BOARD # 228: Can we improve student success and retention by training undergraduate civil engineering majors in effective self-regulation of learning? (NSF IUSE:EHR ESL Level 1 Grant)

Dr. Ann (Beth) Wittig, City College of New York at City University of New York (CUNY)

Dr. Beth Wittig is a licensed professional environmental engineer and LEED Accredited Professional, with a Ph.D. in chemical engineering. After years as a consultant and field engineer, she is now an Associate Professor at The City College of New York, the chairperson of the Department of Civil Engineering, and an ABET program evaluator.

Can we improve student success and retention by training undergraduate civil engineering majors in effective self-regulation of learning? (NSF IUSE:EHR ESL Level 1 Grant)

Motivation: Attrition is a significant issue for STEM undergraduate majors: on average 49% [1] of students transfer to another major or leave college completely by their 8th year of study, with even greater rates for STEM majors who are under-represented minorities or women [2]. Other than financial barriers to retention, two primary drivers of attrition are reported to be difficulty in adjusting to academic and life needs and resolving educational and occupational goals [3]. We posit that these drivers are closely related to ineffective Self-Regulation of Learning (SRL), since SRL addresses an individual's cognition, actions, and behavior as an independent and reflective learner. Another primary driver of attrition is feelings of isolation, which we posit is closely related to a lack of sense of belonging (SOB), since SOB addresses an individual's cognition, actions, and behavior around their perceived legitimacy as a member of a community who is included, involved, valued, and accepted. Further, the literature documents that many students enter college with ineffective SRL, and that STEM majors who are under-represented minorities or female have fewer relatable peers and so are more at risk of having a low sense of belonging.

Guiding question: Can retention of STEM majors be improved by systematically training students in effective SRL and by building their SOB?

Project: This 3-year project draws upon published research of educational psychology social-cognitive frameworks around SOB [4] and SRL [5], [6], and a pilot study [7], to develop and implement an intervention that uniquely and synergistically interweaves the learning of STEM topics with developing effective SRL and building SOB. In each of the three years of the project, a new cohort of civil engineering students at the CUNY City College of New York is exposed to a different version of the intervention. In year one, the intervention focuses on SRL. In year two, it addresses both SRL and SOB. And in year three, it focuses on SOB. Common surveys are used in all three years, so that the respective effectiveness of each intervention can be evaluated. The year one intervention is the focus of this poster.

Broader impacts: This project creatively incorporates evidence-based advances in educational psychology and education into undergraduate STEM education and lays the groundwork for significant institutional improvement in associates and baccalaureate STEM programs by offering a replicable, transferable, and adaptable design. By directly addressing the performance, skills, attitudes of STEM majors, the intervention will indirectly impact retention in STEM; by improving the retention of underrepresented minorities and women, the intervention will also impact the diversity and numbers of STEM professionals at this time of high demand for skilled college graduates. Within the field of Education, the project will contribute to the base of knowledge around the relative value of training in SRL, in SOB, and synergistically in both SRL and SOB. Within the field of Engineering (as surrogate for STEM), the project will contribute to pedagogical methods by creating a unique and actionable modular approach to train students in SRL and SOB while they are learning STEM concepts, so that the training is both authentic and relevant. The training materials are meant to be immediately implementable by STEM baccalaureate instructors without expertise in the educational psychology socio-cognitive models that they draw upon, as well as associate STEM major instructors.

Methodology: The overarching goal of the year one intervention is to train students to effectively self-regulate their learning by guiding them to use the three steps of SRL while doing major assignments. The three steps of SRL are: (1) Before beginning a challenging task, set goals for the task, plan the actions to reach the goal, and self-motivate; (2) Do the task, adhering to the plan and self-monitoring and self-directing actions; and (3) After the task is completed, reflect on performance and experience, and identify adaptations to the plan to improve performance or experience the next time a similar challenging task is assigned.

We began by designing the intervention in Spring 2024, building on educational theory and research, and the typical tasks of an engineering student. The intervention was refined in Summer 2024 in collaboration with two graduate student partners and six undergraduate student partners. The intervention was implemented in the following semester, and data was gathered to describe the participants and assess the effectiveness of the intervention.

Modules: The year one intervention consists of four modules to deliver the training in four class periods within the first seven weeks of the semester. Each module guides students to use SRL while completing a different challenging major task, and includes instructional material, an in-class group activity, and a homework assignment, as detailed in **Table 1**.

Table 1: Modules Delivered in the First Seven Weeks of Semester

Module	Instructional Topics (~25-min)	In-Class Group Activity (~50-min)	Out-of-Class Individual Assignment
1: Introduction to SRL with application to time management	• Student responsibilities • Why and how to manage one's time • Benefits of SRL • Detailed description of SRL processes with examples • Introduce group activity	• In pairs, students reflect on their time management last week, discuss, and identify adaptations (SRL step 3) • In pairs, students are slowly guided in SRL steps 1 and 2 and create their schedule for this week	• Students do SRL step 3 for current schedule and step 1 and 2 for next week's schedule Students set SRL goals
2: Reinforcement of SRL with application to solving a problem	• Critical thinking and the use of the engineering method to prompt it • Presenting ideas clearly • Challenges of low-stake open-resource tasks • Review SRL processes • Introduce group activity	• In pairs, students are slowly guided to complete a full cycle of SRL while solving a challenging engineering problem • As a class, students present and discuss their adaptations	• Repeat SRL step 3 for current schedule and step 1 and 2 for next week's schedule • Students reflect on in class activity and set goals
3: Reinforcement of SRL with application to solving a similar problem	• Review the steps in the engineering method • Review SRL processes • Review prior module's problem statement • Introduce group activity	• In pairs, students are quickly guided to complete a full cycle of SRL while solving the new challenging engineering problem • As a class, students present and discuss their adaptations	• Repeat SRL step 3 for current schedule and step 1 and 2 for next week's schedule • Students reflect on in class activity and set goals
S4: Reinforcement of SRL with application to studying for exams	• Challenges of high-stake closed-resource exams • Introduce best practices for how to study and how to take tests • Introduce group activity	• In pairs, using worksheet, students complete SRL step 3 for how they prepared for a recent major test • In pairs, do SRL steps 1 and 2 for their next test • As a class, students present and discuss their adaptations	• Repeat SRL step 3 for current schedule and step 1 and 2 for next week's schedule • Students reflect on in class activity and set goals

Survey: The year one intervention also includes a survey to assess the effectiveness of the

training, administered in weeks one, seven (i.e., end of the intervention), and fourteen of the semester. The survey includes 76 Likert-type statements for students to self-assess their SRL effectiveness, SOB, and mindset on a five-point scale, where the higher the number, the "truer" the statement is to the student. The statements are reproduced exactly from three published instruments in the literature: Motivated Strategies for Learning [8], [9], [10], Sense of Belonging [11], [12], [13], and Mindful Meaning System [14]. SOB and mindset instruments are included in the survey even though the year one intervention focuses on SRL, to facilitate a later comparison of the relative effectiveness of the year one, two, and three interventions. The survey also includes an open-ended question about the student's recent use of SRL on a challenging task to reveal the sophistication with which they use SRL. The survey components, statements, and rating options are summarized in **Table 2**.

Table 2: Survey Administered in Weeks One, Seven, and Fourteen of Semester

Survey component	Description of statements	Options for students to rate statements
1: Motivated Strategies for Learning	38 statements Factors: "value" with subfactors "intrinsic goals" and "task value"; "expectancy" with subfactors "self-efficacy" and "control of learning"; and "self-regulation" with sub-factors "metacognitive regulation" and "effort regulation" Example: "When I get confused about something I'm learning in my XX 200 level courses, I go back and try to figure it out."	On a 5-point scale: "not at all true of me", "a little true of me", "partly true of me", "mostly true of me", and "very true of me"
2: Sense of Belonging	31 statements Factors: "belonging", "institutional acceptance", "valued competence","social acceptance", and "involvement" Example: "There are other students at this institution who share my views and beliefs."	On a 5-point scale: "not at all true of me", "a little true of me", "partly true of me", "mostly true of me", and "very true of me"
3: Mindful Meaning-System	7 statements Factors: "effort belief", "goals performance", "response to challenge", and "fixed mindset" Example: "Pretend that you got a bad grade on a very important math assignment. If that happened, this means "I can get a higher score next time if I find a better way to study.""	On a 5-point scale: "I do not agree", "I agree a little ", "I partly agree ", "I mostly agree", and "I agree a lot"

Transcript analysis: Transcripts provide supplemental data regarding performance and persistence. These data are statistically analyzed using the Fisher's Exact hypothesis test [15], [16], to determine if differences with and without the intervention are statistically significant. Transcripts also provide supplemental data regarding student descriptors (i.e., academic performance in key pre-requisite courses to the major, freshman/transfer status, and if they had taken any major courses before the intervention). These data are analyzed alongside the survey factor and sub-factor responses for correlations and using inferential statistics (i.e., MANOVA with repeated measures of time).

Results: The intervention was administered in Fall 2024 to a cohort of 54 civil engineering sophomores by embedding it into the first seven weeks of a required major course. Since the student descriptors and responses to the open-ended survey questions are still being analyzed, the results presented below are limited to the impact of the intervention on performance, persistence, and uptake of SRL.

Student performance and persistence: The first analysis draws upon data mined from student transcripts. **Table 3** presents the results of the Fisher's Exact hypothesis test.

Table 3: Impact of Intervention on Performance and Persistence in Major

	Performance of Sophomores in Sophomore-Level Major Courses			Persistence of Failing Sophomores to Retake Course in the Next Semester		
Major course: Data Analysis	**# Pass**	**# Not Pass**	**% Pass**	**# Retake**	**# Not Retake**	**% Retake**
Without intervention (Fall 2021)	5	55	8%	29	26	53%
With intervention (Fall 2024)	4	32	11%	25	7	78%
Fisher Exact Test p-value	0.454			0.016		
Major course: Statics	**# Pass**	**# Not Pass**	**% Pass**	**# Retake**	**# Not Retake**	**% Retake**
Without intervention (Fall 2021)	15	27	36%	24	3	89%
With intervention (Fall 2024)	28	19	60%	13	6	68%
Fisher Exact Test p-value	0.021			0.090		

The passing rates of first-time takers in both major courses are greater for students who received the intervention than for those who did not. However, only differences in performance in "Statics" are statistically significant with 95% confidence (i.e., $p < 0.05$). The persistence rate of students who failed one or both of the major courses varies depending upon the course. For "Data Analysis", the persistence rate is greater for students who received the intervention than for those who did not; this observation is statistically significant with greater than 95% confidence. For "Statics", the persistence rate declines although these findings are not statistically significant.

Student experience: The second analysis focuses on student experience, and draws upon the surveys administered in the first, seventh, and fourteenth weeks of the semester. **Table 4** presents the percent of students rating each factor and subfactor a minimum 10% higher in week seven (i.e., when the intervention ended) than in week one (i.e., before the intervention was administered). Results for negative statements are reverse-coded, so all of the values in the table represent the degree to which student's positively use SRL, or have SOB or a growth mindset.

Table 4: Impact of Intervention on Student SOB, Mindset, and Use of SRL

Component 1: Motivated Strategies for Learning						
Factor	Value		Expectancy		SRL	
Subfactor	Intrinsic Goals	Task Value	Self-Efficacy	Control of Learning	Metacognitive Regulation	Effort Regulation
% of students in week 7	23%	19%	21%	15%	15%	28%
% of students in week 14	24%	16%	22%	13%	18%	27%

Component 2: Mindful Meaning-System					
Factor	Effort Belief	Goals Performance	Response to Challenge		Fixed Mindset
Subfactor			Helpless	Resilient	
% of students in week 7	26%	36%	21%	17%	17%
% of students in week 14	20%	36%	27%	44%	20%

Component 3: Sense of Belonging					
Factor	Peer Belonging	Institutional Acceptance	Valued Competence	Social Acceptance	Involvement
% of students in week 7	32%	40%	34%	36%	36%
% of students in week 14	36%	24%	42%	27%	24%

The shading highlights those factors for which 20% or more students reported the increase. By week seven, this includes several factors related to SRL, such as the MSL SRL Effort Regulation factor and other MSL and MMS factors tied into how a student self-motivates while using SRL. And while it was not the goal of this intervention, all of the SOB factors are highlighted. By week fourteen, the same MSL factors highlighted in week seven, and all of the MMS and SOB factors are highlighted, although some increased more than others.

Later statistical analyses will determine if there is a statistically significant relationship between any student descriptors and these responses (i.e., that is independent of the intervention).

REFERENCES

[1] National Center for Education Statistics. "Table 322.30 Bachelor's Degrees Conferred by Postsecondary Institutions by Race/Ethnicity and Field of Study: 2017-18" in *Digest of Education Statistics*, 2020.

[2] National Academies of Sciences, Engineering, and Medicine. *Barriers and Opportunities for 2-Year and 4-Year STEM Degrees,* S. Malcom & M. Feder, Eds. National Academies Press, 2016.

[3] V. Tinto, *Leaving College: Rethinking the Causes and Cures of Student Attrition* (2nd ed.). University of Chicago Press, 1993.

[4] T. Strayhorn, *College Students' Sense of Belonging: A Key to Educational Success for All Students* (2nd ed.). Routledge: New York, NY, 2019.

[5] B. Zimmerman, "Self-Efficacy: An Essential Motive to Learn," *Contemporary Educational Psychology*, 1, 82–91, 2000.

[6] B. Zimmerman, "Becoming a Self-Regulated Learner: An Overview," *Theory into Practice*, 42(2), 64–70, 2002.

[7] A. Wittig, A. Conway and N. Devineni. "Design of Novel Courses to Bridge Knowledge Gaps in Engineering and Reduce Attrition and Graduation Delays," *ASEE Mid-Atlantic Fall Conference* (virtual), November 2021.

[8] P. Pintrich, D. Smith, T. Duncan and W. Mckeachie, "A Manual for the Use of the Motivated Strategies for Learning Questionnaire (MSLQ)," Ann Arbor, Michigan. 48109, 1259, 1991.

[9] P. Pintrich, D. Smith, T. Duncan and W. Mckeachie, "Reliability and Predictive Validity of the Motivated Strategies for Learning Questionnaire (MSLQ)," *Educational and Psychological Measurement*, 53, 801-813, 1993.

[10] J. Hilpert, J. Stempien, K. van der Hoeven Kraft and J. Husman, "Evidence for the Latent Factor Structure of the MSLQ: A New Conceptualization of an Established Questionnaire," *SAGE Open*, 1-10, 2013.

[11] C. Goodenow, "The Psychological Sense of School Membership (PSSM) Among Adolescents: Scale Development and Educational Correlates," *Psychology in the Schools*, 30, 79-90, 1993.

[12] A. Ribera, A. Miller and A. Dumford, "Sense of Peer Belonging and Institutional Acceptance in the First Year: The Role of High-Impact Practices," *Journal of College Student Development*, 58(4), 545-563, 2017.

[13] E. Knekta, K. Chatzikyriakidou, and M. McCartney, "Evaluation of a Questionnaire Measuring University Students' Sense of Belonging to and Involvement in a Biology Department," *CBE—Life Sciences Education,* 19:ar27, 1–14, 2020.

[14] D. Yeager and C. Dweck, "Mindsets That Promote Resilience: When Students Believe That Personal Characteristics Can Be Developed," *Educational Psychologist,* 47, 2012.

[15] R.A. Fisher, *Statistical Methods for Research Workers*. Edinburgh, SC: Oliver & Boyd, 1970.

[16] A. Agresti, *Categorical Data Analysis* (2nd ed.). New York, NY: Wiley, 2002.

Acknowledgement: This material is based upon work supported by the National Science Foundation under Award No. (NSF 2235705). Any opinions, findings and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.