ASEE AMERICAN SOCIETY FOR ENGINEERING EDUCATION

Paper ID #45438

Student Perceptions of Success: A Comparison of Direct and Indirect Measurements

Dr. Ryan Daniel Doczy, Virginia Military Institute
Dr. Jai Kyoung Jung, Virginia Military Institute
Dr. Aksel Seitllari, Virginia Military Institute

Student Perceptions of Success: A Comparison of Direct and Indirect Measurements

Abstract

This study examines the relationship between direct and indirect measures of student outcomes in engineering education. Direct measures like standardized tests and GPAs provide objective data on knowledge and skills, while indirect measures like surveys capture student perceptions. Comparative analyses and Chi-Square tests were performed on senior exit surveys from 46 students to evaluate potential gaps between students' perceived mastery of ABET outcomes versus their GPAs. The study also compared student perceptions of difficult FE exam subjects against actual exam performance data. Results indicate some correlation between student perceptions and direct success measures, though significant discrepancies exist, particularly among lower-achieving students who tend to be more optimistic about their abilities. The paper argues for integrating both direct and indirect methods to comprehensively assess student outcomes and understand perceived readiness. This balanced approach can inform more effective assessment strategies aligned with educational goals.

Introduction

Typical learning goals for any higher-education science, technology, engineering, and math (STEM) program target the ability of the student to learn and retain information related to their field of study. While the pedagogical strategies employed to meet these goals may differ both at the institutional level and based on their discipline, they can be broken down into a more generalized set of learning goals that are common across STEM. The Accreditation Board for Engineering and Technology, Inc. (ABET) provides the generalized set of learning goals that many engineering institutes of higher learning follow to inform their pedagogical approach and to ensure that the student body is receiving an education that approaches critical thinking in a holistic manner (e.g., formulating problems, working in a laboratory setting, mastery of graphical/written/verbal communication). Institutions collect a series of assessments targeting these individual student outcomes (SOs) with the goal of determining how well the student body can achieve the goals prescribed by ABET. This process provides a thorough overview of student attainment in the SOs from the perspective of the institution and its individual faculty, but it lacks any substantive measure of student self-efficacy.

Self-efficacy is a term used to describe how well an individual believes they can accomplish a task [1]. Self-efficacy in a higher learning setting relates to student self-assessment of their perceived mastery of a given subject. General confidence can factor into a student's self-efficacy. However, other significant variables include planning [2], time management [3], and information processing [3], among others. This suggests a covariation between general traits ascribed to high-achieving students and their GPAs, which aligns with the general thinking that good students will have good study habits. Students seem cognizant of this as their GPA appears

to have a significant correlation to their perception of their higher-order cognitive skill improvement [4]. While connections have been made between student self-efficacy and their GPAs [5] [6], there appears to be a relative dearth of literature delving into student self-efficacy measures related to their mastery over ABET SOs. What research has been conducted has looked at self-efficacy measures at the previous set of eleven ABET SOs [7] and focused on pre- and post-course surveys to document any significant improvements in student self-efficacy ABET scores [7] [8] [9]. The inclusion of a study focusing on student self-assessments of ABET SO attainment, taken by outgoing seniors, can provide their impressions of how well-prepared they feel after completing their entire engineering curriculum.

The Fundamentals of Engineering (FE) Exam, an exam taken during the senior year (or later) for most undergraduate engineering students, provides another potential barometer for institutes of higher learning to gauge the degree to which their students have a mastery over their subject matter. The exam provides a range of questions spanning a chosen engineering discipline to test their breadth of knowledge in a subject. Exam results are provided to each university along with pass rates, institution scores, and two scores comparing the institution scores to other universities (ratio and scaled scores). Similar to the test of self-efficacy versus GPA, the FE exam scores allow for a comparison between a direct measure of student attainment versus an indirect measure of attainment. There is a paucity of existing literature comparing student self-efficacy on individual sections of the FE exam versus their FE scores. This can potentially be an avenue for future research as institutions are looking to use multiple assessment methods to more precisely evaluate their ABET SOs [10].

Research Goals

This study aims to examine (1) how students' self-efficacy relates to their academic performance as measured by GPA and FE exam scores, and (2) how academic performance may influence students' perceptions of their abilities. Specifically, the study assesses the validity of indirect student assessments, using a survey given to outgoing senior students, to predict their mastery of a subject through direct student assessments (i.e., FE exam data and cumulative GPA values). The study monitors how frequently students underrate or overrate their understanding of ABET SOs based on their measured performance. The goal is to provide some degree of validity to the use of self-efficacy surveys in conjunction with more typical direct assessments to properly gauge student performance.

The hypothesis is that there will be a positive correlation between students' self-efficacy measures and their actual performance as measured by GPA and FE exam scores. However there is the expectation that discrepancies will be found, particularly among lower-achieving students who may overestimate their abilities.

Methodology

Data Collection: Student Survey (Indirect Measure)

A survey was developed for the outgoing senior class at the Virginia Military Institute (VMI) to collect data on students' cumulative GPA, self-assessed attainment of ABET Sos, and perceived difficulty of FE exam subjects. The questions were broken down as follows:

- What is your cumulative grade point average?
- Rate your ability to [statement taken directly from ABET's SO]
- If you have taken the F.E. exam, rank the three most difficult subject areas on the exams (students could provide multiple answers for each class of difficulty)
- If you have taken the F.E. exam, rank the three easiest subject areas on the exams (students could provide multiple answers for each class of difficulty)

Students could provide their GPA values by selecting the range they fell in (e.g., 2.25 ~ 2.49, 3.75~3.99). Students rated their level of attainment in an ABET Student Outcome by selecting a value from a 5-point Likert scale, ranging from "No Ability" to "High Ability," based on their perceived mastery of the specific ABET SO.

For the FE exam questions, students could place components of the FE exam into classes of the three hardest and three easiest sets of questions. They could select from a dropdown list of all fourteen FE exam question types for any question. A difficulty score was calculated for each subject with values of 3, 2, and 1 given to the hardest, second hardest, and third hardest classes of subjects, respectively. A similar measure was given for the easiest, second easiest, and third easiest classes of subjects, but with values of -3, -2, and -1 given, respectively. A total of 46 students participated in the survey, with responses for each question ranging from 44-46 (GPA and ABET questions) to 30-31 (FE exam questions).

Data Collection: FE Exam Results (Direct Measure)

A total of 31 students participated in the Fall 2023 FE exam with 55% of them receiving passing marks. Each of the fourteen FE exam question types had a breakdown based on the average scores of the institution's examinees. These values were compared to the average scores from all other participating institutions using the ratio score and scaled score. The scores are similar (using average institution scores and average ABET institution scores), but scale scores include standard deviation in their score calculation.

$$Ratio\ Score = \frac{Institution\ Average\ Performance\ Index}{ABET\ Comparator\ Average\ Performance\ Index}$$

$$Scaled\ Score = \frac{Institution\ Average\ PI - ABET\ Comparator\ Average\ PI}{ABET\ Comparator\ Standard\ Deviation}$$

Data Analysis and Results

To analyze the relationship between student perceptions and actual performance, the study conducted the following analyses:

1. Comparison of survey response versus GPA
2. Chi-square tests to determine the statistical significance of observed trends
3. Correlation analysis between perceived FE exam subject difficulty and actual exam scores

Survey Responses Versus GPA

The student population was broken down into three cohorts based on their GPA ranges: 3.50 to 3.99 (A-grade cohort); 2.75 to 3.49 (B-grade cohort); and 2.0 to 2.74 (C-grade cohort). Expected levels of self-assessed performance on ABET SOs were assigned based on these GPA ranges (Table 1). Students' responses were then classified as 'On_Target', 'Pessimistic', or 'Optimistic' based on how they compared to these expected levels.

Table 1: Expected ABET SO Attainment Versus Student GPA

Expected ABET Outcome	Cumulative GPA Ranges
Some ability	Below 2.0
Adequate	2.0 to 2.74
More than adequate	2.75 to 3.49
High ability	3.50 to 3.99

Table 2 shows an unexpected trend where students in the lower-achieving cohort were more frequently optimistic about their ABET performance than their GPA might suggest. This trend was particularly noticeable for questions related to SOs 4 through 6. The level of pessimism was significantly higher (6.32% vs 40.63%) for those students in the higher-achieving cohorts, particularly those considered to be the highest performers. The level of optimism showed a significant drop when moving from the C-grade cohort to the B-grade cohort (70.41% vs 46.43%). The A-grade cohort was unable to be considered 'optimistic' in this analysis as the A-grade tier coincided with the highest level of ABET SO attainment.

Table 2: Results of Self-Efficacy Survey Versus Their GPA

	C-GPA Cohort of Students			B-GPA Cohort of Students			A-GPA Cohort of Students		
Student Outcome	Pessimisitic	On-Target	Optimistic	Pessimisitic	On-Target	Optimistic	Pessimisitic	On-Target	Optimistic
SO1	6.25%	50.00%	43.75%	33.33%	42.86%	23.81%	25.0%	75.0%	N/A
SO2	18.75%	37.50%	43.75%	33.33%	28.57%	38.10%	37.5%	62.5%	N/A
SO3_Graphical	6.25%	50.00%	43.75%	38.10%	28.57%	33.33%	37.5%	62.5%	N/A
SO3_Verbal	6.25%	25.00%	68.75%	14.29%	38.10%	47.62%	62.5%	37.5%	N/A
SO4	5.88%	0.00%	94.12%	0.00%	14.29%	85.71%	12.5%	87.5%	N/A
SO5_Teamwork_Outside_Engineering	0.00%	12.50%	87.50%	4.76%	33.33%	61.90%	50.0%	50.0%	N/A
SO5_Teamwork_Outside_Civil_Engineering	0.00%	13.33%	86.67%	19.05%	28.57%	52.38%	50.0%	50.0%	N/A
SO5_Teamwork_Manage_Conflict	0.00%	12.50%	87.50%	9.52%	28.57%	61.90%	25.0%	75.0%	N/A
SO6_Lab_Equipment	0.00%	13.33%	86.67%	33.33%	23.81%	42.86%	62.5%	37.5%	N/A
SO6_Software_Data_Analysis	6.67%	6.67%	86.67%	23.81%	38.10%	38.10%	37.5%	62.5%	N/A
SO6_Develop_and_Conduct_Experiment	13.33%	33.33%	53.33%	19.05%	52.38%	28.57%	37.5%	62.5%	N/A
SO7	12.50%	25.00%	62.50%	9.52%	47.62%	42.86%	50.0%	50.0%	N/A
Averages	6.32%	23.26%	70.41%	19.84%	33.73%	46.43%	40.63%	59.38%	N/A

Chi-square testing indicates a significant difference across most questions between the expected distribution of responses and the observed responses. Only ABET SO 1 and one part of ABET SO 6 (related to conducting lab experiments) showed no significant difference.

These results contrast with previous studies [2] [4] [6] that typically found a positive correlation between student performance and surveys used to gauge self-efficacy. This discrepancy may be due to the inclusion of a broader range of ABET outcomes in our study, including aspects often overlooked, such as ethics, professionalism, and teamwork skills.

Table 3: Chi-Square Test Results

ABET Student Outcome (and summary of the outcome)	h-value	p-value
1 – Ability to solve complex engineering problems)	0	0.2513
2 – Application of engineering design for enviro/econ factors	1	0.0026
3 – Ability to communicate (Graphical Communication)	1	0.0203
3 – Ability to communicate (Verbal Communication)	1	8.36E-04
4 – Use of ethics to make informed judgments	1	7.34E-23
5 – Ability to function as a team (Outside Engineering)	1	1.73E-15
5 – Ability to function as a team (Other Civil Engineers)	1	2.88E-08
5 – Ability to function as a team (Managing Conflict)	1	1.38E-10
6 – Developing/conducting experiments (Use of Lab Equipment)	1	0.0064
6 – Developing/conducting experiments (Software use for Data Analysis)	1	0.0035
6 – Developing/conducting experiments (Develop and Conduct Experiments)	0	0.3264
7 – Ability to acquire and apply new knowledge	1	0.0101

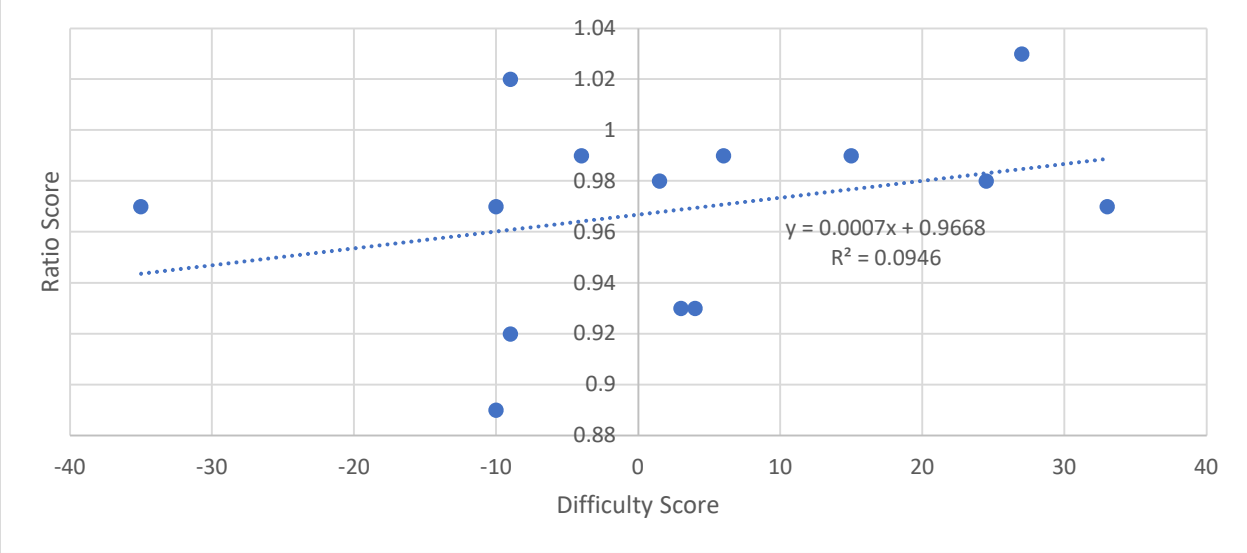
FE Exam Subject Scores Versus Perceived Difficulty

To assess how student perceptions of FE exam subject difficulty compared to their actual performance, a difficulty score was calculated for each subject based on student rankings as described in the methodology section. These scores were then compared to the cohort's performance in these subjects. It turned out that 'Mechanics of Materials', 'Dynamics', and 'Structural Engineering' were the three most difficult subjects and 'Ethics and Professional Practice', 'Math', and 'Surveying' were the three easiest subjects.

FE subject difficulty scores did not display any significant correlation to their ratio scores (positive trend; R-squared = 0.095), scaled scores (positive trend; R-squared = 0.047), or institution scores (negative trend; R-squared = 0.0012). The positive trend for the ratio and scaled scores theoretically suggests that the studied population of students saw better success in their FE exam scores versus their peers as the difficulty of the subjects increased. This performance change only implies a reduction in the gap between the student population and their peers, not that they began outperforming their peers, as can be seen in Figure 1. The negative trend represented by the comparison of the student institution scores and the difficulty of the FE subject implies that their grades did drop versus the easier subject groups. In conclusion, the

results suggest that student perceptions of subject difficulty have very limited predictive power for their actual exam performance.

Figure 1: Self-Assessed FE Subject Difficulty Vs NCEES Ratio Score



Conclusions

This study provides unique insights into the relationship between student self-efficacy and actual performance in engineering education. By examining outgoing senior students' perceptions of their mastery over ABET Student Outcomes (SOs) and comparing these to their cumulative GPAs and FE exam performance, the paper uncovered several unexpected trends:

1. Higher-achieving students exhibited more pessimistic responses to their ABET mastery than expected, especially for outcomes related to problem-solving and design.
2. Inverse relationship between GPA and optimism: Higher-achieving cohorts (based on GPA) exhibited more pessimistic responses to their ABET mastery than lower-achieving cohorts. The C-grade cohort answered pessimistically only about 6% of the time, compared to 20% for the B-grade and 41% for the A-grade cohorts. This trend is particularly noteworthy and diverges from expectations based on prior research [2] [4] [6].
3. Variation across ABET SOs: The A-grade cohort showed reduced levels of pessimism for ABET SOs 1 to 3 (related to problem-solving and design), while lower-achieving cohorts were least optimistic about these same outcomes. This suggests that including a broader range of learning aspects (e.g., ethics, professionalism, teamwork skills) in self-efficacy assessments may yield results different from those focused solely on technical skills.
4. Limited correlation between perceived FE exam difficulty and performance: Student perceptions of FE exam subject difficulty showed little to no correlation with their actual

scores, indicating that student perceptions have limited predictive power for exam performance.

These unique findings highlight the complex nature of self-efficacy in engineering education and underscore the importance of using both direct and indirect measures to comprehensively assess student outcomes. The study demonstrates that relying solely on self-efficacy surveys may not provide an accurate picture of student capabilities, particularly when considering different achievement levels.

The results suggest that institutions should carefully consider how student self-efficacy may vary based on academic performance when interpreting such surveys. While these indirect measures can provide valuable insights into students' perceived readiness for the workforce, they should be used in conjunction with direct performance measures for a more complete assessment.

Future research could build on these unique findings by:

1. Investigating the factors contributing to the unexpected pessimism in higher-achieving students and optimism in lower-achieving students.
2. Examining the relationship between self-efficacy and performance in specific ABET SOs, rather than using cumulative GPA as a proxy for overall performance.
3. Investigating how the inclusion of a broader range of learning outcomes (beyond technical skills) affects the relationship between self-efficacy and performance.

By integrating these findings into assessment strategies, engineering programs can better align their curricula with both objective performance measures and student perceptions of readiness, ultimately enhancing the effectiveness of engineering education.

References

[1] A. Bandura, "Mediating Processes," in *Self-efficacy: The exercise of control*, Macmillan, 1997, pp 116-161.

[2] R.L. van der Merwe, et al., "Relating student perceptions of readiness to student success: A case study of a mathematics module," *Heliyon*, Vol. 6, no. 11, 2020. [Online] Available: https://doi.org/10.1016/j.heliyon.2020.e05204/ [Accessed November 2, 2024].

[3] E.P.W.A. Jansen and J. van der Meer, "Ready for University? A cross-national study of students' perceived preparedness for university," *Aust. Educ. Res.*, Vol. 29, 2012. [Online] Available: http://doi.org./10.1007/s13384-011-0044-6 [Accessed November 3, 2024].

[4] R.V. Bradely, et al., "An Empirical Investigation of the Impact of GPA on Perceived Improvement of Higher-Order Cognitive Skills," *AMCIS 2005 Proceedings*, 496, Aug. 2005. [Online] Available: https://aisel.aisnet.org/amcis2005 [Accessed November 1, 2024].

[5] K. Bartimote-Aufflick, et al., "The study, evaluation, and improvement of university student self-efficacy," *Studies in Higher Education*, Vol 4, no. 10, p1918-1942., Nov. 2016.

[Online] Available: http://doi.org/10.1080/03075079.2014.999319 [Accessed November 1, 2024].

[6] S.P. Becker and R.K. Gable, "The Relationship of Self-Efficacy with GPA, Attendance, and College Student Retention," *NERA Conference Proceedings*, Oct. 2009.

[7] T.D. Wickliff, et al., "Reported Changes in Students' Perceptions of Their Abilities to Succeed on the ABET Student Outcomes During the First-year Engineering Program," 124th *ASEE Annual Conference*, Paper ID 23514, 2017. [Online] Available: http://doi.org/ 10.18260/1-2--28365 [Accessed November 2, 2024].

[8] M. Schar, et al., "Measuring Curricular Impact using an ABET-based Engineering Self-Efficacy Scale," *2018 IEEE Frontiers in Education Conference (FIE)*., 2018. [Online] Available: http://doi.org/10.1109/FIE.2018.8658658 [Accessed November 4, 2024].

[9] J.K. Jung, et al., "A Novel Approach for Integrating the New ABET Student Outcomes (SOs) and Early Impacts on SOs during the COVID-19 Pandemic," *2021 ASEE Southeastern Section Conference Proceedings*, [Online] Available: http://sites.asee.org/se/wp-content/uploads/sites/56/2021/04/2021ASEESE32.pdf

[10] Q.I. Ali, "Surveying Different Student Outcome Assessment Methods for ABET Accredited Computer Engineering Programs," Research Reports on Computer Science, pp. 56-76, 2023. [Online] Available: https://doi.org/10.37256/rrcs.2120232577 [Accessed November 2, 2024].