Relationships Between Student Self-Assessment Ability and Performance

Col. Joel Sloan, United States Air Force Academy

Colonel Joel Sloan Ph.D., P.E. is the Permanent Professor and Head of the Department of Civil and Environmental Engineering at the U.S. Air Force Academy, Colorado. He received his B.S. in Civil Engineering from the U.S. Air Force Academy, M.S. in Civil Engineering from the University of Colorado, and Ph.D. from Virginia Tech. He is an ASEE member and a registered Professional Engineer in Virginia. His research interests include geotechnical engineering, column-supported embankments, and engineering education.

Timothy Frank, United States Air Force Academy

Lt Col Timothy Frank is the Structures Division Chief and Associate Professor of Civil and Environmental Engineering at the United States Air Force Academy. In this role, he develops leaders of character for the Air Force and Space Force by advising, teaching, and mentoring cadets. He received his B.S. and M.S. in Civil Engineering from the University of Illinois, and Ph.D. from Stanford. Lt Col Frank is a registered Professional Engineer in New Hampshire. Courses taught include statics, structural analysis, steel design, concrete design, and engineering in the developing world. Research interests include fiber reinforced cement composites, community resiliency following climate and weather disasters, and engineering education.

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Abstract

Knowledge surveys (KS) are a self-assessment tool where the questions correspond one-for-one with learning objectives in a course. In response to the KS questions, students select a confidence rating that describes their self-assessed ability to demonstrate understanding or perform a skill. Pre-KS at the beginning of a course or unit of instruction serve as an outline of future learning objectives for students and alert faculty to pre-existing student capabilities. Students can access the KS questions continuously during the unit of instruction as a formative learning guide. Post-KS immediately prior to a summative exam enable comparison of student self-assessments of learning with faculty assessments of student performance.

Fundamental Hydraulics is a junior level fluid mechanics course required for civil engineering majors at a small university in the Western United States. KS were employed in eight sections of *Fundamental Hydraulics* from Spring 2019 to Spring 2021 with a total student population of 118. Prior research on KS in this course has shown that student self-assessments via KS are well-aligned with their exam scores. Given the data set in this course, we further explored relationships between student performance and their self-assessment abilities.

Results show that the correlation between student KS scores and their grades on each of the three unit exams in the course improves with each successive cycle of performance and feedback. We also examined the self-assessment ability of the student cohort by upper and lower halves of cumulative GPA, measured as of the semester prior to taking *Fundamental Hydraulics*. These data show that students in the upper half by GPA maintained consistent self-assessment accuracy through the three exams while students in the lower half by GPA improved their self-assessment accuracy by the third exam. Finally, we examined whether student performance improved in conjunction with the improvement in self-assessment accuracy. Although results are mixed as to whether student performance improved in a single semester, the self-assessment skills demonstrated by the entire student cohort, and particularly the improvement shown by the lower half of students by GPA, offers further encouragement that KS are a useful tool to support development of self-assessment skills and student learning.

Introduction

The ability to self-assess is a key component of learning [1] and the practice of self-assessment leads to better student motivation [2] and higher student achievement [3, 4]. The benefits of self-assessment are enhanced when faculty systematically train students on how to assess their own work [4]. For these reasons and others, self-assessment is an important component of self-regulated learning [5] and life-long learning [6].

Self-assessment is an important metacognitive skill [7]. Practicing metacognition has been shown to foster more effective learning [8, 9]. Accurate self-assessment as a part of the metacognitive process helps students to discover what skills they have mastered and what areas

still need development. Pairing instructor assessments with student self-assessments allows for student reflection and calibration of their self-assessment capabilities, which can guide future learning behaviors [7]. Students have demonstrated improvement in self-assessment accuracy with practice [10], which can mitigate under- and over-confidence for a more equitable learning environment [7].

Knowledge Surveys

Ed Nuhfer [11, 12] introduced knowledge surveys (KS) to develop self-assessment skills in students. Rather than requiring students to provide answers to learning prompts, KS require students to rate their ability to perform the specified skill tied to a learning objective. Pre-course or pre-unit of instruction KS allow faculty to discern prior knowledge students may bring to the course while serving as a cognitive "heads up" for students of learning objectives and material to come [10]. KS completed in close proximity to an assessment event (e.g., exam, design project, or writing assignment) allow faculty to compare students' self-assessments of learning with their own assessments of student learning (i.e., the grade on the assignment). Such comparisons help students by allowing them to judge their self-assessment ability and potentially improve that ability with feedback and continued practice.

Research Questions

Given prior findings in courses at the United States Air Force Academy (USAFA), we wanted to further analyze data from the course where KS were used most extensively, *Fundamental Hydraulics*. By examining a data set in this course across six semesters from Spring 2019 to Spring 2021, we wanted to answer the following questions relating student performance and self-assessment ability:

1) Does student self-assessment ability improve with time and practice?
2) Are higher performing students better at self-assessment?
3) Does performance improve along with self-assessment skill?

To answer these questions, we will examine student performance and self-assessment abilities on three exams in the course.

Methods

The USAFA is an undergraduate-only institution with a student body of approximately 4,400 and a requirement to graduate in 4 years and commission as an officer in the United States armed forces. Students come from all congressional districts in the United States and therefore are geographically diverse. Students in this study were approximately 80% male / 20% female and approximately 80% White / 20% non-White.

Students complete a rigorous program of academic, military, and athletic education and training. The core curriculum (general education course of instruction) consists of 93 semester hours of academic courses and an additional 5 semester hours of physical education. Most of the core curriculum is prescribed but there are three electives within the core. Civil engineering

majors at USAFA complete an additional 45 semester hours of majors' coursework beyond the core curriculum. Several other references describe the USAFA civil engineering program in greater detail [13-16].

Given the positive benefits of incorporating self-assessment into a course, and the relative simplicity and ease of implementing KS, faculty at the US Air Force Academy initiated a Scholarship of Teaching and Learning (SoTL) project on KS in 2018. Since that time, nine faculty from the Department of Civil Engineering have incorporated KS into seven different courses. Results have shown that students are able to accurately self-assess with KS [10, 17], KS can be effectively applied to technical writing [18, 19] and design projects [17, 20], KS are a helpful tool for program assessment [21], and KS are generally a robust tool for systematically incorporating a self-assessment component into engineering courses [20, 22].

Fundamental Hydraulics is a junior-level 3-semester hour required course for civil engineering majors. There are three unit exams in the course and a comprehensive final exam. The course is well-scaffolded with boardwork problems on all teaching lessons, low-stakes online assessments for nearly every lesson (each is 0.75% of a student's overall grade, 20 total in the course) and a homework problem set due approximately every four lessons (each is 2% of their overall grade, 10 total in the course). Recent offerings have included student self-grading of the homework problem sets and correcting their submission with a metacognitive reflection statement for each problem.

KS have been employed in *Fundamental Hydraulics* since Spring 2019. In early offerings, students completed a comprehensive pre-KS early in the course. Since Spring 2020, students have completed the pre-KS at the beginning of each unit of instruction. Benefits of a pre-KS prior to each unit of instruction include the material fresher in students' minds and multiple opportunities for spaced retrieval throughout the course [10]. In all offerings, students completed a post-KS within 24 hours prior to the unit exam or final exam. The number of KS questions and sample questions from each unit of instruction are shown in Table 1. Importantly, each KS question gives the level of Bloom's taxonomy to aid the students in determining the cognitive effort required [23].

Table 1: KS question summary for each of the four units of instruction.

Unit	# of KS Questions	Sample KS Question:	Response options for all KS questions:
1	22	(Lesson 6, Bloom Level 3 – Apply) I can calculate forces on horizontal planar surfaces.	a) I am unable to perform the task. b) I can begin to perform the task but am quickly overwhelmed. c) I can make progress toward performing the task but fall well short of completing it. d) I can almost completely perform the task. e) I am able to completely perform the task for the exam.
2	22	(Lesson 18, Bloom Level 3 – Apply) I can apply the impulse-momentum principle to determine forces on stationary objects.	
3	19	(Lesson 23, Bloom Level 3 – Apply) I can estimate the friction factor using the Moody Diagram.	
4	24	(Lesson 38, Bloom Level 3 – Apply) I can compute energy dissipated in a hydraulic jump.	

Prior work on KS has shown that they are reliable instruments [24] and that is also true for the KS in this course. The Cronbach alpha for pre- and post-KS respectively in *Fundamental Hydraulics* are 0.95 and 0.97, with numbers close to 1.0 indicating that the KS are reliable instruments. Exams were written directly from learning objectives, which were aligned with the KS. Additionally, a deliberate effort was made by the instructors to align pre-exam assignments to the learning objectives to provide students with clear expectations on what to expect throughout the course.

The post-KS enables a comparison with the unit or final exam score through the calculation of a normalized self-assessment score (0.0 for response a in Table 1, 0.25 for response b, 0.5 for response c, 0.75 for response d, and 1.0 for response e). The responses are totaled for each student and then divided by the total number of KS questions for that unit to calculate a percentage KS score. Further, the KS minus the exam score is known as “error.” Causes of error could be due to student deficit in self-assessment ability, misaligned course objectives, instructor grading bias, or unclear expectations between the instructor and students [21]. A positive error would indicate overconfidence while a negative error indicates underconfidence. Errors closer to zero indicate accurate self-assessments, and a good goal is for a self-assessment to be within +/-10% of the faculty assessment [25] or within +/- one standard deviation of error [7]. Taking the average absolute value of error for a student cohort on an assessment event also yields a rough measure of the accuracy of the cohort. Large errors provide a signal to faculty to investigate the possible contributors.

Following each exam, students received feedback on how their self-assessments compared to their exam scores which reflect the faculty member’s assessment of their performance. Figure 1 shows an example of this feedback from Exam 2 in Spring 2021. Each student’s anonymous number is on the x-axis and their pre-KS, post-KS, exam score, and error are shown. Students are sorted by error, with negative error to the left (overconfidence), accurate students in the middle, and positive error to the right (underconfident).

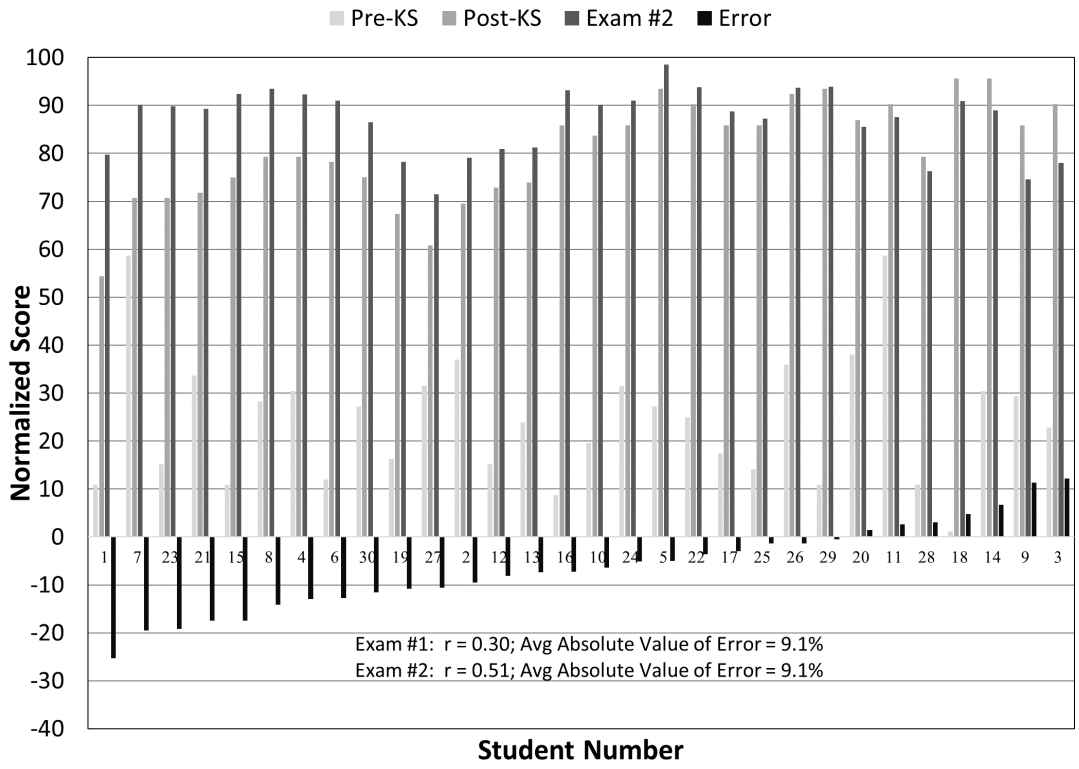

Figure 1: Sample student feedback from Exam 2 (Spring 2021) showing pre-KS, post-KS, Exam score and error for each student

Students knew their own student number so their individual performance and self-assessment characteristics are clear, but they also viewed the characteristics of the entire class. In addition, the instructor presented summary statistics for the entire class in the form of the correlation between the post-KS and exam scores of the class (0.51 in this example) and the average absolute value of error for the entire class (9.1 in this example). Providing feedback to students in this form took about an hour using a spreadsheet on the first iteration, but significantly less time following subsequent exams and in subsequent semesters.

Students were advised to use this feedback to guide subsequent learning and self-assessment behaviors in the course. They were also afforded the opportunity to meet with the instructor during office hours for a more reflective one-on-one discussion about the feedback and recommended actions or behaviors. However, very few students chose to do this. The instructor also pointed out general characteristics of the self-assessment abilities of the cohort, e.g., in this case 17 of the 30 students had self-assessments within +/-10% of their exam score, 11 students were overconfident (error <-10%) but only one of those had an error <-20%, and only two students were underconfident (error >10%).

Although the course does include a final exam, we will only examine data from the three unit exams (50 minutes in length) to assess the research questions due to a difference in format between exam types. The final exam (3 hr 50 min) includes both new material from unit 4 and comprehensive review of units 1-3, and is entirely multiple choice, whereas the unit exams may have up to 3 multiple choice questions but mostly consist of work-out problems.

In the Results section of this paper, we will present data for 118 students in *Fundamental Hydraulics* from Spring 2019 to Spring 2021. The students were taught in 9 sections where 8 sections were all taught by the same instructor. The syllabus and assignments remained consistent across the time period of the data in this study. Using this data set, we will evaluate the following:

- To assess Research Question 1: The correlation of KS scores to exam scores across the three exams in the *Fundamental Hydraulics* course.
- To assess Research Question 2: Correlation of cumulative GPA as of the semester prior to taking *Fundamental Hydraulics* to student self-assessment error.
- To assess Research Question 3: The correlation of Exam score to student self-assessment error.

Results

In order to evaluate whether self-assessment skills may change across the three exams in the course and to broadly evaluate the role of student GPA and self-assessment accuracy, Table 2 shows several correlations across the three exams in the course. First, the correlation between KS score and exam scores is positive starting with Exam 1 ($r = 0.27$), but increases slightly at Exam 2 ($r = 0.30$), and then again on Exam 3 ($r = 0.39$). As expected, this finding indicates students were reasonably good self-assessors at the beginning of the course and become better self-assessors with feedback and practice on each successive exam. The mixture of both positive and negative correlations between GPA and error indicates, however, that there is no clear trend between student performance and habitual over or underestimating.

Table 2 shows that the correlation of GPA to absolute value of error is negative in all cases. This negative correlation indicates that higher-performing students are better self-assessors (higher GPA correlates to a smaller error). While this is generally true across the three exams in this course, the correlation closest to zero occurs on Exam 3, indicating that the lower GPA students may be starting to close the gap in self-assessment skills with continued practice at self-assessment and feedback like that shown in Figure 1.

Table 2: Correlation of multiple parameters across the three exam scores in *Fundamental Hydraulics*

Parameter	**Exam 1 (N = 106)**	**Exam 2 (N = 112)**	**Exam 3 (N = 107)**
Correlation of KS score to exam score	0.27*	0.30*	0.39*
Correlation of GPA to absolute value of error (absolute value of KS minus exam score)	-0.11	-0.25*	-0.05
Correlation of Exam score to absolute value of error (absolute value of KS minus exam score)	-0.07	-0.20	0.22

*statistically significant correlation ($p<0.01$)

While Table 2 shows an increase in self-assessment ability across the entire student cohort, it is helpful to divide this cohort into the upper and lower half by GPA to examine the

relationship of a global measure of student performance such as GPA on self-assessment ability. Figure 2 shows the percentage of students in the upper and lower half by GPA whose error is within one standard deviation of the entire cohort for each of the three unit exams. Figure 2a illustrates that the upper half of students shows consistently strong self-assessment abilities from Exam 1 to 3 with more than 50% of students within one standard deviation of error on all three exams. Of the upper cohort, roughly three quarters of the students self-assessed to within two standard deviations of error and there are only two outliers whose self-assessments are greater than three standard deviations of error. In contrast, the lower 50% of students by GPA only had 40-45% of students within one standard deviation of error of on both Exams 1 and 2. However, by Exam 3, 59% of the lower half of students by GPA self-assessed within one standard deviation of error, and fewer students were between 1-2 and 2-3 standard deviations of error. Thus, the lower half of students by GPA demonstrated a substantial improvement in their self-assessment ability by the third exam.

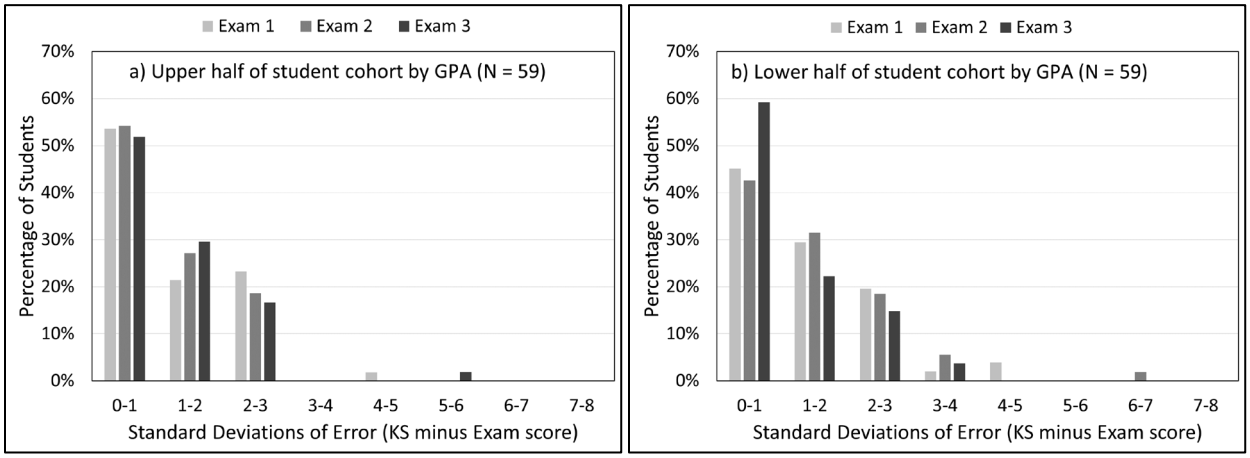

Figure 2. Distribution of students by standard deviation of error for a) the upper half by GPA, b) lower half of GPA.

In order to evaluate whether student performance improved along with the improvement in self-assessment ability from the lower 50% of students by GPA, Figure 3 shows the percentage of students in the upper and lower half by GPA sorted by the number of standard deviations above or below the mean score of the entire student cohort. As expected, the upper half of students by GPA is shifted to the right and shows more students who scored more than one standard deviation above the mean with fewer students who scored more than one standard deviation below the mean.

There were no students in the lower half of GPA that scored more than one standard deviation above the mean on the first exam, but several scored more than one standard deviation above the mean on Exams 2 and 3. Likewise, one student scored more than three standard deviations below the mean on Exam 1 but no students scored more than three standard deviations below the mean on Exams 2 and 3. Both of these observations indicate that the lower half of students by GPA may be improving in their performance across the three exams. However, Figure 3b does show a decrease in lower half of GPA students on Exam 3 who were within one standard deviation below the mean and a corresponding increase in students who were between 1

and 2 standard deviations below the mean. This trend would indicate that the lower half of students by GPA did not perform nearly as well on the third exam compared to their peers.

Although GPA is a broad measure of student performance, we also wanted to investigate whether student self-assessment ability on the individual exams was related to their performance on that same exam. Table 3 shows the percentage of students by standard deviation of error in the upper and lower half based on their exam score. The top 50% of students on Exam 1 self-assessed slightly more accurately (53% within one standard deviation error) as opposed to the lower half of students (45%). Exam 2 shows a mixed trend as the upper half of students by exam score had more students within one standard deviation of error, while the lower half of students had a slightly higher number within two standard deviations of error. Exam 3 showed the highest percentage of all students within one standard deviation of error (reflecting the overall lower error and better accuracy of the cohort shown in Table 2 and Figure 1) with the lower cohort of students by exam score self-assessing better than the upper cohort (69% within one standard deviation of error as opposed to 55%, and 85% within two standard deviations of error as opposed to 74%).

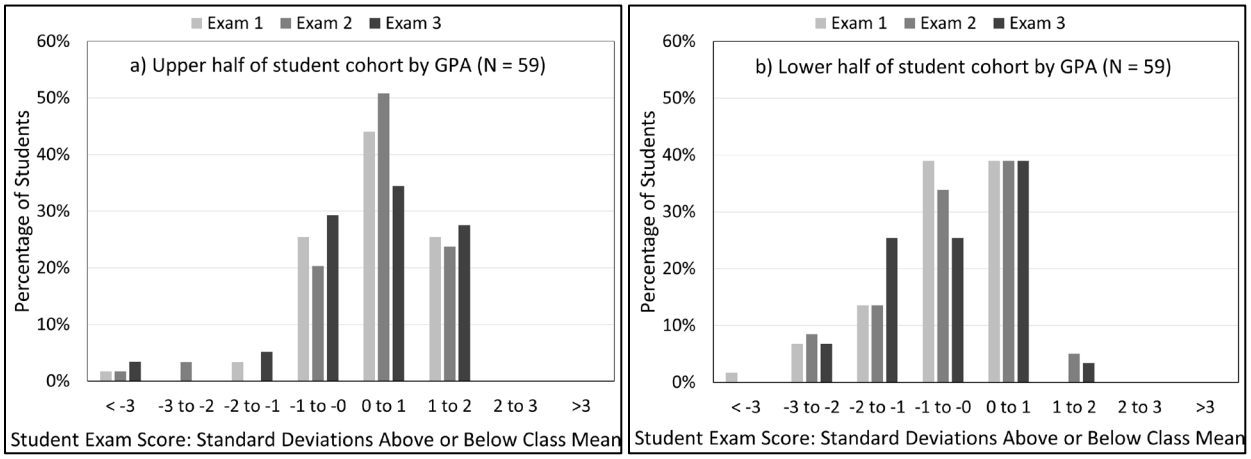

Figure 3: Number of standard deviations above or below the mean as a measure of student performance for the a) upper half by GPA, and b) lower half by GPA.

Table 3: Percentage of students with 1, 2, 3 or 4 standard deviations of the mean self-assessment error as grouped by performance on each exam

Parameter	Good ≤1 Std dev	Adequate ≤2 Std dev	Marginal ≤3 Std dev	Inadequate ≤4 Std dev
Exam 1 (Upper half of exam scores)	53	77	100	100
Exam 1 (Lower half of exam scores)	45	77	98	100
Exam 2 (Upper half of exam scores)	57	75	98	100
Exam 2 (Lower half of exam scores)	39	80	95	98
Exam 3 (Upper half of exam scores)	55	74	98	100
Exam 3 (Lower half of exam scores)	69	85	98	100

Discussion

RQ 1: Improvement in Self-Assessment Skills

The consistent increase in correlations between student KS and exam scores across each of the three unit exams in the course is a strong indication that student self-assessment ability increases with practice and feedback during the course. These results align with those from Sung and colleagues [26] who found that students' objectivity in self-assessment improved and showed better correlation with instructor assessments of student learning over time.

Although the students in the upper half of GPA show strong self-assessment ability beginning with Exam 1 (Fig 2a), there is some small improvement in the ability to self-assess from this cohort illustrated by the ~10% reduction in students that have an error that is 2-3 standard deviations and a ~10% increase in the students with an error 1-2 standard deviations, while consistently maintaining more than 50% of the cohort with error of less than one standard deviation. On the other hand, the students in the lower half of the cohort by GPA show substantial improvement in their self-assessment abilities by Exam 3 (Fig 2b). Table 2 also shows that the entire cohort has better alignment between their KS scores and Exam scores with each successive exam. From these data, we can conclude that both *the higher and lower performing students (based on prior GPA) showed some improvement in their self-assessment abilities in the course, but the lower half of students by GPA showed the greatest gains*. Given the work showing the importance of self-assessment to learning [5, 7], this offers hope that the deliberate practice and continued improvement in self-assessment skills via KS may be a key to helping students to better achievement.

RQ 2: Are Better Students Better Self-Assessors?

Higher achieving students do tend to be better at self-assessment at the beginning of the course, but this gap appears to be closing as evidenced by the correlation of GPA to error being closest to zero on Exam 3 (Table 2) and the improvement in self-assessment ability of the students in the lower half by GPA by the third exam (Fig 2b). Some studies have shown that higher achieving students tend to be better at self-assessment [27, 28] while others have found that expert learners (e.g., faculty as compared to undergraduate students) are more accurate [7].

The definition of higher and lower performing varies over time as students develop learning skills, learn, and grow. So whether better students are better self-assessors is not really the main point. Studies have shown that self-assessment is important to learning [3, 4] and the results of this study show that these skills can be systematically cultivated using KS.

RQ3: Does improvement in self-assessment result in an improvement in performance?

Results from Fig 2 are mixed. Students in the lower half by GPA improved their self-assessment abilities over just three opportunities within one course. But how much practice and in how many contexts does it take for self-assessment ability to truly "stick"? Boud and colleagues [28] suggested students may need as many as three courses for self-assessment gains to stick. And how long does it take before self-assessment gains result in better performance? Students with

higher GPAs have likely refined self-assessment skills over time, perhaps without even knowing it, as a part of the learning process.

Results from Table 3 show that a greater percentage of higher performing students on exams 1 and 2 self-assessed within one standard deviation of the mean error, while more lower performing students on exam 3 actually self-assessed within one standard deviation of the mean error.

Although results on improvement in performance is inconclusive given the three cycles of performance and feedback with self-assessment in this course, the improvement in self-assessment abilities using knowledge surveys demonstrated in this course, combined with other literature on the importance of self-assessment to learning offers hope that continued cycles of self-assessment practice are likely to pay dividends through higher student achievement. The literature offers a wealth of guidance on KS as a systematic way to introduce a self-assessment component into nearly any course [10-12, 17-22, 29].

Student Perspectives

Surveys were administered to the students at the end of each semester, which consisted of 4-point Likert-scale questions aimed at gleaning insights into student perceptions about whether they either (1) disagree, (2) are neutral, (3) agree, or (4) strongly agree with the following three statements:

a) The knowledge surveys provide clear guidance as to what I'm expected to know or be able to do for the exam.
b) The knowledge surveys are a useful addition to this course with respect to supporting my learning of the course material.
c) The knowledge surveys are a useful addition to this course with respect to supporting my ability to self-assess my knowledge and preparation for exams.

On average, students found KS to be beneficial. Eighty students completed the survey, and average responses were 3.17, 3.11, and 3.14 to the three questions, respectively, where a score of 3 indicates “agree.”

In addition to the quantitative student perceptions, students could also provide open-ended comments about their perceptions of KS on the end of course surveys. While about 7% of the comments indicated that KS did not help students, comments were overwhelmingly positive. Themes emerged about how they helped students learn, reinforced learning objectives, and aided in self-assessment. One sample response, from a student just above the mean GPA, highlights several of these themes:

> "I actually enjoyed this as an aspect of the class as it added almost like a mini study guide for me to work through and remember what the particular survey covered. This allowed me to formulate a study plan to ensure any questions I felt deficient on were covered again adequately. I treated these as my form of study guide and I did not feel it necessary to work out many problem types over again when I understood them to my desired

extent. I felt that these surveys closely followed the learning objectives too and asked something about almost every topic type so I felt prepared for a test when I used these actively."

Conclusion

Knowledge surveys were employed in eight sections of the *Fundamental Hydraulics* course at USAFA from Spring 2019 to Spring 2021 as a student self-assessment tool. In general, students improved their self-assessment skills across three unit exams in the course, while the lower half of students by GPA showed a greater increase in self-assessment ability than students in the upper half by GPA. This finding indicates that implementing KS in conjunction with instructor assessment and feedback encouraged equity in the classroom between students of different incoming performance levels. Future work should investigate whether KS promotes inclusion with respect to race/ethnicity and gender. While this study produced some encouraging results that relate higher self-assessment ability to higher exam performance, more research is needed to form a conclusive determination.

References

[1] Andrade, H. & Valtcheva, A. (2009). Promoting learning and achievement through self-assessment. *Theory Into Practice,* 48(1), 12-19, DOI: 10.1080/00405840802577544.

[2] McMillan, J. H., and J. Hearn. 2008. "Student self-assessment: The key to stronger student motivation and higher achievement." Educ. Horiz. 87 (1): 40–49.

[3] Thompson, G., A. Pilgrim, and K. Oliver. 2005. "Self-assessment and reflective learning for first-year university geography students: A simple guide or simply misguided?" *J. Geogr. Higher Educ*. 29 (3): 403–420. https://doi.org/10.1080/03098260500290959.

[4] Ross, J. A. 2006. "The reliability, validity, and utility of self-assessment." *Pract. Assess. Res. Eval.* 11 (10): 1–13.

[5] Sullivan, K., & Hall, C. (1997) Introducing Students to Self-Assessment. *Assessment & Evaluation in Higher Education*, 22(3, Sept. 1997), p. 289. https://doi.org/10.1080/0260293970220303.

[6] Boud, D. & Falchikov, N. (2005). Redesigning assessment for learning beyond higher education. *Higher Education Research and Development.* January 2005.

[7] Wirth, K.R., Nuhfer, E.B., Watson, R., Fleisher, S.C., & Bailey, R. (2021). "Knowledge surveys: Supporting students along pathways to self-directed learning with self-assessment." in E. Mentz, D. Laubscher & J. Olivier (eds.), *Self-Directed Learning: An imperative for education in a complex society* (NWU Self-Directed Learning Series Volume 6), pp. 127–164, AOSIS, Cape Town. https://doi.org/10.4102/aosis.2021.BK279.06

[8] Schunk, D. H. (2012). Learning theories an educational perspective. Pearson Education, Inc.

[9] Millis, B. J. (2016). Using Metacognition to Promote Learning. *IDEA Paper# 63*. IDEA Center, Inc.

[10] Sloan, J.A. and Scharff, L.F. (2022). "Student self-assessment: Relationships between accuracy, engagement, perceived value, and performance." *ASCE Journal of Civil Engineering Education*. 148(3): 04022004. DOI: 10.1061/(ASCE)EI.2643-9115.0000063

[11] Nuhfer, E. B. (1993). Bottom-line disclosure and assessment. *Teaching Professor*. 7(7): 8.

[12] Nuhfer, E. B. (1996). The place of formative evaluations in assessment and ways to reap their benefits. *Journal of Geoscience Education*, 44, 385-394.
[13] Stanford, M. S., & Sloan, J., & Pocock, J. B., & Russell, M. M. (2020, June), *A Construction Management Competition as the Basis of a Capstone Culminating Event* Paper presented at 2020 ASEE Virtual Annual Conference Content Access, Virtual Online. https://peer.asee.org/33987
[14] Wambeke, B. (2022, August). Construct First, Design Later–Evolution over the past 25 years. *In 2022 ASEE Annual Conference & Exposition.*
[15] Wambeke et al 2023
[16] Sloan, J.A., Beauregard, M.S., and Russell, M.M. (2023). "Chapter 4: High impact practices in the civil engineering major at the United States Air Force Academy." *High Impact Practices in Higher Education: International Perspectives (Innovations in Higher Education Teaching and Learning, 51)*. Sengupta, E. Editor. Emerald Publishing Ltd, U.K.
[17] Beauregard, M.S., Sloan, J.A., Brannon, M. (2019). "Summarizing the Use of Knowledge Surveys to Inform Effective Learning and Teaching Practices." Proceedings of *Rocky Mountain Section of the American Society for Engineering Education's Annual Conference*. May 2019, Laramie, WY.
[18] Sloan, J., Becker, K., and Frank, T. (2022) "Implementing a technical communication block in a civil engineering computer applications course: lessons learned." Proceedings of the 2022 ASEE annual conference, Minneapolis, MN. https://peer.asee.org/41191
[19] Becker, K.L. and Sloan, J.A. (2023). "Implementing technical communication instruction in a civil engineering course: The value of knowledge surveys and peer review." *Journal of Civil Engineering Education*. 149(4): 05023004. https://doi.org/10.1061/JCEECD.EIENG-1927
[20] Sloan, J.A., Frank, T.E., Scharff, L.F., and Becker, K. L. "Knowledge surveys: A robust self-assessment tool." Under review.
[21] Sloan, J.A., and Frank, T.E. (2023). "Student self-assessment data: an instrument for program assessment" *Intersection: A Journal at the Intersection of Assessment and Learning*, (4)2.
[22] Scharff, L.F., Tetley, J., Chandler-Garcia, L.M., Sloan, J.A., and Post, M.L. (2023, February). "Knowledge Surveys Benefit Students and Instructors." Oral presentation at *SOTL Commons*, Savannah, GA, hosted by Georgia Southern University
[23] Bloom, B.S., Englehart, M.D, Furst, E.J., Hill, W.H., & Krathwohl, D.R. (1956). *Taxonomy of educational objectives: The classification of educational goals. Handbook I: Cognitive domain.* New York: David McKay Company.
[24] Nuhfer, E.B. & Knipp, D. (2006). Re: The use of a knowledge survey as an indicator of student learning in an introductory biology course. *CBE – Life Sciences Education*, 5(Winter 2006), 313-316.
[25] Nuhfer, E., Cogan, C., Fleisher, S., Gaze, E., & Wirth, K. (2016). Random number simulations reveal how random noise affects the measurements and graphical portrayals of self-assessed competency. *Numeracy*, 9(1), 4.
[26] Sung, Y.-T., Chang, K.-E., Chiou, S.-K., & Hou, H.-T. (2005). The design and application of a web-based self- and peer-assessment system. *Computers & Education*. 45(2005), 187-202. doi:10.1016/j.compedu.2004.07.002

[27] Lew, M. D. N., W. A. M. Alwis, and H. G. Schmidt. 2010. “Accuracy of students’ self-assessment and their beliefs about its utility.” *Assess. Eval. Higher Educ.* 35 (2): 135–156. https://doi.org/10.1080/02602930802687737.
[28] Boud, D., Lawson, R., & Thompson, D. G. (2013). Does student engagement in self-assessment calibrate their judgement over time?. *Assessment & Evaluation in Higher Education*, 38(8), 941-956.
[29] Scharff, L.F., Chandler-Garcia, L.M., Culver, C., Frank, T.E., Post, M., Tetley, J., Sloan, J.A. Book chapter proposal accepted for TILTed Pedagogy, Elon’s Center for Engaged Learning (CEL) Open Access Book Series.