Summarizing the Use of Knowledge Surveys to Inform Effective Learning and Teaching Practices

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Abstract: It is widely understood that students' ability to self-assess their own learning is a key component in their effectiveness as lifelong learners. When students are skilled in their ability to identify what they do or do not know, they are better able to learn independently. One method for both encouraging and quantifying a student's ability to self-assess is the use of knowledge surveys. Knowledge surveys are a series of questions that require a student to assess their ability to perform a task, but do not require them to actually complete the task. Knowledge survey results can then be compared to an instructor's assessment of the student's learning (e.g. an exam or design project) to evaluate a student's ability to self-assess. This paper focuses on results from knowledge surveys implemented across two 3rd and 4th year required and elective courses for civil engineering majors at the United States Air Force Academy. Results indicate that while students are reasonably good self-assessors at all levels, there may be greater variability at lower Bloom levels within the cognitive learning domain. This study further underscores the importance of proper alignment between the lesson objectives, lesson material, and assessment method. Included in this study is a summary of how results from knowledge surveys have been used to adjust and evaluate effective teaching practices.

INTRODUCTION

The ability to self-assess is a key component of both learning in a structured, classroom environment [1] and life-long learning [2]. However, efficient and effective self-assessment requires a practiced level of self-awareness and may not come naturally to most students. There has been research completed which indicates practice of metacognition skills is imperative and can foster effective learning (Millis 2016). One method for assessing self-assessment and practicing metacognition is incorporating knowledge surveys (KS) into classroom pedagogy. KSs were first introduced by Nuhfer ([5],[6]) and have also been described in detail by Wirth and Perkins [10] and Clauss and Geedey [3], though this list is not exhaustive. In their most basic form, KSs are tests given to students in which the questions are meant to assess how well a student thinks they can complete a task, and not how well they can actually complete that task. KSs can be used to assess all Bloom levels [7],[3], although Clauss and Geedey [3] found it most difficult for students to assess at the intermediate Bloom levels. Figure 1 presents a graphic of basic Bloom levels, including examples of verbs related to various levels.

In addition to improvements in student learning, the current body of research related to KSs has also indicated that use of KSs by faculty members aids in course organization, course planning, curriculum development, and may also contribute to program assessment and overall teaching success [7]. With this understanding of how KSs may be beneficial for both teaching and learning, the department of civil and environmental engineering at the United States Air Force Academy (USAFA) has implemented KSs into several civil engineering courses across multiple years of study. This study focuses on how KSs were used in these classrooms to enhance student learning, improve teaching pedagogy, and better align lesson and course objectives to testable course material.

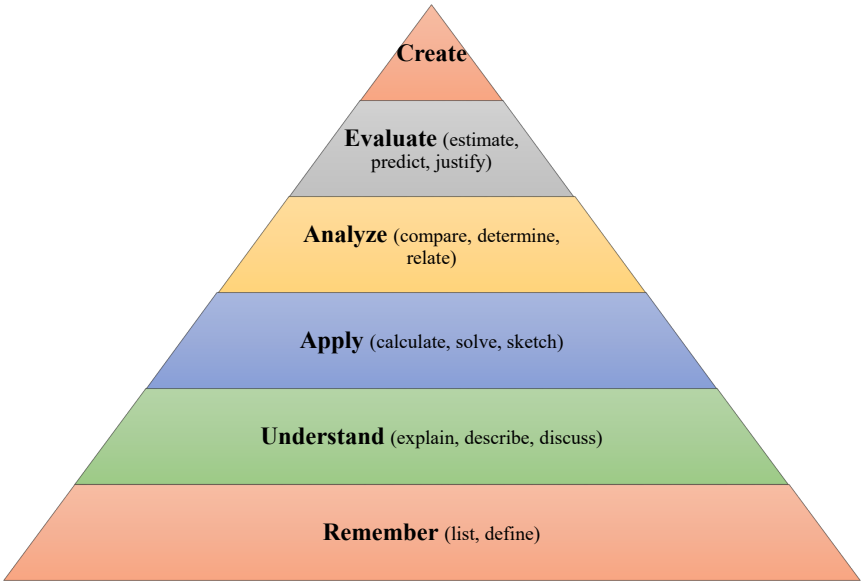


Figure 1: Six levels of Bloom's Taxonomy

KNOWLEDGE SURVEY IMPLEMENTATION

The United States Air Force Academy (USAFA) is a military service academy providing an undergraduate education to future officers in the United States Air Force. USAFA is located in Colorado Springs, Colorado and is home to approximately 4,000 students. The KS study reported

in this paper was implemented by the department of civil and environmental engineering and is limited to major's courses taken by civil engineering students. Although the number of major's in civil engineering fluctuates, there are approximately 30-50 civil engineering graduates in each graduating class.

KSs were implemented via the Blackboard learning management system. In each of the courses included in this study, the purpose of the KSs was explained on the first day of class along with a definition of metacognition and introduction to Bloom's taxonomy. A sample KS question follows:

> I can list the foundation failure modes:
> a) I am unable to perform the task at this time.
> b) I am able to partially perform the task at this time.
> c) I can perform the task for evaluation at this time.

This paper describes the KS implementation in two courses at USAFA, Introduction to Geotechnical Engineering (CE390), a required major's course typically taken in students' junior year, and Foundation Engineering (CE491), a major's elective typically taken in students' senior year. All students enrolled in CE491 had previously taken CE390, but not all CE390 students may elect to take CE491. Although the above KS example represents how questions were formatted in each course, the number of surveys taken and when those surveys were open to students varied between courses. Goals for implementing KSs included:

- determining whether USAFA cadets are effective at self-assessment,
- determining whether cadet effectiveness at self-assessment varies with time/experience, GPA or other factors,
- determining which assessment events KSs best correlate to
- gaining faculty insight into the implementation and utility of KSs.

Each KS question represents a single lesson objective

Introduction to Geotechnical Engineering

CE390 is a junior-level course requirement for civil engineering majors at USAFA. Dr Melissa Beauregard directed the course and also taught one of two sections offered in fall 2018. Lt Col Michael Brannon taught one additional section. Between the two offered sections there were 26 students (N = 26), though student response to the non-mandatory surveys was not 100 percent. The course is similar in scope to other soil mechanics or introductory geotechnical engineering courses offered at other universities, and key concepts include soil classification, effective and total stress calculations, calculating change in stress within a surface layer, and consolidation of saturated clay materials. The final block of the course touches briefly on slope stability and bearing capacity, and there are three lesson dedicated to one- and two-dimensional flow through soil.

Eleven homework assignments were assigned throughout the semester, and each lesson also required the students to do small (less than 10 minute) reading assignments assessed with a reading quiz at the beginning of each lesson. Notetakers were utilized in the course, with students receiving a shell of the lesson's notes which could be filled out as the lesson progressed. Each notetaker also listed lesson objectives for that day's lesson and students were encouraged to use those objectives as a guide for studying. Additional major assessment events in the course include two mid-term exams, one final exam, an individual assignment related to consolidation

of a saturated clay layer, and one group report summarizing results from five laboratory tests completed throughout the semester. The laboratory lessons included the following: soil classification, soil compaction, hydraulic conductivity, direct shear, and unconfined compressive strength. Laboratory exercises typically occurred after being exposed to lesson material covering each laboratory topic.

KSs in CE390 were only open to students directly before each of the two mid-term exams. Each KS only contained questions relevant to the content of the exam, and no pre-course surveys were offered to students. The pre-exam KS for the first exam contained 25 questions and was completed by 15 of 26 students. The pre-exam KS for the second exam contained 43 questions and was completed by 6 of 26 students. The relatively low completion rate for the surveys was addressed in subsequent offerings by offering course credit for completing the exams.

Foundation Engineering

CE 491 is a senior-level design elective for civil engineering majors at USAFA. Dr Joel Sloan taught a single section with six students (N = 6). There are two major blocks in the course: one on shallow foundations and one on deep foundations. Lateral earth pressures are also covered briefly as a part of the deep foundations block. KSs were developed for each block of the course. The shallow foundations block was assessed with an exam and the deep foundations block was assessed with a design project completed in three teams of two. There were also eight homework assignments throughout the course and a cumulative design project.

Course instruction consisted of notetakers that the students filled in through the course of the lesson with example problems. Each notetaker listed the lesson objectives for that lesson (generally 2 to 5 objectives per lesson). The KS for block 1 contained 41 questions and the KS for block 2 contained 25 questions.

RESULTS

Knowledge Surveys

The results from the KSs were compared with exam scores in CE390 and with both exam scores and project scores in CE491. If students assessed that they were unable to perform the KS task, then that response was assessed as a grade of 0 percent. If the student responded that they were partially able to complete the task or able to complete the task, then those responses were assessed as grades of 50% and 100%, respectively. This enables the calculation of the self-assessment score from the KS which can be directly compared with an exam or project score.

Introduction to Geotechnical Engineering

KS results were compared to student performance in CE390. Relatively low response rates for KSs in this course offering forced the instructor to only include pre-exam KS and exam performance results for the first graded examination, which covered 43 of the 80 course objectives.

Figure 2 presents a normalized KS score organized by each individual KS question. The results indicate mid- to high-level confidence for the vast majority of the survey questions, with the exception of question 4, which asked the students how well they thought they were able to name and describe the three major rock types, a low level of learning in the Remembering category for Bloom's taxonomy.

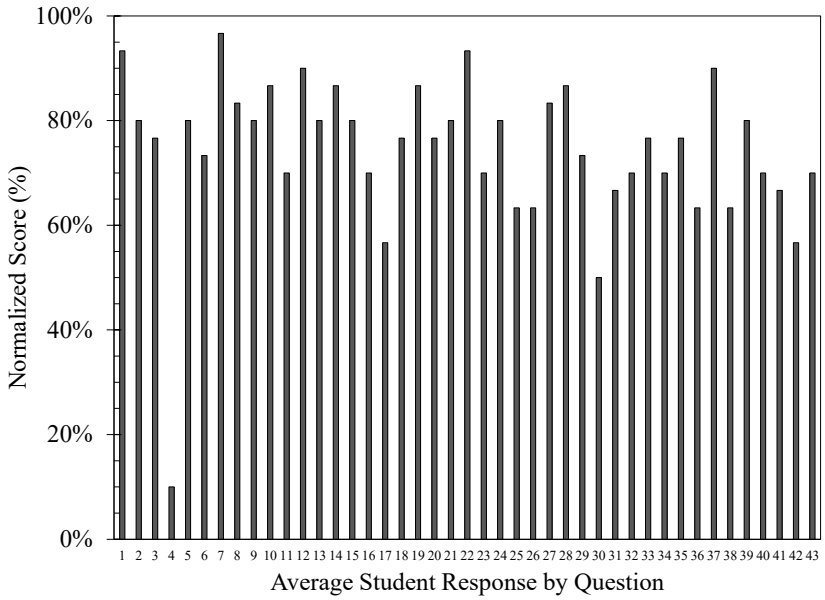
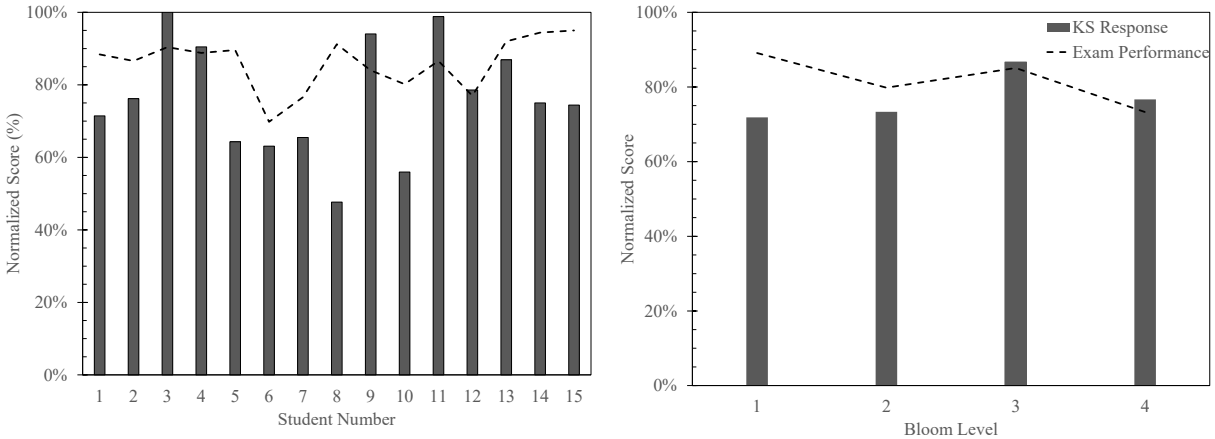


Figure 2: Pre-exam #1 normalized KS score organized by survey question

A comparison of how individual student response to the KS questions compared with their exam performance is presented in Figure 3a. These results indicate that the majority of students in CE390 generally underestimated their understanding of the course material when taking the KS, and exhibits a relatively low correlation (R = 0.05). The reason for this difference is likely due to several factors, including the possibility that students studied those materials they were least confident in before taking the test. Finally, a comparison of KS normalized scores organized by Bloom level is presented in Figure 3b. In this figure, the two highest Bloom levels are not present due to a lack of level 5 and 6 material on the exam. For the remaining 4 levels, questions on the both the survey and exam were assigned a bloom level of 1 through 4. Where an individual question may involve multiple levels, the highest possible Bloom level was selected. This figure indicates similar results to a previous study which found that students struggled most with self-assessment at low-level Bloom's, often underestimating their ability to perform those tasks [3]. However, this data does vary somewhat from the previous study in that CE390 students were unable to accurately self-assess at the lowest Bloom level, which does not agree with previous results. This could be due to the coarseness of student response in CE390, where students were restricted to three potential responses. The Clauss and Geedey [3] study allowed for four levels of response, with two intermediate responses between 0 and 100% confidence.



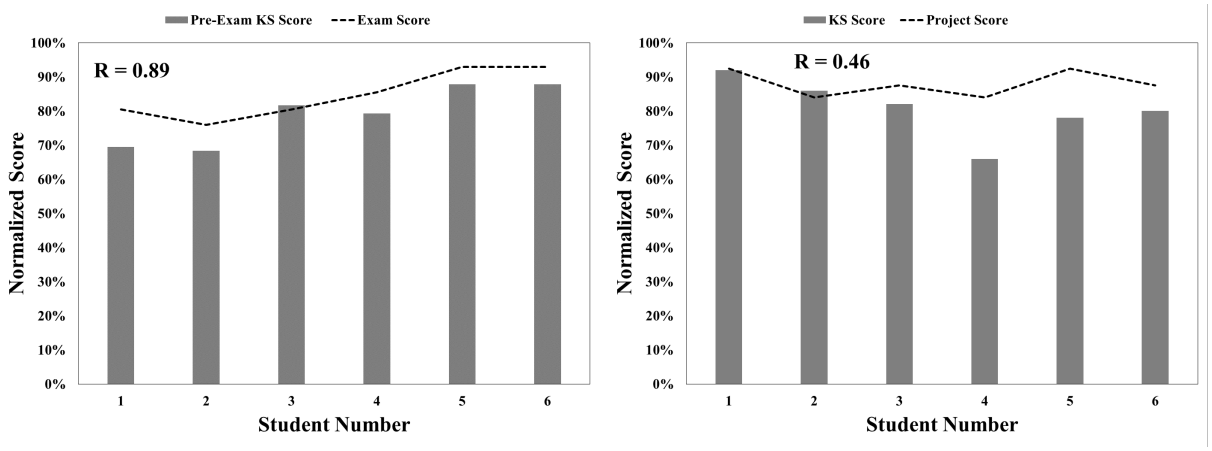
(a) (b)

Figure 3: Normalized KS score compared with a) exam #1 performance and b) Bloom level for students in CivEngr 390 (n=15)

Foundation Engineering

Figure 4a shows a comparison of the self-assessment scores (completed prior to taking the exam) from the KS along with the exam score. Comparison of the two data sets for each student results in a correlation of 0.89 which is quite good. This data supports the conclusions from previous studies that students are reasonable self-assessors.

Figure 4b shows the comparison of the self-assessment scores and project scores from block 2 of the course. The project was completed in groups of two students (e.g. students 1 and 5 have the same project score, likewise with students 2 and 4, and students 3 and 6). Students completed the KS's after completing the project but before turning it in. Comparison of the two data sets shows a strong positive correlation once again (R = 0.46) although the correlation is not as strong as the correlation between KS and exam scores in block 1. This is partially due to the team nature of the project as the individual team members self-assessed at different levels but received the same project score. The nature of the assessment event, e.g. a project vs an exam, may also have played a role in the weaker correlation for block 2 (project) in comparison to block 1 (exam) but it is impossible to state this conclusively.



(a) (b)

Fig 4. Comparison of a) pre-exam KS and exam scores and b) post-project KS and project scores

Faculty Observations
In this section, general comments by faculty involved in this study are summarized. From these comments, it is clear how implementation of KSs in the classroom both motivated instructors to re-visit their course design and also assisted in that effort.

- Assign a Bloom level on the lesson objectives and KS questions. Also put the Bloom level on the GR/Final Exam question.
- Developing my KS questions forced me to revisit the organization of my classroom materials. I saw too many lessons with all low-level Bloom's, and I believe that a mix of cognitive learning expectations makes for a better lesson.
- KS's seem more appropriate for examination prep/study than for preparation to complete a design project.
- For a design project, maybe it's better to take the KS prior to completing the design project as a review/refresher of what was covered in that block of the course
- [Implementation of KSs] is easier in a course that has smaller blocks…8-10 lessons as opposed to longer. Perhaps dividing the course material into smaller chunks is a better strategy anyway?
- Using KS is analogous to setting clear expectations for your employees…what you require of them (i.e. a basic leadership principle). Same in an academic setting, what you expect your students to know and providing them with a tool to assess their own knowledge learning.

DISCUSSION
The purpose of this study was not only to assess how USAFA civil engineering students self-assess, but also to use that data to adjust teaching pedagogy in an effort to enhance learning and better create life-long learners. Results from the study indicate good agreement with previous studies: students are reasonably good self-assessors but tend to underestimate their abilities for foundational Bloom levels. One benefit of this study and the implementation of KSs has been the opportunity to update course material by creating an opportunity to revisit a backwards course design approach without completely redesigning the course. Examples of those charges are as follows:

- Lesson Objectives were adjusted with some material moved to add more variety in Bloom level to various lessons
- Exams were updated to align with lesson objectives in a more deliberate way
- Language in lesson objectives was updated to be more consistent (e.g. create versus design or describe versus explain)
- Laboratory activities were attached to lesson objectives to be more clear about the relevance of the labs

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