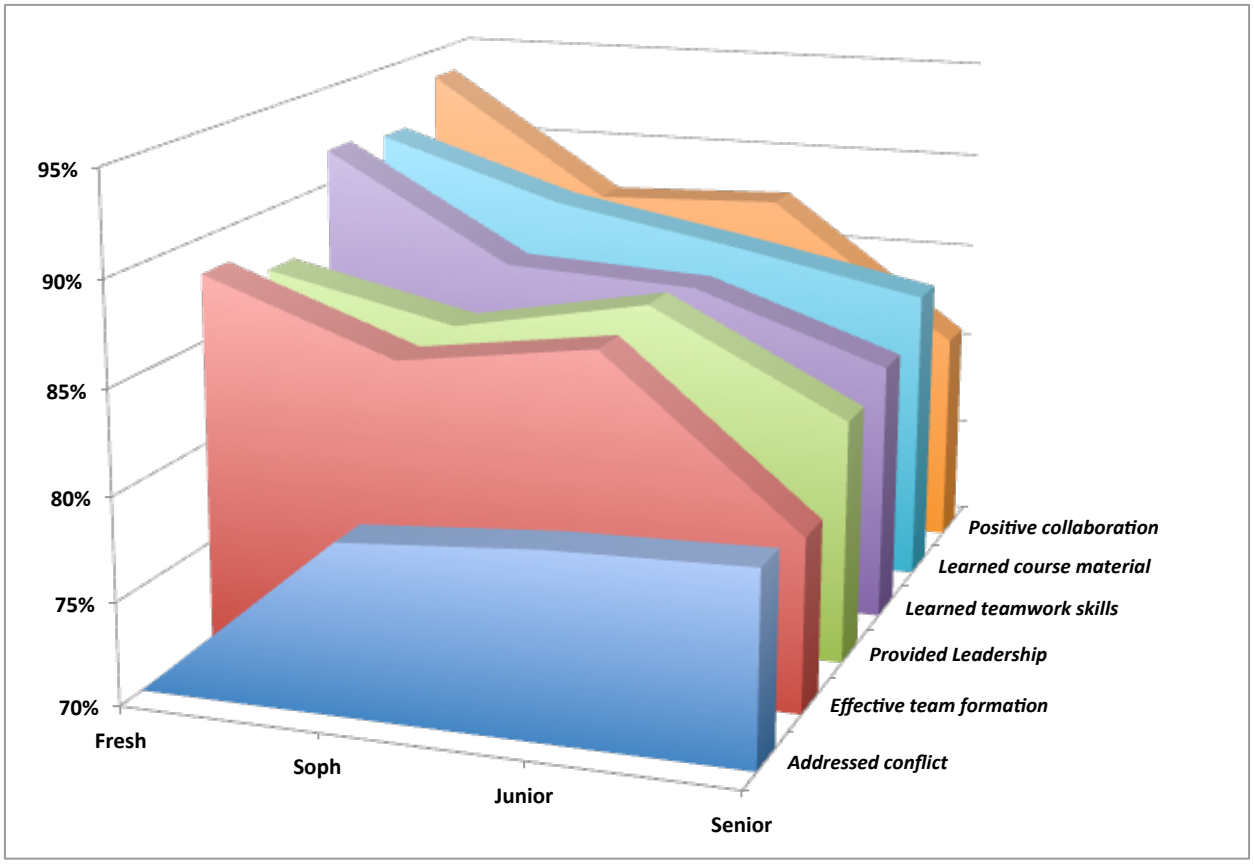

Figure 1. Combined Student Perception of Course Teamwork, Freshman-Senior Trends

In addition to comparing aggregated student perspective data by academic year, some additional insightful trends were noted from changes in perceptions of seniors as they progressed through all eight civil engineering courses for a subset of the six individual teamwork questions. As shown in Figure 2 regarding team formation, 66% was the lowest student perception for a rigorous highway engineering (CE 302) design project in which teams were formed randomly. Conversely, 87% student perception was the highest for two courses, capstone design (CE 432) teams that were formed using CATME software, and teams assigned by academic rank in geotechnical engineering (CE 409). Additional explanation of these differences can be attributed to peer evaluation of team contributions. For CE 302, peer evaluation of teams and individual student contribution to team goals was not included as part of the assignment. For CE 432, peer

evaluation was ongoing via CATME and any inequities in student contribution to team goals were arbitrated with input from the professor. As for CE 409, team assignments were relatively short and team members were rotated interchangeably as new team exercises were assigned.

As shown in Figure 3, student perception indicated that the need to address conflict to complete team assignments increased from 68% in Introduction to Civil Engineering (CE 103) freshman year to 89% in Capstone Engineering Design (CE 432) senior year. This comparison further supports that as teamwork assignments become more complex and more demanding, an increase in academic rigor is frequently accompanied by increased team conflict, which students may dislike, however, these leaning experiences can provide some of the most valuable educational lessons. For CE 432, not only did this course provide the highest student perception value, 89%, for need to address conflict, results indicated considerable agreement among students, with a low Standard Deviation of 13%. Additionally, it should be noted for CE 409 where team assignments are shorter and team membership frequently interchanges, 76% student perception of the need for conflict resolution is markedly lower for an upper level civil engineering course.

As shown in Figure 4, student perception of providing leadership in completing team assignments increased progressively over four years from 77% in Introduction to Civil Engineering (CE 103) freshman year to 89% in Capstone Engineering Design (CE 432) senior year. For CE 432, leadership responsibilities rotate through all of the members of the team with each student being responsible for a major design project submittal or deliverable.

To evaluate differences in perspectives occurring over time for common student experiences, data for CE 103 was compared across all four years. Perceptions for the six survey indicators produced similar values, providing some evidence data was comparable as a result of similarity and consistency in the Department's student stream, occurring across successive years.

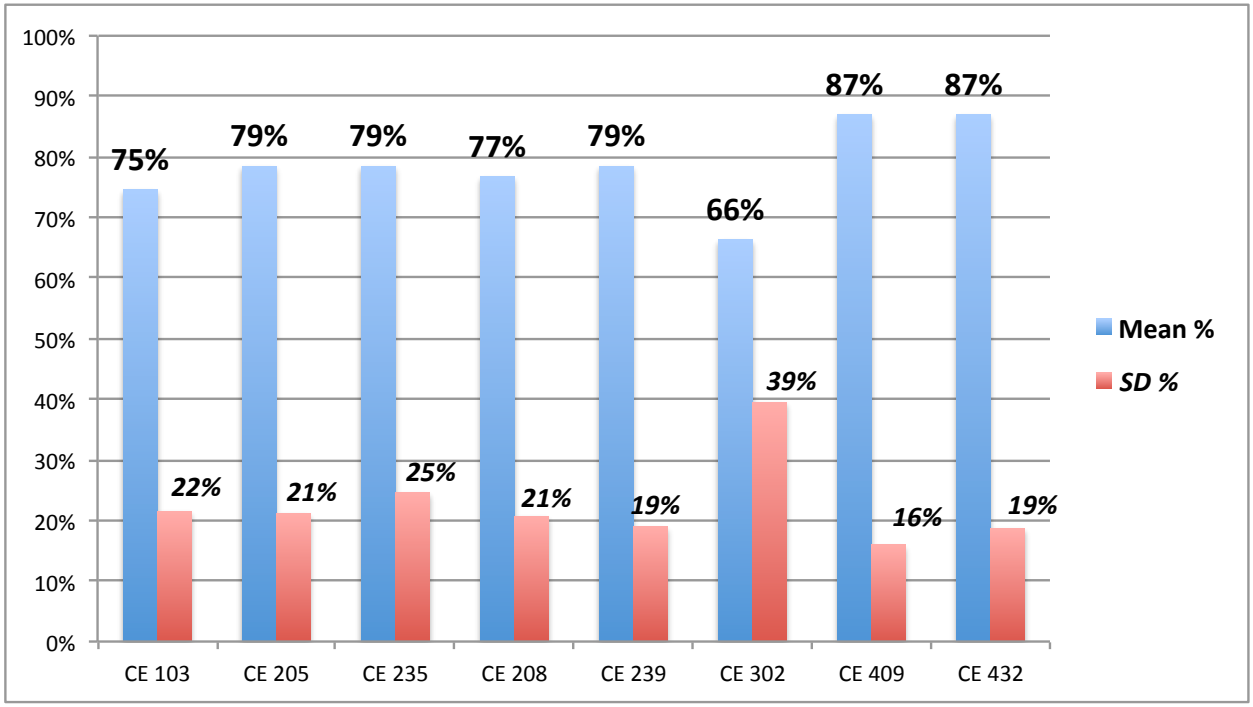

Figure 2. Senior Student Perception of Effective Team Formation (n=41)

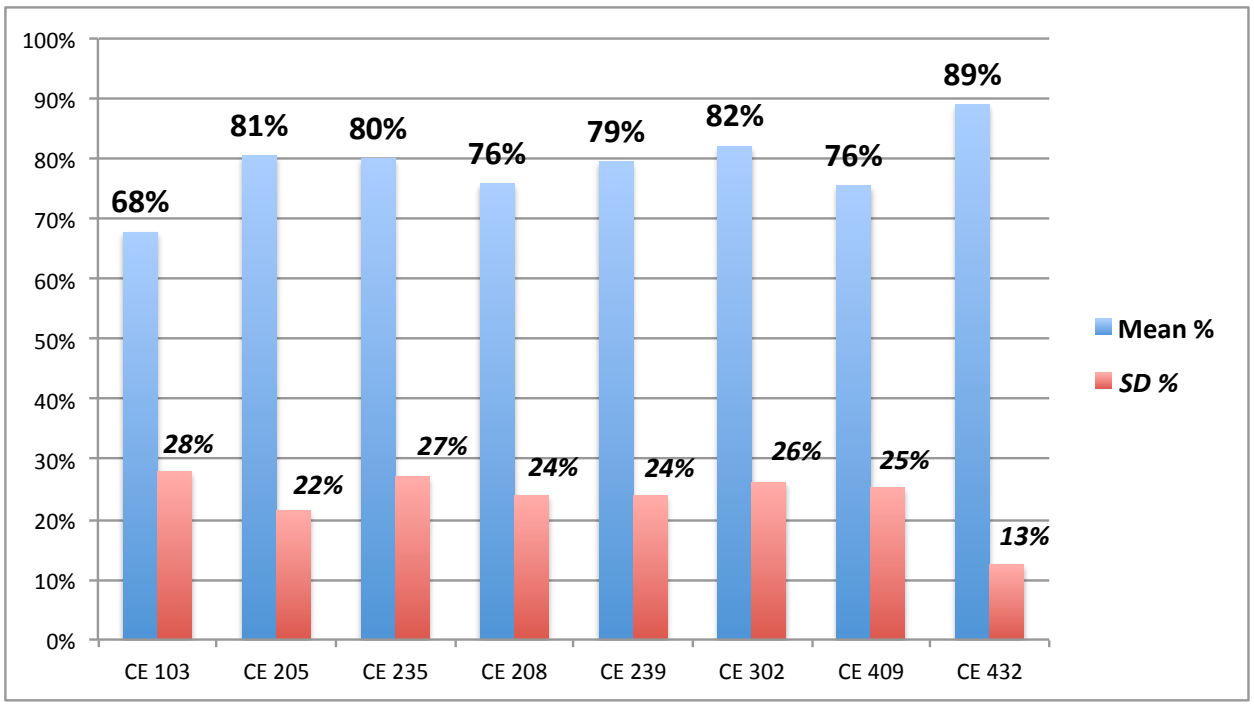

Figure 3. Senior Student Perception of Need to Addressing Team Conflict (n=41)

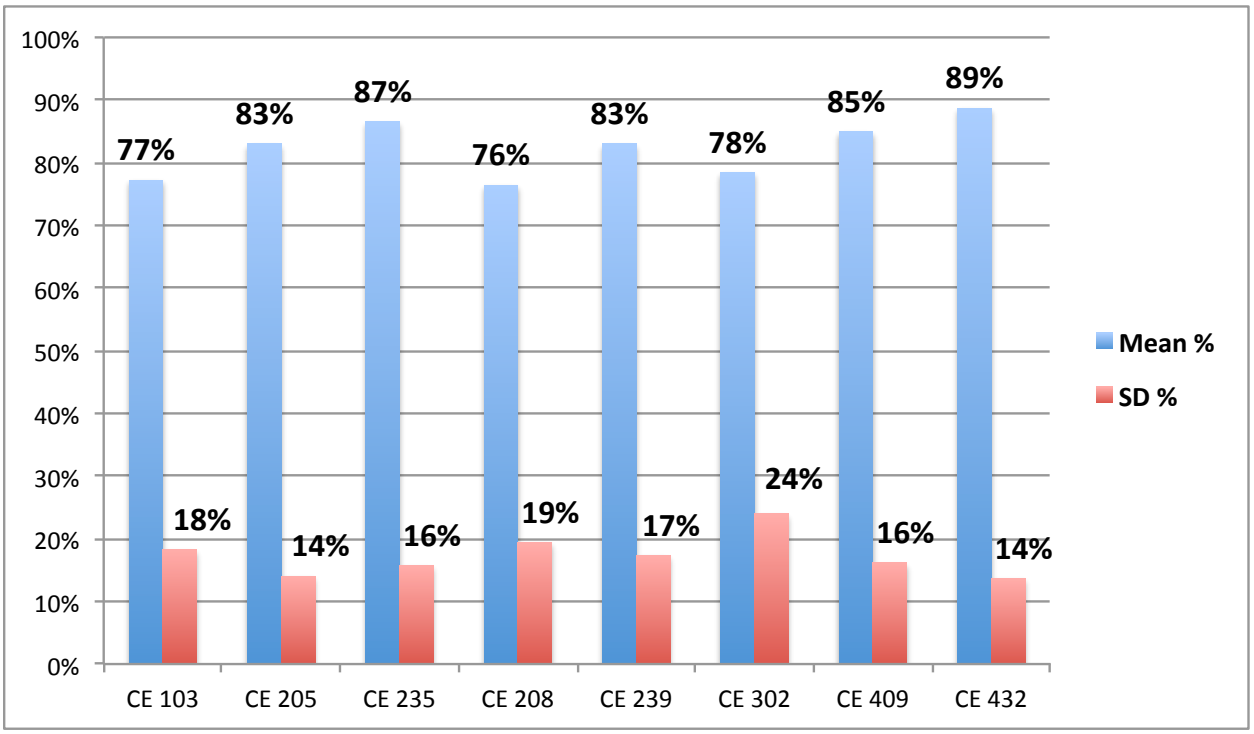

Figure 4. Senior Student Perception of Leadership in Completing Team Tasks (n=41)

Civil Engineering Department Embedded Indicators

The Department's assessment plan is predicated upon use of course embedded indicators supporting each adopted outcome, linking across all four years of the civil engineering curriculum. Embedded indicators are aligned with suitable 1-6 levels of Bloom's Taxonomy as identified in Table 3, faculty can use a prescribed array of instructional tools to measure intended levels of cognitive performance. Students are evaluated using instructional tools selected by faculty. Course embedded indicators on tests, assignments, and projects are used to evaluate CEE Department outcomes. If average student performance for an embedded indicator tool is measured as 75% or higher, it is concluded students have collectively achieved appropriate learning requirements and met departmental standards. Example work from three students (good, average, poor) for each tool is included with an embedded indicator summary that provides an assessment of student performance and is mapped to reflect linkage with appropriate Departmental outcomes. Results from embedded indicators and other measures are systematically evaluated to ensure overall performance standards are met and to formulate solutions in the event problems are identified.

Table 3. Embedded Indicator Instruments and Bloom's Taxonomy Levels

	Bloom's Taxonomy Level						
Embedded Indicators	**1**	**2**	**3**	**4**	**5**	**6**	**Instrument**
True/ False Questions	X	X					Test, or Test Question
Matching Questions	X	X					Test, or Test Question
Fill In Blank Questions	X	X					Test, or Quiz Question
Multiple Choice Questions	X	X	X				Test, or Test Question
Short Answer Questions	X	X	X	X			Test, or Test Question
Calculation Based Problems	X	X	X	X			Test, or Test Question
Essay Questions	X	X	X	X			Test, or Test Question
Research Papers	X	X	X	X	X	X	Entire Paper
Lab Reports	X	X	X	X	X	X	Lab Report
Design Problems	X	X	X	X	X	X	Project
Capstone Projects	X	X	X	X	X	X	Project

Bloom's Taxonomy Levels: 1.) Knowledge, 2.) Comprehension, 3.) Application, 4.) Analysis, 5.) Synthesis, 6.) Evaluation

Course Embedded Indicator Data

Departmental assessment of the teamwork outcome is mapped to three specific civil engineering courses using embedded indicators linked to individual course goals/objectives. Faculty collaboratively establishes common course goals, linkage to specific Departmental outcomes,

and adopts appropriate levels of Bloom's Taxonomy. Each of the Department's twenty-two outcomes is supported by at least three embedded indicators. Average scores of graded student performance are tabulated and compared to an adopted Departmental performance standard (75 or higher). Embedded indicators from Introduction to Civil Engineering (CE 103), Highway Engineering (CE 302) and Professional Sustainability (CE 317) are used to assess teamwork. Data tabulations cover five years from 2012 to 2016, and include a total student sample size of n = 965, extending across a total of 14 individual embedded indicators. Over this period 12 embedded indicators passed and two failed, both with student performance averages of 60 for Highway Engineering (CE 302) in the previous two years. This problem also was reflected in the student perception survey and was partially attributed to the fact that peer evaluation of teams and individual student contribution to team goals was not included as part of the assignment.

Overall review of embedded indicator data for teamwork shows average student performance across all the three courses ranging from 81.1 to 90.8, clearly exceeding the Departmental standard of 75 or higher and this evidence was used collectively to assess teamwork skills where being learned by students and outcome thresholds are being met. In evaluating these tabulations and comparisons it is important to note that Bloom's Taxonomy levels (1-6) vary according to each specific course goal. Obviously, the two junior level courses exhibit higher embedded indicator Bloom's levels, than the course offered during freshman year.

Table 4. Teamwork Embedded Indicators, (n = 14 embedded indicators, n = 965 students)

	CE 103 (Goal 5)		**CE 302 (Goal 7)**		**CE 317 (Goal 1)**			
Year	**EI Avg**	**n**	**EI Avg**	**n**	**EI Avg**	**n**	**Sum**	**Wt EI Avg**
2015-16	99	83	60	76	88	68	227	82.6
2014-15	95	83	60	62	83	83	228	81.1
2013-14	90	115	75	48	95	56	219	88.0
2012-13	94	107	80	54	92	50	211	89.9
2011-12	97	25	---	---	88	55	80	90.8
Overall	**94.3**	**413**	**67.5**	**240**	**88.6**	**312**	**965**	**85.8**

1.) % value shown is average student performance for each embedded indicator.
2.) n is the sample size for each embedded indicator, sum is total sample size per year.
3.) Collective weighted means were calculated for all embedded indicators for each year.
4.) Overall weighted means were calculated over the 5-year application period for each EI.
5.) --- Indicates year when results were not available.

Senior Exit Survey Data

At the end of each academic year, immediately preceding graduation, a Senior Exit Survey is administered to all graduating students focusing on student feedback related to a wide range of educational objectives and Departmental outcomes. Students are asked to self-assess how well they perceive their individual achievement of competencies for each adopted Departmental outcome and rate their preparedness to apply knowledge in their forthcoming professional

careers. See Table 5 for senior exit survey responses to teamwork skills using a 1-5 Likert scale by posing the following self assessment statement to students: "I can work with others in a team that requires the use of knowledge from several different disciplines." Senior Exit Survey data from the previous eight years, 2009 to 2016, was tabulated for teamwork question, including a total student sample size of n = 316, ranging annually from a low of 28 to high of 60 students. Once again, 1-5 Likert scores were converted to percentages for ease of comparison with other data, based on percent of the five-point scale. Annual means for this Senior Exit Survey self-assessment ranged from a low of 90.3 to a high of 97.1, indicating that students strongly agree they are prepared to effectively work on teams. Furthermore the annual tabulations also include standard deviation values and percent to provide additional insight into student perceptions.

Table 5. Senior Exit Survey Results, Teamwork Outcome Responses (n = 316 students)

	Likert Scale Response									
Year	**1**	**2**	**3**	**4**	**5**	**Sum**	**Mean**	**SD**	**%Mean**	**%SD**
2015-16	0	0	1	14	45	60	4.73	0.48	94.8%	9.5%
2014-15	0	0	1	11	24	36	4.64	0.54	92.8%	10.7%
2013-14	0	0	1	5	27	33	4.79	0.48	95.8%	9.5%
2012-13	0	0	1	11	32	44	4.70	0.50	94.1%	10.1%
2011-12	0	0	0	13	21	34	4.62	0.49	92.4%	9.7%
2010-11	0	0	6	10	34	50	4.56	0.70	91.2%	13.9%
2009-10	0	1	1	10	19	31	4.52	0.71	90.3%	14.3%
2008-09	0	0	0	4	24	28	4.86	0.35	97.1%	7.0%
Overall	0	1	11	78	226	316	4.67	0.53	93.5%	10.7%

1.) Student Self-Assessment Question at Time of Graduation: I can work with others in a team that requires the use of knowledge from several different disciplines.

2.) Likert response: 1=strongly disagree, 2=disagree, 3=neutral, 4=agree, 5=strongly agree

Comparison and Evaluation of Assessment Data

Comparison of direct and indirect data, collected each year through the Department assessment process, is useful to examine trends or relationships for creating a more comprehensive depiction of student performance for adopted Departmental outcome standards, specifically in this instance teamwork. In creating year-by-year comparisons from embedded indicator results and senior student exit survey responses, it is important to note data is being collected from different groups of students within the same student stream. This is particularly relevant with regard to embedded indicator results that provide in-progress measures of student performance for various outcomes at specified Bloom's Taxonomy levels. Senior Exit Surveys provide self-assessment immediately prior to graduation. Student perception surveys also constitute in-progress data and so far have only been collected for a single year. Measurement, evaluation, and comparison of Departmental data related to teamwork are all assumed to be indications of student preparedness to effectively begin successful careers in civil engineering. Figure 5 provides relative

comparisons between teamwork course embedded indicators, Senior Exit Survey self assessment of teamwork proficiency and aggregated results from the Student Perception Survey of teamwork preparedness across eight courses focusing on team skill building activities. The following trends and relationships between measures are noted for data presented in Figure 5:

- Senior Exit Survey responses for teamwork preparedness (n = 316) over an eight-year analysis period range from 90.3 to 97.1% (Avg. 93.5%) and generally trend higher than Embedded Indicator results over a five-year analysis period and aggregated results from the Student Perception Survey. Box-and-whiskers plots of the Senior Exit Survey provide an indication of the magnitude of data variation to be considered in evaluating these values.
- Embedded Indicator results for student performance of teamwork skills (n = 965) for 14 course embedded indicators over an five-year analysis period, range from 81.1 to 90.8% (Avg. 85.8%) and trend visibly lower than Senior Exit Survey responses over an eight-year analysis period and aggregated results form the Student Perception Survey.
- Student Perception Survey (n=159) for eight courses across six questions regarding course specific teamwork perceptions produced an aggregated average of 81.4 percent, lower than both of the other two measures.

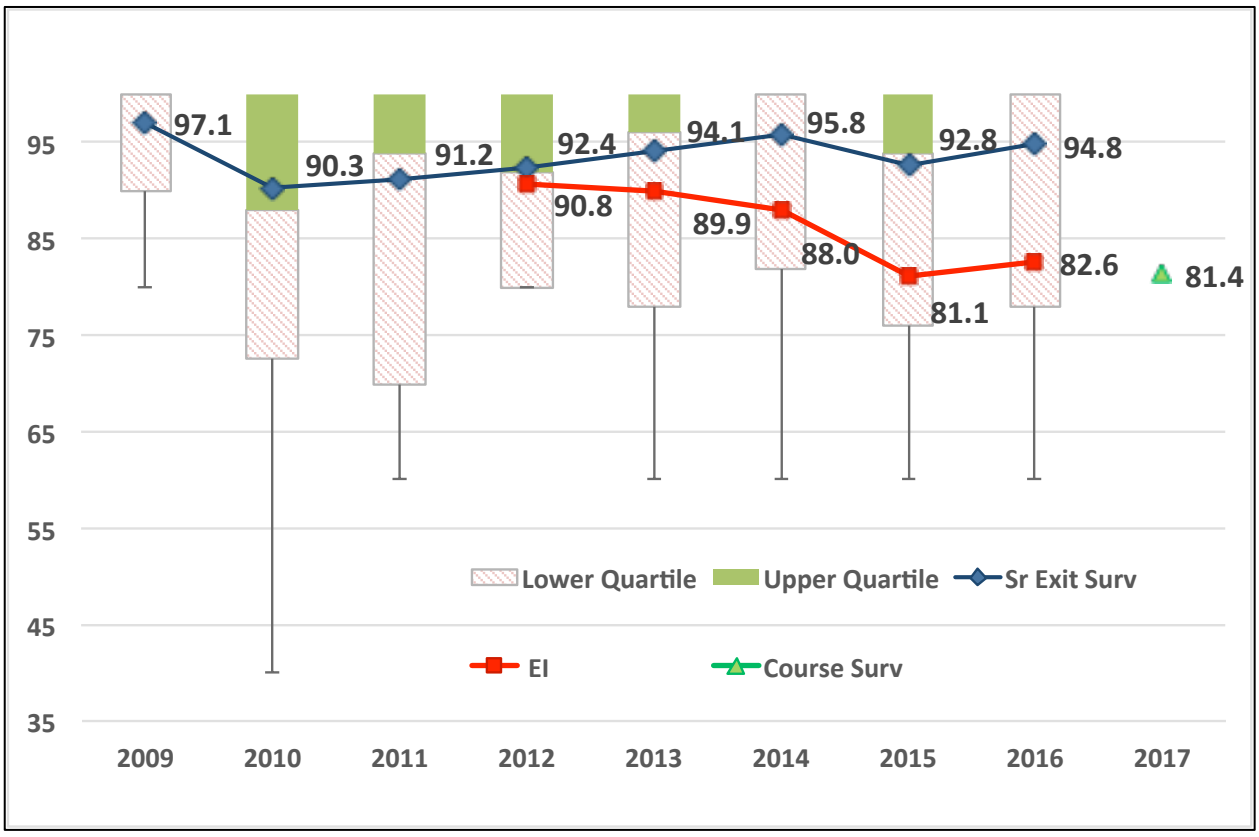

Figure 5. Teamwork Outcome, Comparison of Assessment Measures (Avg. % Score), 2009-2017

Summary of Findings

Tabulation, evaluation, and comparison of data measuring student teamwork competencies, over an eight-year analysis period, provides an insightful depiction of undergraduate performance measures as students prepare for successful civil engineering careers. Through evaluation and comparison of assessment data, the following observations were noted:

1. Trends between direct and indirect measures are visibly evident over the eight-year analysis period and useful in defining relationships between Embedded Indicator results, Senior Exit Survey responses, and course-based Student Perception Surveys.
2. Students tend to generously self assess their proficiency of teamwork competencies, as Senior Exit Survey responses were considerably higher than results from the other two student performance measures.
3. An evaluation of response standard deviation is also helpful in better understanding student performance in evaluating and comparing Embedded Indicator results, and Senior Exit Survey responses and course-based Student Perception Surveys, as this provides a useful indication of student uncertainty.
4. Embedded Indicator results lagged Senior Exit Survey responses by an average of 7.5% (ranging from 1.6% to 12.2% annually) over the five-year analysis period. Box-and-whiskers plots of the Senior Exit Survey provide an indication of the magnitude of data variation to be considered in comparing these values.
5. Aggregated course-based Student Perception Surveys trailed Senior Exit Survey responses by an average of 12.1%. Box-and-whiskers plots of the Senior Exit Survey provide an indication of the magnitude of data variation to be considered in comparing these values.
6. Aggregated course-based Student Perception Surveys trailed Embedded Indicator results by an average of 4.4%.

Future Steps

The use of multiple assessment measures to evaluate student performance of teamwork proficiencies is a promising approach to improving understanding of instructional effectiveness and providing a basis for continuous improvement. Based on evaluation and comparison of data over eight years, some evident improvements are needed. Future steps for continued enhancement and advancement include:

1. Further refine survey instrument and periodically implement a course-based Student Perception Survey focused on teamwork competencies to support more insightful comparisons over time and continued benchmarking with the other assessment measures.
2. Creation and implementation of Embedded Indicators to assess Capstone Engineering Design Courses. Embedded indicator results would better reflect student performance against adopted Departmental standards as students near graduation and be more directly comparable with Senior Exit Survey responses and FE Exam scores.
3. Expand course-based Embedded Indicator results to include sample standard deviation allowing analysis of sample variance and evaluation of standards with regard to acceptable lower distribution limits for student performance, rather than merely a comparison of a student average.

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