Work in Progress: Measuring Student Cognitive Engagement Using the ICAP Framework In and Outside of the Classroom

Mrs. Allyson Jo Barlow, Oregon State University

Ally Barlow is a graduate from LeTourneau University where she studied Water Resources in Civil Engineering. She is currently fusing her technical background with her passion for education in pursuing a doctoral degree in Civil Engineering while conducting research in Engineering Education at Oregon State University. Her research interests include student engagement, instrument development, and adoption of teaching best practices in engineering classrooms.

Dr. Shane A. Brown P.E., Oregon State University

Shane Brown is an associate professor and Associate School Head in the School of Civil and Environmental Engineering at Oregon State University. His research interests include conceptual change and situated cognition. He received the NSF CAREER award in 2010 and is working on a study to characterize practicing engineers' understandings of core engineering concepts. He is a Senior Associate Editor for the Journal of Engineering Education.

WIP: Measuring Student Cognitive Engagement Using the ICAP Framework In and Outside of the Classroom

Abstract

The following is a Work in Progress paper related to the deployment of an instrument to holistically measure the cognitive engagement of STEM students. Engagement continues to be shown as an important factor in the academic success of STEM students, and therefore of interest to both educators and the research community. Of the components said to make up engagement (behavioral, emotional, and cognitive), cognitive engagement persists as difficult to measure due to its lack of observable characteristics. The ICAP theory proposed by Chi and Wylie uses validated means to link levels of cognitive engagement with overt, observable behaviors in students. While this theory does much to advance teachers' perceptions of engagement in their own classroom, it is explicitly not a measurement schema. We set out to use the validated link between overt behaviors and cognitive states to develop a tool that allowed students to report on their own cognitive engagement. As the ICAP theory suggests, cognitive engagement is influenced by the environment in which student learning takes place. Despite educators developing curriculum (i.e. homework, projects, writing assignments, etc.) to influence student's out-of-class environment, cognitive engagement outside the classroom is rarely addressed in the literature on STEM students. One of the unique contributions of our instrument is the measurement of cognitive engagement in two distinct environments: inside the classroom and outside the classroom. We developed a measurement schema that prompted students to report on their in-class engagement and out-of-class engagement for each instrument item. Here we analyze data from over 500 early respondents to our instrument. We use paired t-tests to present preliminary findings, indicating that students have unique responses to in-class and out-of-class items. Our results suggest the importance of a measurement schema that allows for students to report more holistically on their cognitive engagement experience as it relates to a single class. This work has the potential to allow educators to glean information that empowers them to make targeted changes on the curriculum they develop for students inside and outside the classroom.

Introduction and Relevant Literature

The current emphasis on active learning prompts educators to modify their courses in ways that increase the engagement of their students with the suggested benefit being increased learning gains, retention, and greater academic success [1]. Yet, even within the research community it is acknowledged that engagement is multi-faceted and difficult to define [2]. Educators are therefore left to make their own judgements on what their classrooms will look and feel like if their students are engaged. Research has shown that it is cognitive engagement (over behavioral or emotional engagement) that is indicative of higher-order processing [3]. It therefore becomes important that educators are able to assess the cognitive engagement of their students in straightforward and meaningful ways.

Chi and Wylie made strides towards the assessment of cognitive engagement in the classroom with their ICAP framework [4]. The framework ties overt, observable behaviors to four distinct modes of cognitive engagement: **I**nteractive, **C**onstructive, **A**ctive, **P**assive. ICAP allows educators to observe their classroom and infer a mode of cognitive engagement among their students: Interactive Engagement is associated with perspective-sharing conversations between students, Constructive Engagement with adding notes to those provided, Active Engagement with underlining and highlighting a text, and Passive engagement with sitting and listing to instruction,

etc. [4]. The framework also allows for the development of learning activities that target a particular mode of engagement among students [5]. In this way, it is an ideal framework for educators seeking to meet the calls of the community to implement active learning strategies in the classroom. There remains room for the ICAP framework to expand into an explicit measurement tool of cognitive engagement, as it was not developed as such. Additionally, the ICAP framework limits educator knowledge of student engagement to that which happens in the classroom and can be directly observed. There currently existed few ways for educators to assess how their students interact with course material once they are outside the classroom.

Educators often intend for important learning to take place out-of-class; flipped courses intend for content learning to take place at home, homework assignments imply a need for practice outside the classroom, and group assignments facilitate interactivity beyond classroom walls. Simmons et al. profiled the out-of-class engagement of civil engineering students using the Postsecondary Student Engagement (PosSE) Survey, finding that the majority of these students reported actively engaging with out-of-class activities [6]. Additional work with the PosSE called for research on *how* and *why* students engage in out-of-class activities.

In our previous work, we have discussed the ability of the ICAP framework to be transitioned into a reliable self-report instrument. We developed a set of items related to each mode of engagement and rigorously developed the Student Course Cognitive Engagement Instrument (SCCEI). In this extensive development process, we interviewed both faculty and students about their thoughts on cognitive engagement broadly and our items specifically. It was in these interviews that we began to note the interplay between engagement in the classroom and engagement outside of the designated lecture period. While our intent was always to develop instruments to measure holistic engagement—inside and outside the classroom—we recognized the potential value in measuring in-class engagement and out-of-class engagement in a single instrument. We therefore developed a single set of items to address both in-class and out-of-class engagement.

One aim of our work is to answer the question: *in what ways to can student's in-class cognitive engagement be distinct from out-of-class cognitive engagement in self-report instruments*? More broadly, with future work, we seek to report to educators on the in-class and out-of-class cognitive engagement of their students, with strategies to increase students' alignment with higher modes of cognition. In this work, we present our preliminary findings that indicate a significant difference between in-class and out-of-class engagement as measured by the SCCEI. Such results suggest that the ICAP framework can be meaningfully expanded to include out-of-class engagement. With future work, distinctly measuring in-class and out-of-class engagement has the potential to influence how educators make targeted changes to their courses to provide students with the benefits associated with active learning.

Methods

The work presented here is part of a larger, ongoing project to measure student cognitive engagement inside and outside the classroom. While our extensive item development and refinement process [7], [8] and data from student and faculty interviews [9], [10] has been outlined elsewhere, we have yet to analyze and present the intersection of in-class and out-of-class engagement. Data from student responses to the SCCEI are analyzed for significantly different responses to in-class and out-of-class items for each mode of engagement.

Student Course Cognitive Engagement Instrument

As noted, we determined out-of-class cognitive engagement to be an understudied area, and relevant to educators. We saw a need to facilitate a direct comparison between the two when our previous work found that students often conflated their in-class and out-of-class engagement [10]. We therefore developed items that could be applied to both inside and outside the classroom learning, and had students respond to the items with two separate 3-point Likert scales. Likert scales were related to frequency of cognitive behaviors or engagement (see **Table 1** below)

Table 1: The three-point Likert scale students were prompted with for items related to in-class and out-of-class engagement. Student viewed both scales simultaneously, as shown below.

Prompt: *I justify my perspective to others when discussing course content.*

In lecture			**Outside the classroom**		
Few to no lecture periods	Some lecture periods	Most lecture periods	Hardly ever	Some days	Most days

Through several rounds of development, we established a set of 21 items reliably factored into six distinct modes of engagement: Interactive, Constructive, Active Thinking, Active Doing, Passive, and Disengaged. The ways in which the factors differed from the ICAP theory are as follows: Active Engagement factored into Thinking and Doing modes, with one mode representing students' reporting on their cognition directly (Thinking) and the other using the established proxy of behaviors (Doing); Disengaged is the construct that represents a lack of engagement, a construct which is noted in the ICAP framework [4] but not included. For each of the six modes, students were prompted with three to four questions related with either their behavior or cognitive engagement. Items included *I defend my approach to others when discussing course content*, *I think about previous concepts covered in the course*, etc (see **Appendix A** for all survey items and factor groupings)

Data Collection

Approximately 530 undergraduate STEM students from four northwestern universities were recruited for validation of the SCCEI. In previous work, this data allowed us to perform the Exploratory Factor Analysis (EFA) required to validate the six constructs (or modes of engagement) being measured. With knowledge of items that factored together, we began student scoring. Scores were obtained by first converting Likert data to ordinal data, with 0 equivalent to *few to no lectures/hardly ever*, 0.5 equivalent to *some lectures/some days*, and 1 equivalent *to most lectures/most days*. This scoring system was intentionally selected—and mirrors the way other educational surveys have been scored, see [11]—one can think of the score as a percentage of alignment with an item (i.e. *few to no lectures* is representative of 50% alignment with an item). Scores for individual items related to each construct were then averaged, indicating an average percent alignment with each mode of cognitive engagement, for inside and outside the classroom, for all participants. Null values were assigned to participants who opted out of a question, and they had no impact on the average score.

Comparison of In-Class and Out-of-Class Scores

Our interest was in seeing if students meaningfully distinguished between their in-class and out-of-class engagement when presented with two scales simultaneously. Therefore, we ran six paired t-tests in SPSS, one for each established mode of cognitive engagement. Paired t-tests were appropriate, as each participant was measured in both samples being compared.

Results and Discussion

The results from our paired t-test (see **Table 2)** indicate in-class and out-of-class engagement can be measured distinctly along all modes but Interactive. This was accomplished with a simultaneously presented Likert scales, and is true at the 95% confidence level ($p < .05$). One plausible reason Interactive engagement was not found to be significant is students who engage Interactively are connected both inside and outside the classroom. Implications might include a need for instructors to synchronously facilitate Interactive engagement inside and outside the classroom to increase Interactive engagement in the course. Additionally, means for Disengagement were significantly *lower* inside the classroom than outside. Plausible explanations include that students who are Disengaged in the classroom may choose to cognitively engage outside the classroom (i.e homework). This points to questions regarding how to reach Disengaged students; possibly such students are and can be engaged deeper in contexts other than lecture. Such findings fit within the limited body of literature discussing out of class engagement [6], [12], [13]

Table 2: Rests from paired-t test. For each pair, individual student scores were averaged for all items relevant to the construct.

Construct (Pair)	Location	Mean alignment with construct	Std. Dev	Difference in Mean	t	df	Sig .(2-tailed)
Interactive	In-class	.560	.243	-.0119	-1.322	537	.187
	Out-of-class	.572	.239				
Constructive	In-class	.423	.390	.0228	2.574	532	.010*
	Out-of-class	.400	.296				
Active Thinking	In-class	.680	.238	.0472	6.175	534	.000*
	Out-of-class	.634	.242				
Active Doing	In-class	.446	.280	.0542	6.265	534	.000*
	Out-of-class	.392	.285				
Passive	In-class	.839	.225	.1102	10.838	525	.000*
	Out-of-class	.729	.270				
Disengaged	In-class	.269	.256	-.0709	-7.277	536	.000*
	Out-of-class	.340	.250				

Future Work

While we have shown the SCCEI measures modes of cognitive engagement inside and outside the class distinctly, work remains to clarify the meaning of these constructs to students and educators. We plan to continue this work both quantitatively and qualitatively. We have proposed interviewing students with respect to their in-class and out-of-class engagement for all of their courses as a means to identify consistencies and inconsistencies. Additionally, a quantitative study is underway in which a larger sample of courses is collected from a more diverse set of institutions to further validate the results.

There is room for further study in how students think about their cognitive engagement differently in different contexts. Particularly, there is an interest in how students Interactively engage with one another both inside and outside the classroom. Is there a correlation between educators forming groups in their classroom and Interactive engagement that takes place outside the classroom? Moreover, can Disengaged students be modified by educational practices in the classroom, or are such students more responsive to out-of-class activities? We see this work pointed towards empowering educators to make meaningful changes inside and outside the classroom.

Appendix A: Student Course Cognitive Engagement Instrument (SCCEI)

ICAP Category	*Question*
Interactive	I defend my approach to others when discussing course content.
	I discuss my position with others regarding the course content.
	I explain concepts to others when discussing course content.
	I justify my perspective to others when discussing course content.
Constructive	I add my own notes to the notes provided by the teacher.
	My course notes include additional content to what the teacher provided.
	I add my own content to the course notes.
Active (*Doing*)	I take verbatim notes (meaning word for word directly from the board/PowerPoint slide/doc camera etc.).
	I copy solution steps verbatim (meaning word for word directly from the board/PowerPoint slide/doc camera etc.).
	I only copy the notes the teacher writes down.
Active (*Thinking*)	I connect current concepts with previous course content.
	I apply current solution steps with previous course content.
	I think about previous concepts covered in the course.
	I consider how multiple ideas or concepts relate.
Passive	I pay attention to my teacher or whomever is speaking.
	I follow along with my teacher or whomever is speaking when they discuss examples.
	I listen when my teacher or whomever is speaking.
	I follow along with the activities that take place during the course.
Disengagement	I do not think about course content.
	I do not pay attention to course content.
	I focus my attention on things other than course content.

References

[1] M. Prince, "Does Active Learning Work? A Review of the Research," *J. Eng. Educ.*, vol. 93, no. 3, pp. 223–231, Jul. 2004.

[2] J. J. Appleton, S. L. Christenson, D. Kim, and A. L. Reschly, "Measuring cognitive and psychological engagement: Validation of the Student Engagement Instrument," *J. Sch. Psychol.*, vol. 44, pp. 427–445, 2006.

[3] G. M. Sinatra, B. C. Heddy, and D. Lombardi, "The Challenges of Defining and Measuring Student Engagement in Science," *Educ. Psychol.*, vol. 50, no. 1, pp. 1–13, 2015.

[4] M. T. H. Chi and R. Wylie, "The ICAP Framework: Linking Cognitive Engagement to Active Learning Outcomes," *Educ. Psychol.*, vol. 49, no. 4, pp. 219–243, 2014.

[5] M. T. H. Chi *et al.*, "Translating the ICAP Theory of Cognitive Engagement Into Practice," *Cogn. Sci.*, vol. 42, pp. 1777–1832, 2018.

[6] D. R. Simmons, Y. Ye, M. W. Ohland, and K. Garahan, "Understanding Students' Incentives for and Barriers to Out-of-Class Participation: Profile of Civil Engineering Student Engagement," *J. Prof. Issues Eng. Educ. Pract.*, vol. 144, no. 2, p. 04017015, 2018.

[7] A. J. Barlow, B. D. Lutz, N. P. Pitterson, N. Hunsu, O. Adesope, and S. A. Brown, "Development of the Student Course Cognitive Engagement Instrument (SCCEI)," *Rev.*, 2018.

[8] B. D. Lutz, A. J. Ironside, N. Hunsu, C. J. Green, S. A. Brown, and O. Adesope, "Measuring Engineering Students ' In-class Cognitive Engagement : Survey Development informed by Contemporary Educational Theories," *ASEE Annu. Conf. Expo. Proc.*, 2018.

[9] A. J. Ironside *et al.*, "Incorporating Faculty Sense Making in the Implementation and Modification of an Instrument to Measure Social and Cognitive Engagement," in *American Society for Engineering Education Annual Conference & Exposition*, 2017.

[10] A. Ironside, B. Lutz, and S. Brown, "Student Perspectives on Cognitive Engagement: Preliminary Analysis from the Course Social and Cognitive Engagement Surveys," *ASEE Annu. Conf. Expo. Proc.*, 2018.

[11] E. M. Walter, C. R. Henderson, A. L. Beach, and C. T. Williams, "Introducing the Postsecondary Instructional Practices Survey (PIPS): A Concise, Interdisciplinary, and Easy-to-Score Survey," *CBE--Life Sci. Educ.*, vol. Winter 201, no. 15: ar53, 2016.

[12] D. R. Simmons, J. Van Mullekom, and M. W. Ohland, "The Popularity and Intensity of Engineering Undergraduate Out-of-Class Activities," *J. Eng. Educ.*, vol. 107, no. 4, pp. 611–635, 2018.

[13] D. Rutledge, S. Pe, and V. Tech, "Developing the Postsecondary Student Engagement

Survey (PosSES) to Measure Undergraduate Engineering Students ’ Out of Class Involvement Developing the Postsecondary Student Engagement Survey (PosSES) to Measure Undergraduate Engineering Students ’,” 2015.