Paper ID #24602

Work in Progress: Pilot Study of an Engineering Modified Problem-Solving Inventory using Civil Engineering Undergraduate Students

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WIP: Pilot Study of an Engineering Education Focused Problem-Solving Inventory using Civil Engineering Undergraduate Students

Abstract

This work in progress (WIP) paper describes the development of a new engineering modified - problem solving inventory (EM-PSI). The EM-PSI is a student's self-assessment of their problem solving and critical thinking abilities broken down into three sub-categories, 1) problem solving confidence, 2) approach-avoidance style, and 3) personal control. The EM-PSI is an innovative tool that is eventually intended be used as an evaluation metric, together with traditional metrics such as GPA and test scores, to improve pedagogical techniques and curricular content.

The EM-PSI was evaluated in a pilot study by distributing a 30 question survey to undergraduate civil engineering students and engineering faculty at Washington State University in the Fall 2017 and Spring 2018. The survey was voluntary and there was a total of 73 responses in the target groups. Internal consistency of the EM-PSI items was evaluated using Cronback's alpha for each sub-category and it was determined that each has acceptable reliable. Initial results for an ANOVA analysis are also presented.

The initial statistical results show that EM-PSI is statistically significant between undergraduate students and engineering faculty. Post-hoc analysis that will be conducted in the future will determine if class year, gender, type of high-school education, and/or parents being engineers has any significant effect on EM-PSI score. Future research hopes to demonstrate that the EM-PSI is reliable, consistent, and a good predictor of technical problem solving. EM-PSI scores will provide educators with another tool to track the effects of pedagogical changes (i.e. flipped classroom, problem-based learning modules, etc.) and curricular changes on student self-assessment of their critical thinking and problem solving ability.

1. Motivation

All instructors have observed differences in problem solving ability and self-motivation between students. Even among well performing students with high GPA's there are those who are excellent a self-guiding through problems and those who can only follow a prescriptive process. Problem solving and critical thinking are often lauded as the primary skills developed during formal engineering education. However, the most common evaluation metrics do not measure overall problem solving ability. Instead, they test student proficiency for a specific subject or method. A tool is needed to measure student critical thinking and problem solving ability.

This study developed a metric for measuring student's self-assessment of their technical problem solving and critical thinking abilities, called the engineering modified problem solving inventory (EM-PSI). While measuring student perceptions does not provide a direct measure of actual problem solving ability, it does provide information about other components of critical thinking, such as self-confidence and self-control. This work-in-progress paper lays the conceptual foundation for the EM-PSI, describes how the EM-PSI is envisioned to be used for curricular development and student assessment, and presents initial findings of a pilot study on 73 undergraduate students and faculty members in Civil Engineering at WSU.

2. Background on Problem Solving Inventory

Critical thinking and problem-solving has been studied extensively in psychology [1], [2], [3] and engineering education [4], [5]. Heppner and Peterson [6] developed a problem-solving inventory (PSI) that identified three different underlying dimensions of real-life problem solving using principal-components factor analysis. The three dimensions were labeled problem-solving confidence (PSC), approach-avoidance style (AAS), and personal control (PC). The PSC items assess an individual's confidence in engaging in a wide range of problem-solving activities. The AAS items assess whether an individual approaches or avoids different challenging problems. Lastly, the PC items measure an individual's self-control and self-efficacy.

Though other problem solving inventories exist [7], none have been studied and validated as much as the Heppner and Peterson PSI. Over a hundred studies have demonstrated the validity and internal consistency of the PSI for measuring perceptions of problem-solving [8], many specifically focused on students and teachers [9], [10], [11], [12], [13], [14], [15]. Despite the large body of research supporting the PSI, some criticisms can also be made. Namely, self-assessment of personal abilities is inherently affected by self-esteem, or an individual's feelings about their own value and capabilities. Poor appraisals can be associated with low self-esteem rather than low self-efficacy, which could be the case for an individual who scores low on PSI but is known by an instructor to be a good self-motivated student who succeeds a problem-solving. Similarly, a known bad student at problem-solving could score high on PSI due to an over-inflated evaluation of their own abilities.

3. Engineering Modified Problem Solving Inventory

The Heppner and Peterson [6] PSI was developed to measure adults' individual perceptions of their problem-solving ability for day-to-day life and is a 35 item instrument, with 3 filler items (therefore scored out of 32 items) measured on a 6-point Likert-type scale. The Heppner and Peterson PSI questions were modified for engineering students because the original questions were too vague to illicit student perceptions about their *technical* problem solving, rather they would answer based on how they approach *everyday* problem solving. The EM-PSI retained the format of the original PSI, but was reduced to 25 items to make it quicker to complete and thereby possibly increase the number of participants who would complete the full survey.

The original PSI consisted of three interrelated subscales, problem solving confidence (PSC), approach-avoidance style (AAS), and personal control (PC). The EM-PSI retained these three subscales and the pilot study did not attempt to re-analyze the component factor analysis. Instead it was assumed that the critical subscales would remain consistent with the original PSI research. Since the wording of the individual items was modified, the internal validity of the EM-PSI questions was evaluated and is discussed in the next section.

Table 1 shows the questions of the EM-PSI and what subscale each question is associated with. Due to space constraints, the original PSI is not provided, but some questions were modified more than others. For example, item 2 is unmodified from the Heppner and Peterson PSI, however item 7 was modified from "*when I have a problem, I think up as many possible ways to handle it as I can until I can't come up with any more ideas"* to what is shown in Table 1.

Table 1 – Questions of the EM-PSI

Item	Engineering Modified PSI (EM-PSI)	Subscale
1	When I face a complex problem, I first define exactly what the problem goal(s) is.	AAS
2	When a solution method to a problem was unsuccessful, I do not examine why it did not work.	AAS
3	If my first effort to solve a problem was unsuccessful, I become unsure about my ability to solve the problem without assistance.	PC
4	After I have successfully solved a problem, I do not analyze what went right and what went wrong during the process.	AAS
5	I am usually able to think of creative and effective approaches to solve a problem.	PSC
6	After I have attempted to solve a problem, I compare the actual outcome with my expected outcome.	AAS
7	When faced with a new problem, I consider as many viable solution methods as possible.	AAS
8	I have the ability to solve most problems, even if no solution is immediately apparent to me.	PSC
9	Many problems I face regularly are too complex for me to solve without assistance.	PSC
10	When starting a problem, I tend to try the first solution method I think of to solve it.	AAS
11	When deciding on a solution method, I do not consider the chances of success of each method versus the time investment required to implement each method.	AAS
12	When I make a plan to solve a problem, I am almost certain that I can make it be successful.	PSC
13	I try to predict the overall outcome of carrying out a particular solution method before starting the problem.	AAS
14	If I try to think of viable solution methods, I usually do not come up with many options.	AAS
15	If given sufficient time, I believe I can solve most problems without assistance.	PSC
16	When faced with a new type of problem, I have confidence that I can handle potential difficulties.	PSC
17	Frequently, when solving a problem, I feel like I am guessing or regurgitating past solutions of similar problems without understanding the underlying theory (theories).	PC
18	I have a systematic method for comparing viable solution methods to make problem-solving decisions.	AAS
19	When I begin a new type of problem, I first conduct a literature survey to collect and research relevant information.	AAS
20	Sometimes I am overwhelmed by a problem and do not attempt to solve it unassisted.	PC
21	After implementing a solution method for a problem, my expected outcome usually matches the actual outcome.	PSC
22	When confronted with complex problems, I am frequently unsure of whether I can solve them unassisted.	PSC
23	When faced with problems that I do not immediately know how to solve, I know what strategies works best for me to learn the necessary information or skills.	PC
24	I am confident that I can rely on my fundamental engineering knowledge to solve, or learn how to solve, most problems.	PSC
25	If my first attempt to solve a problem fails, I re-examine the problem and attempt it again using a different solution method.	PC

4. Pilot-Study on Civil Engineering Undergraduates

The EM-PSI was administered to 73 undergraduate civil engineering students and engineering faculty. Of the sample, 59 participants were undergraduate students (81%) and 14 were faculty members (19%). The breakdown of undergraduate students was 8 sophomores (11% of total), 23 juniors (32% of total), and 28 seniors (38% of total). 50 of the participants were male (68%) and 23 were female (32%). The majority of the undergraduate students, 85%, had attended public high-schools before attending WSU, 12% attended private high-schools, and 3% were home-schooled. Of the undergraduate students, 17% have at least one parent or guardian that is an engineer. Of the faculty members, 13 had completed PhD degrees and one had completed a M.S. degree (architecture faculty where M.S. is typically the terminal degree).

The reliability of the survey was assessed using the widely utilized Cronbach's alpha, which measures inter-item correlation to scale items. A standard of 0.7 for Cronbach's alpha was used to indicate that the results were acceptably reliable [16] and all the EM-PSI subscales exceeded the minimum standard. The Cronbach alphas for PSC, AAS, and PC were 0.795, 0.779, and 0.742, respectively. Test-retest reliability was not determined for the EM-PSI, but many original PSI studies show it to be reliable [6].

A Wald ANOVA with post-hoc tests using the methods of Westfall [17] is still pending, therefore finalized results are not ready for presentation. However, initial analysis seems to show that there are significant differences in EM-PSI score and subscale scores between the faculty and undergraduate students. This suggests that faculty have a greater perception of their problem solving ability than undergraduates. The post-hoc tests will determine if class year, gender, type of high-school education, and/or having parents that are engineers have any statistical correlation to the EM-PSI. Establishing an average EM-PSI score for faculty members also provides a "high-water mark" that can be used to evaluate student scores in a relative manner. For example, if the average faculty EM-PSI and AAS was 100 and 45, respectively. Then the EM-PSI was given to a group of undergraduate engineering students whose average EM-PSI was 82, but most of the difference came from the AAS subscore which was 30, it would suggest that student perceptions are to avoid challenging problems rather than approach them. This could be remedied in the curricula by introducing more open-ended type design problems.

5. Conclusions

The intent of the EM-PSI is to provide faculty with quantitative data on student perceptions of their problem-solving and critical thinking ability as they progress through an engineering program. If the EM-PSI score is administered annually and coupled with an evaluation of student grades, it may help to guide curricular and pedagogical interventions. For example, tracking student GPA, or in-major GPA, plus EM-PSI score will help identify increases in technical mastery (measured by GPA) and problem-solving ability (EM-PSI) from year-to-year.

The future direction of this research is to administer the EM-PSI to a larger group of students linearly over multiple years to track EM-PSI score for a consistent group of students. This will help shed light on the development of problem-solving skill and possibly which subscales increase at faster or slower rates than other subscales. Additionally, future studies will address the test-retest reliability and gather sufficient data to re-analyze the component factor analysis. The last part of the future research direction is to involve multiple Universities to try and capture regional and cultural differences in problem-solving perceptions and development.

Acknowledgements

This work was made possible by the Samuel H. and Patricia W. Smith Teaching and Learning Grant at Washington State University.

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