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Undergraduate Engineering Student Perception of Professional Skill Preparedness

Dr. William J. Davis P.E., The Citadel

William J. Davis is a professor in Civil & Environmental Engineering at The Citadel in Charleston, SC. He received his Ph.D. in civil engineering from Georgia Tech and is a registered professional engineer. His research interests focus on transportation infrastructure planning and design, highway safety, and active living by design. He teaches courses in transportation engineering, geographic information systems, engineering management, and land surveying.

Dr. Simon Thomas Ghanat, The Citadel

Dr. Simon Ghanat is an Assistant Professor of Civil and Environmental Engineering at The Citadel (Charleston, S.C.). He received his Ph.D., M.S., and B.S. degrees in Civil and Environmental Engineering from Arizona State University. His research interests are in Engineering Education and Geotechnical Earthquake Engineering. He previously taught at Bucknell University and Arizona State University.

Dr. Kevin C Bower P.E., The Citadel

Dr. Kevin Bower is a Professor and Head of the Department of Civil and Environmental Engineering at The Citadel, Charleston, South Carolina. Dr. Bower's teaching research interests are in improving active learning environments and the development of classroom pedagogy to improve moral development in engineering students.

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An Evaluation of Direct and Indirect Measures for Assessment of Professional Skills in an Undergraduate Civil Engineering Curriculum

Introduction

The undergraduate Civil Engineering curriculum at The Citadel emphasizes preparation of graduates to serve as principled leaders in design, construction, maintenance and operation of the built-environment. In support of this vision, department faculty adopted a series of outcomes focusing on the professional skills needed to prepare graduates for successful engineering careers. Course material is provided recurrently within the curriculum that emphasizes student development of professional skills needed to establish a foundation for a successful career and fulfill the high calling of a practicing Civil Engineer.

Procedures for systematic collection of assessment data were instituted and have been in place for more than ten years. Data is collected on all twenty-two adopted outcomes, including a subset of nine outcomes specifically focused on professional skills. Data from direct and indirect measures are collected on an annual basis including Fundamentals of Engineering (FE) knowledge area scores, Embedded Indicator results, and Senior Exit Survey responses. Each of these assessment methods is described, collected data is summarized over a period of several years, and results are compared to investigate useful relationships between these three assessment tools. Findings are anticipated to be of interest to other engineering programs as an example of assessment techniques for use in improving objective curricular measures, linked with evidence based outcomes.

Background

American Society of Civil Engineers (ASCE) published an expanded set of 24 Civil Engineering outcomes in the Civil Engineering Body of Knowledge for the 21st Century[1]. Many undergraduate programs are adopting these outcomes as evidence of continuous improvement in fulfillment of ABET, Inc. (formerly known as Accreditation Board for Engineering and Technology) Criterion[2]. To prepare students to meet an increasing demand for professional skills in the engineering profession, undergraduate programs are responding through modification of academic curriculum material and course content[3,4].

Development of professional and leadership skills has been shown to improve through the college experience[5]. Leadership principles covered in the curriculum have proven to make improvements in student development and studies indicate faculty interaction also has a positive effect[5]. Assessing student obtainment of fundamental professional skills and leadership concepts at lower levels of Blooms Taxonomy through assessment is relatively straightforward through application of course Embedded Indicators, FE exam scores, and Senior Exit Surveys[6,7].

Use of Embedded Indicators as a direct assessment measure is considered a highly effective means of measuring student attainment of established standards[8]. Application of course-based Embedded Indicators, grading rubrics, and aggregated student scores compared to a department standard constitute an objective and are measurable for conducting meaningful assessment[9]. Use of FE examination knowledge area scores as a direct assessment measure is readily available and a beneficial method of assessment[10]. Assessment results can be used to modify course content and ensure topics on the exam are covered appropriately within the curriculum[11]. Use of Senior

Exit Survey responses, as an indirect assessment measure, serves as predictors that are correlated to learning, but do not measure learning itself[12]. Numeric relationships and trends between direct and indirect assessment measures are evident in some cases and can be used to provide additional insight into student learning[13].

A robust outcome-based assessment process should include multiple direct and indirect tools to provide valuable insight into individual outcomes, and provide an overall perspective of the effectiveness of the curriculum and serve as the basis of continuous improvement[14]. Data presented in this paper provides a comparison of direct and indirect assessment methods that are collectively focused on analysis of student attainment of professional skills. Adopted departmental outcomes and important elements of the assessment process are described along with trends and relationships identified in the data evaluation and comparisons occurring over multiple year periods, ranging from four to seven years.

Civil Engineering Department Professional Outcomes

Departmental outcomes aligning the curriculum along professional skills were established to link course goals across a step-by-step strategy for student development. An essential component of this plan was adoption of Embedded Indicators, aligned with CEE Department outcomes, and mapped across all four years of the undergraduate curriculum. Embedded Indicators are mapped to appropriate Bloom's Taxonomy levels and organized sequentially to provide a progression of student development under professional practice outcomes.

After students are exposed to instructional material, Embedded Indicators collectively measure student performance as determined by graded test questions, assignments, reports and projects commonly used by instructors to assess student learning. Prior to teaching a Civil Engineering course, faculty pre-identifies specific Embedded Indicator tools for use in measuring each goal contained in the course syllabus. Table 1 outlines acceptable tools faculty can use to measure appropriate levels of cognitive performance. Throughout the semester, students are assessed using pre-designated tools. If average student performance for an Embedded Indicator tool is measured as 75% or higher, it is concluded that 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 1-22 outcomes.

The entire departmental assessment process is predicated upon twenty-two outcomes developed and adapted from ABET, Criterion 3, student outcomes A-K[2] and ASCE Body of Knowledge[1]. Each outcome provides a succinct statement describing material students are expected to learn over a four-year development period before graduation. Attainment of proficiency for each outcome is measured using Embedded Indicators based on mapping to the six levels of Bloom's Taxonomy[15,16]. Table 2 summarizes the CEE Department nine professional skills related outcomes. Course Embedded Indicators on tests, assignments, and projects are used to evaluate CEE Department 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 1. Embedded Indicator Tools and mapping to Bloom's Taxonomy Levels

Embedded Indicators	Bloom's Taxonomy Level						Instrument
	1	2	3	4	5	6	
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							

Assessment Data Collection Methods

Assessment data is collected annually for all twenty-two Departmental outcomes. Each outcome is evaluated using data from multiple direct and indirect assessment measures. An overall rubric is used to provide a cumulative determination of the student's performance for each outcome at the end of each academic year. Primary sources of data for the outcomes assessment process include course Embedded Indicators, FE examination knowledge area scores, and Senior Exit Survey responses. Each of these tools is briefly described and summarized along with the data used in the evaluation of professional skills.

Embedded Indicators: Professional skills outcomes are aligned with courses in the Civil Engineering curriculum and assessed using Embedded Indicators directly linked through course goals/objectives. End of term course reports are used along with an Embedded Indicator process to support the Department's outcomes assessment[16]. Faculty work collectively on a course-by-course basis to adopt common course goals, link outcomes, and determine student competency, via Bloom's Taxonomy, levels. Each of the Department's twenty-two outcomes is linked with at least three Embedded Indicators. Average scores of student performance are determined and compared to an adopted Departmental standard. For analysis of professional skills Embedded Indicators for public policy, communication, business, and contemporary issues were used.

Three Embedded Indicators are used to cover each outcome. Data tabulations cover four years from 2012 to 2015, and include a total student sample size of n = 2,628, extending across a total of 48 individual Embedded Indicators.

Table 2. Summary of CEE Department Professional Skills Oriented Outcomes

Dept. Outcome	Outcome Criteria
Contemporary Issues	Describe influence of contemporary issues on engineering solutions.
Project Management	Explain what a project is and key elements of project management.
Communication a.) Graphical b.) Verbal c.) Written	Organize and deliver effective graphical, verbal and written communication.
Public Policy	Discuss and explain key concepts involved in Public Policy and Public Administration.
Business	Explain key concepts and processes used in business.
Leadership	Explain the role of a leader and leadership principles and attitudes.
Interdisciplinary Teams	Function effectively as a member of an interdisciplinary team.
Self-Directed Learning	Demonstrate the ability for self-directed learning.
Ethical Responsibility	Apply standard of professional and ethical responsibility to determine an appropriate course of action.

Fundamentals of Engineering Examination: Since 2012, the results from the NCEES FE Examination have been used in the Departmental assessment process; students are required to take the FE Exam before graduation. Prior to that time, a majority of graduating students (70-80 percent) were already taking the exam. Specific subjects, or knowledge areas, are mapped to outcomes based on relevance. Averages for each knowledge area are compared to both Carnegie comparators, as well as the national average. For analysis of professional skills, FE knowledge area scores related to Ethics and Business Practice, and Engineering Economics were tabulated for seven years, from 2009 to 2015, and include a total sample size of n = 220, for the two knowledge areas of interest.

Senior Exit Survey: Each year the Department administers a Senior Exit Survey to graduating students that focuses on student feedback related to educational objective and Departmental outcomes. A specific series of questions included on the survey focuses on student self assessment of how well they perceive their individual achievement of competencies for each of the outcomes and preparedness to apply these skills in their professional careers. See Table 3 for survey categories, questions and 1-5 Likert scale responses. To gage the cumulative effect, student perception of professional skills data for a subset of eight outcomes from the previous seven years, 2009 to 2015, was tabulated and includes a total student sample size of n = 267.

Table 3. Senior Exit Survey, Professional Skills Outcomes

Outcome	Student Self-Assessment at Time of Graduation	Likert Scale
Multidisciplinary Teams	1. I can work with others in a team that requires the use of knowledge from several different disciplines.	1 2 3 4 5
Professional and Ethical	2. I understand my professional & ethical responsibilities and the way they affect my decision-making.	1 2 3 4 5
Communication	3. I have effective oral, written, and graphical communication skills.	1 2 3 4 5
Lifelong Learning	4. I can demonstrate a commitment to learning and continued professional development outside the classroom.	1 2 3 4 5
Public Policy	5. I can explain public policy and public administration.	1 2 3 4 5
Leadership Principles	6. I have an understanding of the role of a leader and leadership principles and attitudes.	1 2 3 4 5
Project Management	7. I can explain project management, construction, and asset management concepts.	1 2 3 4 5
Contemporary Issues	8. I can describe how engineering solutions influence economy, political landscape, or society.	1 2 3 4 5
Likert scale definitions: 1=strongly disagree, 2=disagree, 3=neutral, 4=agree, 5=strongly agree		

Assessment Data and Analysis

Embedded Indicator data from 2011 to 2015 is tabulated and presented in Table 4 across four professional skills related outcomes and 48 individual Embedded Indicators. In comparing these values it is important to note that Bloom's Taxonomy levels (1-6) vary by course. Obviously, junior and senior level courses commonly exhibit higher Embedded Indicator Bloom's levels, than courses offered during freshman and sophomore years. Another important point in analyzing Embedded Indicator data is that these values provide an in-progress measure of student achievement of Departmental outcomes, where as other assessment measures occur at, or near, the end of student undergraduate education, prior graduation. Although clearly pervasive trends in the data tabulations in Table 3 are not evident, the following observations are noted:

- Relatively small variations exist in data tabulations for these four outcomes over the four-year analysis period with an overall student performance of 82%.
- Results from the four outcomes are bracketed with Contemporary Issues (85%) and Communication (84%) falling on the upper bound and Public Policy (81%) and Concepts in Business (78%) falling on the lower bound. A possible explanation for lower performing outcomes is likely related to the difficulty in explaining complicated engineering business and public policy nuances needed for future successful careers to undergraduate students who have little experience or knowledge of real world situations.

Table 4. Summary Results for Embedded Indicators, 2011-2015, (n = 48 Embedded Indicators, n = 2,628 students)

Year	Contemporary Issues			Key Concepts in Business			Communication			Public Policy			Weighted Mean
	CE 322 (Goal 1)	CE 327 (Goal 7)	CE 404 (Goal 9)	CE314 (Goal 3)	CE314 (Goal 4)	CE317 (Goal 2)	CE317 (Goal 3)	CE418 (Goal 6)	CE419 (Goal 6)	CE305 (Goal 2)	CE314 (Goal 5)	CE317 (Goal 5)	
2011-12	68% (52)	80% (53)	- -	73% (68)	70% (68)	85% (34)	82% (34)	75% (44)	83% (47)	90% (57)	92% (41)	76% (34)	**79% (532)**
2012-13	79% (44)	83% (52)	85% (60)	90% (34)	81% (34)	80% (50)	85% (50)	87% (54)	84% (58)	69% (51)	69% (34)	84% (50)	**82% (571)**
2013-14	94% (51)	82% (47)	88% (40)	77% (102)	83% (102)	78% (56)	90% (56)	83% (44)	86% (39)	77% (43)	85% (102)	78% (56)	**83% (738)**
2014-15	97% (52)	85% (67)	91% (44)	75% (79)	84% (79)	74% (83)	78% (83)	90% (53)	86% (42)	86% (69)	86% (79)	78% (83)	**83% (813)**
Weighted Means	**85% (199)**	**83% (219)**	**88% (144)**	**77% (283)**	**80% (257)**	**78% (223)**	**83% (223)**	**84% (195)**	**85% (186)**	**81% (220)**	**84% (256)**	**79% (223)**	**(2628)**
Overall Mean	**85% (562)**			**78% (763)**			**84% (604)**			**81% (699)**			**82%**

NOTES: 1.) % value shown is average student performance for each Embedded Indicator.
2.) Value in parenthesis is the sample size for each Embedded Indicator.
3.) Collective weighted means were calculated for all professional skills related Embedded Indicators for each year.
4.) Individual weighted means were calculated over the 4-year application period for each Embedded Indicator.
5.) -- Indicates year when results were not available.

- A year-by-year tabulation of all four professional skill outcomes indicates the annual student performance has slightly increased over the four-year period from 79% to 83%.

FE Examination data from 2009-2015 is tabulated and presented in Tables 5 and 6 for two knowledge areas related to professional skills including Ethics and Business Practice and Engineering Economics. In comparing these values it is important to note that the FE examination changed during this period from an eight-hour exam to a six-hour exam with additional modification to the list of materials covered in the examination. However, comparisons of the institution performance to the national average provide a useful measure of student performance pertaining to professional skill outcomes. The following observations are noted for data summarized in Tables 5 and 6:

- Table 5, Institution results for Civil Engineering students generally trends equitably with the national average and are essentially the same, average of 78% correct, over the seven-year period from 2009-2015.
- Table 5, Institutional results for Civil Engineering students indicate a slightly larger standard deviation (5.3) and boarder range (18) in comparison with national averages, which is likely due to a smaller sample size.
- Table 5, over the seven-year study period, the institutional average percent correct equaled or exceeded the national average for nine of the eleven FE exam periods.
- Table 5, Institutional percent correct for Civil Engineering students has trended up and down over the seven-year period from a high of 88% to a low of 70% with no noticeable useful trends evident in the data, other than lower percent correct scores are noted when a larger number of students take the exam.
- Table 6, Institutional results for Civil Engineering students trends lower by an average of 9% as compared to the national average from 2009-2015, with an average institutional average of 61% correct in comparison with a national average of 67%, over the same seven-year analysis period.
- Table 6, only during two of eleven FE exam periods over the past seven years did the institutional average percent correct equal the national average in the Fall of 2009 (n = 21) and Fall of 2014 (n = 4).

Senior Exit Survey response data from 2009-2015 is tabulated and presented in Table 7 across eight professional skills related outcomes. It should be noted that the student survey did not include a question regarding contemporary issues prior to 2012. For equitable comparison with other assessment data, student survey responses on a 1-5 Likert scale were converted to a percentage basis, with 5 as 100%. Additionally, seven-year averages were determined for each of the eight outcomes and provided with standard deviation values to provide further insight into student perceptions. The following observations are noted for data summarized in Table 7:

- The highest survey response (96%) was noted for perceived student understanding of professional and ethical responsibility. This outcome also has the lowest standard deviation (9%) indicating a concurrence of student perception on this professional skills outcome and providing further evidence of a strong positive response.

Table 5. FE Exam Ethics and Business Practice Results, 2009-2015 (n=220)

FE Exam Administration	Institution CE Avg. % Correct	National Avg. % Correct	Ratio of Institutional Avg. % Correct / National Avg.
S 2009 (2) F 2009 (21)	88 79	83 78	1.06 1.01
S 2010 (11)	83	78	1.06
S2011 (16) F 2011 (35)	79 82	75 82	1.05 1.00
S 2012 (18) F 30012 (47)	86 78	85 74	1.01 1.05
S 2013 (11) F 2013 (24)	83 70	83 77	1.00 0.91
F 2014 (4)	88	74	1.19
S 2015 (31)	71	73	0.97
2009-15 (220) Mean (SD/Range)	**78 (5.3/18)**	**78 (3.9/12)**	**1.00 (0.05/0.28)**

Table 6. FE Exam Engineering Economics Results, 2009-2015 (n=220)

FE Exam Administration	Institution CE Avg. % Correct	National Avg. % Correct	Ratio of Institutional Avg. % Correct / National Avg.
S 2009 (2) F 2009 (21)	60 69	76 69	0.79 1.00
S 2010 (11)	68	70	0.97
S2011 (16) F 2011 (35)	49 61	63 63	0.78 0.97
S 2012 (18) F 30012 (47)	67 59	72 63	0.93 0.94
S 2013 (11) F 2013 (24)	59 56	64 63	0.92 0.89
F 2014 (4)	67	67	1.00
S 2015 (31)	64	69	0.93
2009-15 (220) Mean (SD/Range)	**61 (5.5/20)**	**67 (4.1/13)**	**0.91 (0.06/0.22)**

Table 7. Tabulation of Results for Senior Exit Survey, 2009-2015 (n=267)

	Multidisciplinary Teams		Professional & Ethical		Communication		Lifelong Learning		Public Policy		Leadership Principles		Project Management		Contemporary Issues	
Year (n)	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
2009 (28)	97%	7%	96%	10%	86%	15%	98%	6%	89%	14%	94%	11%	89%	13%	--	--
2010 (31)	90%	14%	99%	5%	90%	16%	91%	13%	77%	17%	92%	10%	84%	16%	--	--
2011 (51)	91%	14%	96%	10%	86%	14%	93%	11%	79%	18%	93%	13%	83%	16%	--	--
2012 (44)	92%	10%	91%	10%	87%	13%	90%	5%	78%	17%	87%	13%	84%	10%	85%	11%
2013 (44)	94%	10%	95%	10%	89%	14%	93%	11%	86%	19%	91%	12%	85%	14%	86%	13%
2014 (33)	96%	10%	99%	3%	95%	10%	98%	7%	85%	14%	96%	8%	87%	13%	92%	11%
2015 (36)	93%	11%	96%	10%	92%	14%	93%	13%	87%	17%	91%	15%	91%	16%	91%	13%
09-15 Avg (267)	**93%**	**11%**	**96%**	**9%**	**89%**	**14%**	**93%**	**9%**	**83%**	**17%**	**92%**	**12%**	**86%**	**14%**	**88%**	**12%**

NOTES: 1.) Mean % is average 1-5 Likert scale student response converted to a percentage basis, with 5 as 100%.
2.) SD is the standard deviation of the mean calculated for each professional skills related outcome.
3.) Value in parenthesis represents student sample size for each year.
4.) Individual weighted averages were calculated over the 7-year period for each professional skills related outcome.
5.) -- Indicates years when results were not available.

- The lowest survey response (83%) was noted for student perception of public policy. This outcome also has the highest standard deviation (17%) indicating a higher variation of responses to this professional skills outcome and less student certainty of preparedness. As previously discussed, it is likely difficult to teach complicated public policy concepts to undergraduate students with limited experience or knowledge of real world situations.
- Additional high survey responses include multidisciplinary teams (93%) and life long learning (93%) indicating perceived student preparedness for these professional skills for beginning their careers upon graduation.
- Lower survey responses were noted for project management (86%) and communication (89%) both of which have higher standard deviations (14%) indicating a higher variation of responses response to these professional skills and less student certainty of preparedness.

Comparison and Evaluation of Assessment Data

Direct and indirect data, collected annually through the Department assessment process, is compared and evaluated to investigate evidence of useful trends or relationships for providing a better understanding of student performance with respect to adopted Departmental outcome standards. It is important to note in conducting a year-by-year comparison using FE knowledge area scores, Embedded Indicator results, and Senior Exit Survey responses, performance values are being derived from different groups of students. This is especially relevant in the case of Embedded Indicator results, which serve as in-progress measures of student understanding of outcome related material, at specified Bloom's Taxonomy levels. FE exam knowledge area scores occur during student's senior year relatively close to graduation; however, a large portion of students take the exam during the fall semester. Additionally, in the event students do not pass the test in the fall, they often retake the exam in the spring. Senior Exit Surveys are the only assessment measure that occurs immediately prior to graduation. Measurement, evaluation, and comparison of Departmental data related to professional skills outcomes are all assumed to be indications of student preparedness to effectively begin successful Civil Engineering careers.

Table 8 provides outcomes based comparisons for communication, public policy and contemporary issues using FE knowledge area scores in Ethics and Business Practice and Engineering Economics, Senior Exit Surveys, and Embedded Indicator averages. These outcomes were selected to be representative of the nine outcomes related to professional skills. Comparisons extend across four-years from 2011-2015, as this period has uniform data for all assessment measures. These comparisons are based on data with adequately large sample sizes, including 135 students for the FE exam, 84-90 for the Senior Exit Survey responses and 562-699 for Embedded Indicator results. In additional to tabular summary of data provided in Table 7, results are also represented graphically in Figure 1. The following trends and relationships are noted for professional skill outcomes data presented in Table 8 and Figure 1:

- FE knowledge area scores for Ethics and Business Practice, ranging from 70 to 83% (Avg. 79%), and FE Engineering Economics, ranging from 56 to 64% (Avg. 62%), both trend considerably lower than other measures over the four-year period for all three professional skills outcomes: Communication, Public Policy and Contemporary Issues.

- Communication, Embedded Indicator results and generally parallel Senior Exit Survey responses at an average score of 9% below Senior Exit Survey responses, and combined FE scores for Ethics and Business Practice and Engineering Economics at an average score of 19% lower than Senior Exit Survey responses, over the four-year analysis period.
- Public Policy, Embedded Indicator results and generally parallel Senior Exit Survey responses at an average score of 2% below Senior Exit Survey responses, and combined FE scores for Ethics and Business Practice and Engineering Economics at an average score of 13% lower than Senior Exit Survey responses, over the four-year analysis period.
- Contemporary Issues, Embedded Indicator results and generally parallel Senior Exit Survey responses at an average score of 3% below Senior Exit Survey responses, and combined FE scores for Ethics and Business Practice and Engineering Economics at an average score of 17% lower than Senior Exit Survey responses, over the four-year period.

Table 8. Outcome Comparison of Assessment Measures, 2011-2015

Outcome Assessment Measure	**2011-12**	**2012-13**	**2013-14**	**2014-15**	**Mean**
Communication, Sr. Exit Survey	87%(44)	89%(44)	95%(33)	92%(36)	90%(157)
Communication, E.I. Avg.	72%(125)	85%(162)	84%(139)	83%(178)	81%(574)
Public Policy, Sr. Exit Survey	78%(44)	86%(44)	85%(33)	87%(36)	84%(157)
Public Policy, E.I. Avg.	87%(132)	75%(135)	81%(201)	83%(231)	82%(699)
Contemporary Is., Sr. Exit Survey	85%(44)	86%(44)	92%(33)	91%(36)	88%(157)
Contemporary Is., E.I. Avg.	74%(105)	83%(156)	88%(138)	90%(163)	85%(562)
FE – Ethics & Business Practice	83%(65)	79%(35)	70%(4)	73%(31)	79%(135)
FE – Engineering Economics	63%(65)	59%(35)	56%(4)	64%(31)	62%(135)

In addition to outcome specific comparisons, larger aggregations were also created to allow a more generalized view of broader relationships between direct and indirect assessment measures related to professional skills assessment, over a the entire seven-year analysis period from 2009-2015. The following trends and relationships are noted for the professional skill outcomes data presented in Table 9 and Figure 2:

- Senior Exit Survey responses (n = 267) for professional skill outcomes (n = 8), ranging from 87 to 94% (Avg. 91%) trend considerably higher than FE exam scores and Embedded Indicator results over the seven-year analysis period.

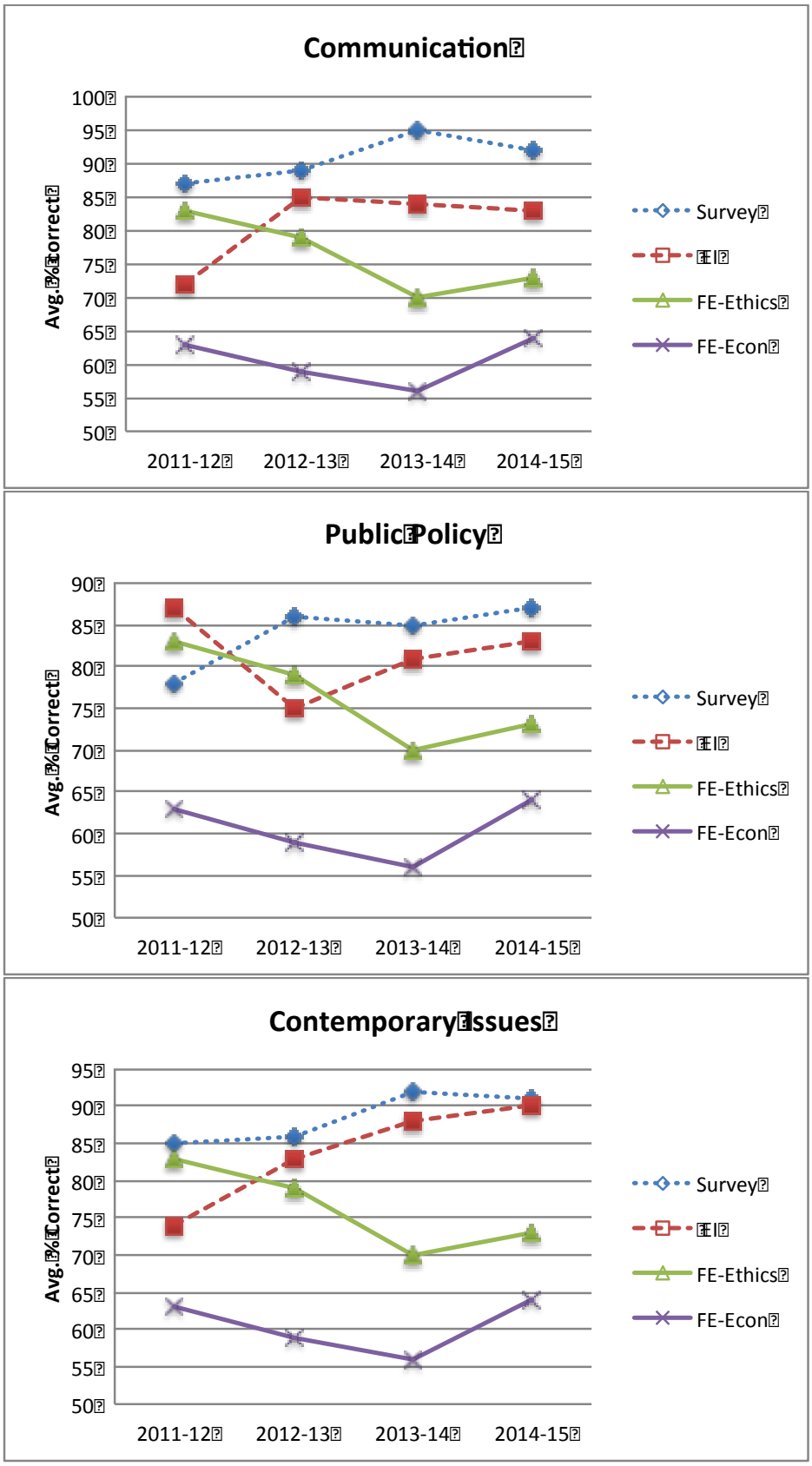

Figure 1. Outcome Specific Comparison of Assessment Measures, 2011-2015

- FE Exam scores (n = 220) for professional skills knowledge areas (n = 2), ranging from 63 to 75% (Avg. 70) trend considerably lower than Senior Exit Survey responses and Embedded Indicator results over the seven-year analysis period.
- Embedded Indicator results (n = 2,628) for professional skills outcome indicators (n = 48), ranging from 79 to 83% (Avg. 82%) trended in between Senior Exit Survey responses and FE Exam scores over the four-year period of available data.

Table 9. Overall Combined Comparison of Direct and Indirect Measures, 2019-2015

Year	FE Exam[1]	Sr. Exit Survey[2]	Embedded Indicators[3]
2009	74%	93%	
2010	75%	89%	
2011	64%	89%	
2012	73%	87%	79%
2013	69%	90%	82%
2014	63%	94%	83%
2015	69%	92%	83%
Mean	**70%**	**91%**	**82%**

NOTES: 1) FE scores based on the average of 2 knowledge areas, 7-years, total n = 220.
2) Sr. Exit Survey scores based on the average 8 questions, 7-years, total n = 267.
3) Embedded Indicators based on average of 48 E.I's, 4-years, total n = 2,628.

Use of Direct and Indirect Data in Department Assessment Process

Each of the twenty-two adopted outcomes is assessed annually using multiple direct and indirect measures comprised of course-based Embedded Indicators (minimum of three), FE Examination knowledge area scores, Senior Exit Survey questions, Faculty Survey questions, and mapped curriculum measures. Using data obtained from all of these assessment tools, well-defined rubric criteria is applied to determine an overall 1-5 assessment for each of the twenty-two outcomes. When problems are identified in the overall outcome assessment, or in individual measures, improvements are identified, implemented, and tracked as the basis for the Department's continuous improvement process for the civil engineering curriculum and overall civil engineering program. Examples of recent assessment-based improvements aligned with Professional Skills outcomes are summarized in Table 10.

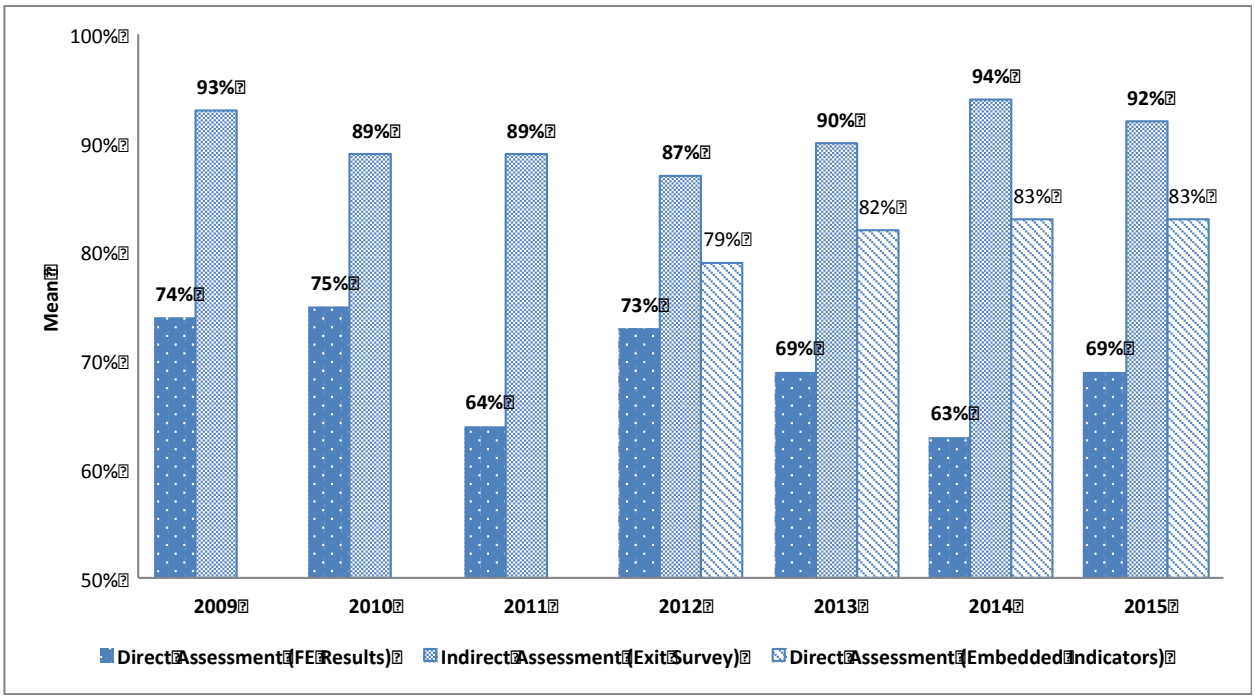

Figure 2. Overall Combined Comparison of Direct and Indirect Measures, 2009-2015

Table 10. Example Assessment-Based Department Curriculum Improvements

Year	Outcome	Curriculum Improvement
2014	Communication	1.) Conduct a prerequisite workshop by CEE faculty to evaluate course prerequisites, based on evidence gathered and create a detailed list suggested changes. 2.) Work with English Department faculty to develop a new technical writing course.
2014	Public Policy	1.) Make changes to CEE courses to better cover FE related topics as determined by Course Content Subcommittees. 2.) Conduct a prerequisite workshop by CEE faculty to evaluate course prerequisites based on evaluation of evidence gathered and implement suggested changes. 3.) Redesign the FE Review course to better address the nature of the new computer based test (CBT).
2015	Leadership	1.) Confirm and/or realign course-based Embedded Indicators used for leadership outcome assessment. 2.) Monitor changes that were made during the previous academic year by course instructors to better cover FE related topics to evaluate if these improvements will have a meaningful and lasting effect on FE Results. 3.) Faculty incorporate results of the prerequisite workshop and continue to work on appropriate alignment of the curriculum particularly between lab and lecture classes.

Summary of Findings

Tabulation, evaluation, and comparison of eight, CEE Department outcomes supporting student professional skills development, over a seven-year analysis period, creates an informative representation of undergraduate performance measures as students prepare for successful careers in Civil Engineering. Through evaluation and comparison of professional skills assessment data, the following summary points and insights were observed:

1. The tendency of students to generously assess their own knowledge proficiency of professional skills was evident, as Senior Exit Survey responses were considerably higher than results from the direct assessment measures.
2. Trends and relationships between direct and indirect assessment data is noticeably evident over the seven-year analysis period and useful in better understanding associations between FE Exam scores, Embedded Indicator results, and Senior Exit Survey responses.
3. Both outcome specific comparisons and overall combined annual comparisons reveal useful trends and relationships between direct and indirect assessment data.
4. In addition to a comparison of FE Exam scores, Embedded Indicator results, and Senior Exit Survey responses, an evaluation of data standard deviation, when available, is also insightful in understanding student performance.
5. Embedded Indicator combined results trailed Senior Exit Survey combined responses by an average of 9% (ranging annually from 8% to 11%) over the four-year analysis period.
6. FE Exam combined scores trailed Senior Exit Survey combined responses by an average of 21% (ranging annually from 14% to 31%) over the seven-year analysis period.
7. FE Exam combined scores trailed Embedded Indicator combined results by an average of 13% (ranging annually from 6% to 20%) over the four-year analysis period.

Future Steps

CEE Department faculty at the Citadel has been using direct and indirect measures to assess student performance for all twenty-two adopted outcomes, or former outcomes, including the eight current professional skill outcomes, for more than ten years. Based on evaluation and comparison of data collected from the previous seven years, a number of improvements are needed. Some of the initial future steps for further enhancement and improvement include:

1. Adoption and use of a specific subset of Embedded Indicators focused on assessing outcomes during Senior Engineering Capstone Design Courses. This would allow Embedded Indicator results to reflect student knowledge and performance against desired standards at a time in the curriculum close to graduation and more equitably comparable with other direct and indirect assessment data.
2. Expand systematic Embedded Indicator reporting to include calculation of sample standard deviation allowing an analytically based evaluation of appropriate Departmental standards with respect to acceptable lower distribution limits for student performance.
3. Use of knowledge from this data evaluation and comparison to similar assessments of design related outcomes for each discipline specific technical area of the civil engineering curriculum including: structures, environmental, transportation, and geotechnical.

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