Pre-Conference Workshop: Affect and Identity in Engineering Education: Understanding how emotions, feelings, and values shape our students' work and contribute to their engineering identity

Jessica Swenson
Department of Engineering Education
University at Buffalo
Buffalo, USA
jswenson@buffalo.edu

Emma Treadway
Department of Engineering Science
Trinity University
San Antonio, USA
etreadwa@trinity.edu

***Abstract*—In this workshop, we introduce participants to vocabulary and theory to understand their students' affective experiences of doing engineering work. As attention to emotions and other affective elements of engineering student experiences has grown in the literature, this workshop will aid instructors in considering the importance of attitudes, emotions, and values/beliefs for student learning and identity development. The workshop will provide ample opportunity for discussion and reflection, and will empower instructors both to consider scaffolding of assignments with affect in mind and to survey students about their affective experiences in order to iterate on assignment design.**

***Index Terms*—undergraduate, emotion, affect, identity**

I. Description and Relevant Literature

This workshop will equip participants to begin engaging with their students' emotions as a powerful tool for improving learning and building engineering identity. This workshop draws on the results of our National Science Foundation-funded study on affect and engineering identity. Our project examines engineering students' affect (their emotions, feelings, and attitudes [1]) experienced while problem-solving or doing design. While engineering is often seen as purely rational, our data and previous studies have shown affect to be an important part of students' experiences [2]–[8]. Since engineers should have the "ability to identify, formulate, and solve complex engineering problems" [9, p. 6], it follows that an important part of teaching students to become engineers is helping them to handle the emotions that come with complex problem-solving that requires assumption-making, estimation, uncertainty, and failure [10]–[13].

Workshop participants will be introduced to important concepts related to affect, including local affect, affective pathways, global affect, and meta-affect [1]: an affective pathway consists of the moment to moment feelings (local affect) experienced while solving a disciplinary problem. Depending on how these problem solving experiences end, positively or negatively, the pathway may influence a student's overall (global) affect towards the discipline. These affective pathways and students' reactions to them are shaped by meta-affect, or a student's cognition and feelings about their feelings.

During the workshop, we will help participants understand how students' affective experiences can influence their learning [14]–[16] as well as the development of an engineering identity [17], particularly when engaging in complex problem-solving [2]. The development of a student's engineering identity has been shown to influence whether an undergraduate student stays in engineering or not, thus having implications for retention of students in the discipline [18]–[21]. While many descriptions of engineering identity exist, we will draw on a social identity framework which describes engineering identity in terms of socially-constructed norms, values, and stereotypes of engineering [22]; we will discuss students' development of an engineering identity using a model based on the work of [17], [23], [24], in which engineering identity is composed of four components: interest in engineering, ability to socially perform engineering tasks (performance), ability to understand engineering concepts (competence), and recognition of the student as an engineer (by oneself or by important others). Each component of identity can be strengthened or weakened by students' experiences, meaning that instructors have potential opportunities to strengthen students' engineering identities by attending to their affective experiences.

During the workshop, participants will reflect on their course contexts and students' affective experiences, and develop strategies for emotional scaffolding [8] of complex problems to promote learning and identity development. We will share our survey instrument for measuring students'

This material is based upon work supported by the National Science Foundation under Grant No. 2204726. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

affective pathways [25], [26], how we analyze our results, and our findings from using this question.

II. Goals

The goals of this workshop are:

1) To communicate the importance of affect and meta-affect in students' learning and identity development to instructors.
2) To provide examples from our data on how we have seen affect shape student experiences.
3) To share a survey instrument for measuring affective pathways as a tool for assessing students' local affect throughout an assignment.
4) To provide opportunities for participant reflection on their own teaching contexts and for reframing assignments to help students embrace negative feelings they may encounter in engineering.

In order to get the most out of the workshop, participants can bring a complex or challenging multi-step assignment/project from one of their classes (or an idea for a complex assignment that has not yet been scaffolded that they would like help thinking through). Throughout the workshop (see agenda in Section III), participants will have opportunities to discuss their course contexts, reflect on how to use assessment tools to understand students' affective experiences, and think about scaffolding for productive affect.

III. Agenda and What to Expect During the Workshop

Our workshop is intended to be informative, reflective, and productive. The discussion and reflection elements as noted below are for participants to talk in small groups, share with the larger group, and reflect on their own teaching practice and curriculum. The approximate schedule of the workshop is given in Table I. More details on the content covered in the schedule is provided in the sections below.

A. Affective Pathways

Affective pathways are sequences of emotions, or local affect, an student experiences as they solve a problem [2], [27]. The local affect in a pathway can have positive, negative, and/or neutral emotions. If a pathway ends in a few positive emotions, the pathway is positive and may contribute positively to a student's global affect. If a pathway ends in a few negative emotions, the pathway may contribute negatively to a student's global affect. For example, if a student constantly ends their problem solving experience in dynamics in a state of confusion and frustration, this might create dislike of the subject and negative global affect.

Building off previous work of mathematics researchers Goldin [27] and Gómez-Chacón [28], we created a survey question to document engineering student's affective pathway. Previous research has documented multiple iterations we have made on which words are included and how we ask this question, and gathered evidence towards instrument validation [25], [26]. The current version can be found in Figure 1.

TABLE I
Workshop Agenda

Workshop Component	**Approx. Time**
Overview and introductions	15 min
Discussion: Where do complex problems show up in your curriculum?	10 min
Introducing affect and affective pathways	15 min
Discussion: What types of complexity bring up strong emotions for your students? How have you seen affect or affective pathways in your classroom?	10 min
Affective pathway vignettes and a survey tool	15 min
Reflection: How could I use this tool in my classrooms or modify it to serve my needs?	10 min
Meta-affect and the shaping of affect	15 min
Discussion: Meta-affect and regulation	15 min
Linking affect and identity	15 min
Reflection: During what activities do you notice your students feeling like an engineer? What are ways you have seen students' experiences aid or hurt their engineering identity?	10 min
Reflection: How could you modify the scaffold or frame of one existing assignment to help students embrace uncertainty or feeling stuck, or even to experience these feelings as productive or build their engineering identities?	20 min
Wrap-up	10 min
Networking and questions	20 min

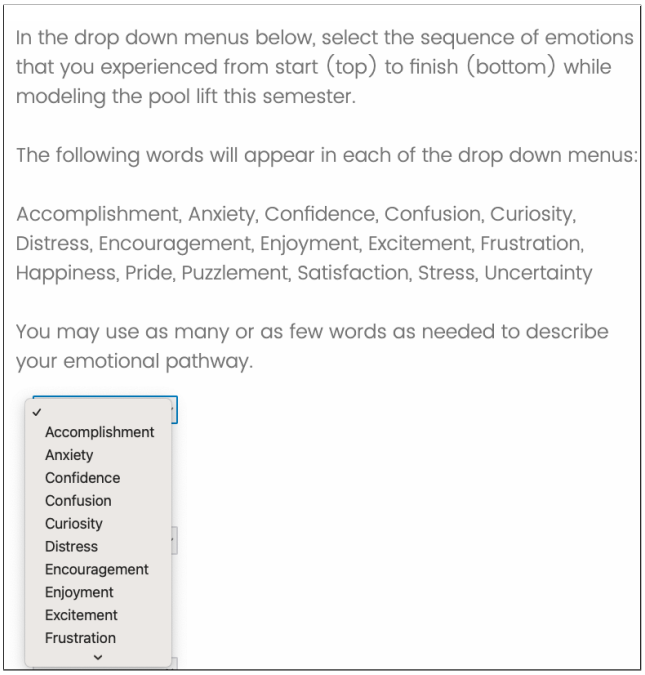

Fig. 1. Affective Pathway question

An example of a student's recalled experience solving an open-ended problem designing a pool lift [29], [30] that we characterized as positive included the following words:

Puzzlement → Confusion → Curiosity → Stress →

Satisfaction → Happiness → Pride

While this student's experience did contain confusion and stress, we see their resultant emotions ending with satisfaction, happiness, and pride.

Another student had a different experience solving the problem:

Confusion → Accomplishment → Puzzlement → Frustration → Anxiety

This student's experience ended with frustration and anxiety, two negative emotions, and thus has a negative ending.

Other pathways can have what we determine to have neutral endings as they have neutral, or both positive and negative words at the end.

Confidence → Confusion → Anxiety → Uncertainty → Stress → Uncertainty → Confusion

In the workshop we will discuss ways faculty can use this tool to measure students' experiences during a problem to determine how to alter the scaffolding of problems to either better support students and mitigate negative emotions, or open up problems to more ill-definedness.

B. Meta-Affect

While students' local affect can be a reaction to external circumstances, it does not exist entirely outside the realm of students' control or understanding. Meta-affect, consisting of both affect about affect and cognition about affect, can determine how students experience their emotions [1], [31]. A common example of meta-affect is affective regulation, which is a skill that enables students to manage their emotions. We have seen engineering students do this in the following ways [2, p. 292]:

- "Recognize discomfort as necessary
- Regulate the engineering work to regulate the emotions
- Check with a friend
- Reassure yourself
- Take a break"

However, meta-affect can take on many forms and play various roles in problem-solving. Students are said to have productive meta-affect when their meta-affect supports learning or accomplishment [32]. The development and stabilization of such productive meta-affect over time is known as the process of meta-affective learning [32]. In our research, we have seen engineering students do the following [2, p. 292]:

- "Recognize as authentic disciplinary activity
- The part that's 'supposed' to be difficult seems easy
- See challenge as confidence-building
- See challenge as learning"

A student's meta-affect may establish a context in which emotions are experienced [2], [31]–for example, in an in-class problem-solving session with a supportive instructor, it may feel "safe" to experience frustration while solving a problem; the same frustration may be interpreted very differently by the same student if it occurs while solving an exam problem. In these two cases, the same emotion (frustration) is experienced; however, students' beliefs (about the problem, the class, the instructor, the subject matter, etc.) can lead to different meta-affective contexts that shape the experience of such an emotion [4], [31].

C. Linking Affect, Identity, and Assignment Scaffolding

Our grant also explores how affect, affective pathways, and meta-affect may influence a student's engineering identity. Our previous work [2] includes examples that suggest that, for some students at least, the affective experience of overcoming frustration while solving complex problems can lead to strong feelings of pride and competence (which is a component of engineering identity). As described in the previous section, students' meta-affect plays an important role in the effects that their affect has on their engineering identity development.

Because the emotions that students experience while problem-solving have implications for both their global affect [1] and their identity development, it is important that instructors consider local affect and affective pathways when scaffolding assignments, particularly highly complex ones. During the workshop, we will share strategies from our own work [2, pp. 300-301] to help instructors scaffold to help students embrace feelings of discomfort and frustration:

1) "Offer complex open-ended problem, but scaffold them to support student learning and mitigate overwhelming negative affect"
2) "Offering choice can improve students' epistemic affect"
3) "Normalize negative affect during disciplinary problem-solving"
4) "Encourage affective regulation (to a point)"

We will also share and connect to strategies from other literature [5], [8], [15].

IV. Expected Outcomes

Participants will come away with an understanding of affect, affective pathways, and meta-affect, and how these affect students during problem-solving activities. Participants will be guided through revising the scaffolding of a complex assignment from their own courses and be given a tool to measure affective pathways in their courses. Links will also be made to how these influence engineering identity.

V. About the Facilitators

The workshop will be facilitated by the Co-PIs on a grant focused on affect and identity in engineering, Dr. Emma Treadway and Dr. Jessica Swenson. They are also co-authors of a recent JEE article entitled "Engineering students' epistemic affect and meta-affect in solving ill-defined problems" [2].

Dr. Swenson is an Assistant Professor in Engineering Education at the University at Buffalo. She has engaged in engineering education research for thirteen years and has a passion for translating her research into practice with an

emphasis on engineering science courses at the undergraduate level. She has delivered professional development for many types of engineering instructors including engineering professors and teaching assistants, and K-12 teachers. She also teaches the introductory course on engineering education in her department's doctoral program. Her current research focuses on engineering judgement, teachers of emerging multilingual elementary students, and affect and identity.

Dr. Treadway is an Assistant Professor in the Department of Engineering Science at Trinity University, where she has taught numerous undergraduate engineering courses with a focus on implementation of research-based pedagogical methods. She also has experience in professional development facilitation, having previously worked as an Engineering Teaching Consultant at the Center for Research on Teaching and Learning in Engineering at the University of Michigan. She is currently active as part of the Curricular Transformation Team associated with Trinity University's participation in the Howard Hughes Medical Institute Inclusive Excellence 3 (ie3) initiative, helping to plan and lead annual curricular summits that focus on issues of inclusion and equity in introductory STEM curricula.

ACKNOWLEDGMENT

Thanks to our participants for their time and energy in completing interviews, as well as to the numerous students on our research team who have contributed to the analysis of transcripts and surveys over the course of this project and its development: Krista Beranger, Alyndra Plagge, Danielle Usinski, Leah Maykish, Shea Lape, Mitchy Lee, Kailey Tubbs, and Melissa Caserto.

REFERENCES

[1] V. A. DeBellis and G. A. Goldin, "Affect and Meta-Affect in Mathematical Problem Solving: a Representational Perspective," *Educ Stud Math*, vol. 63, no. 2, pp. 131–147, Oct. 2006.

[2] J. Swenson, E. Treadway, and K. Beranger, "Engineering students' epistemic affect and meta-affect in solving ill-defined problems," *J of Engineering Edu*, vol. 113, no. 2, pp. 280–307, Apr. 2024.

[3] E. Treadway and J. Swenson, "Research Initiation: Understanding Interactions Between Affect and Identity in First- and Second-Year Engineering Students," in *American Society for Engineering Education Annual Conference*, Portland, OR, 2024.

[4] A. Plagge, E. Treadway, J. E. S. Swenson, and D. Usinski, "Putting Affect in Context: Meta-Affect, Beliefs, & Engineering Identity," in *2024 ASEE Annual Conference and Exposition Proceedings*. Portland: ASEE, 2024.

[5] N. Kellam, T. Costantino, J. Walther, and N. Sochacka, "Uncovering the Role of Emotion in Engineering Education within an Integrated Curricular Experience," in *2011 ASEE Annual Conference & Exposition Proceedings*. Vancouver, BC: ASEE Conferences, Jun. 2011, pp. 22.1560.1–22.1560.11.

[6] N. Kellam, J. Walther, G. Wilson, K. Gerow, and M. Lande, "Uncovering the Role of Emotion in Learning through First- and Second-Year Engineering Students' Narratives," in *6th Research in Engineering Education Symposium: Translating Research into Practice, REES 2015*, Dublin, 2015, pp. 1–9.

[7] N. Kellam, K. Gerow, G. Wilson, J. Walther, and J. Cruz, "Exploring emotional trajectories of engineering students: A Narrative Research Approach," *International Journal of Engineering Education*, vol. 34, no. 6, pp. 1–15, 2018.

[8] J. Lönngren, T. Adawi, and J. Holmén, "When emotions are NOT outlawed: Using emotional scaffolding to enhance student learning," in *Blended Learning in Engineering Education: challenging, enlightening – and lasting?: SEFI 49th Annual Conference, Proceedings*, H.-U. Heiß, H.-M. Järvinen, A. Mayer;, and A. Schulz, Eds. Berlin: Société européenne pour la formation des ingénieurs (SEFI), 2021, pp. 1556–1560.

[9] ABET, "Criteria for Accrediting Engineering Programs, 2023 – 2024," Baltimore, Tech. Rep. E001 12-28-2020, 2024.

[10] J. Gainsburg, "The Mathematical Disposition of Structural Engineers," *Journal for Research in Mathematics Education*, vol. 38, no. 5, pp. 477–506, 2007.

[11] H. Petroski, *Design Paradigms: Case Histories of Error and Judgment in Engineering*, 1st ed. University of Cambridge, 1994.

[12] R. J. Aleong, C. Joslyn, and R. S. Adams, "Capitalizing on Surprise and Doubt in Design Experiences," *International Journal of Engineering Education*, vol. 34, no. 2, pp. 558–566, 2018.

[13] D. P. Crismond and R. S. Adams, "The Informed Design Teaching and Learning Matrix," *Journal of Engineering Education*, vol. 101, no. 4, pp. 738–797, Oct. 2012.

[14] R. Pekrun, "The Control-Value Theory of Achievement Emotions: Assumptions, Corollaries, and Implications for Educational Research and Practice," *Educ Psychol Rev*, vol. 18, no. 4, pp. 315–341, Nov. 2006.

[15] K. R. Muis, M. Chevrier, and C. A. Singh, "The Role of Epistemic Emotions in Personal Epistemology and Self-Regulated Learning," *Educational Psychologist*, vol. 53, no. 3, pp. 165–184, Jul. 2018.

[16] D. D. Arboleda, "Board 426: Work in Progress: Real-Time Ecological Momentary Assessment of Students' Emotional State in Statics," in *American Society for Engineering Education Annual Conference*. Portland: ASEE, 2024, pp. 1–8.

[17] A. Godwin, "The Development of a Measure of Engineering Identity," in *2016 ASEE Annual Conference & Exposition Proceedings*. New Orleans, Louisiana: ASEE Conferences, Jun. 2016, p. 26122.

[18] K. L. Tonso, "Engineering Identity," in *Cambridge Handbook of Engineering Education Research*, A. Johri and B. M. Olds, Eds. New York: Cambridge University Press, 2013, pp. 267–282.

[19] B. E. Hughes, W. J. Schell, B. Tallman, T. Sybesma, M. B. Kwapisz, E. Annand, S. Ranch, C. Krejci, C. Bozic, and D. Kotys-Schwartz, "Entering the community of practice: changes in engineering students' engineering identities and perceptions of the field," *European Journal of Engineering Education*, pp. 1–19, Jul. 2021.

[20] H. M. Matusovich, R. A. Streveler, and R. L. Miller, "Why Do Students Choose Engineering? A Qualitative, Longitudinal Investigation of Students' Motivational Values," *J of Engineering Edu*, vol. 99, no. 4, pp. 289–303, Oct. 2010.

[21] A. Godwin and A. Kirn, "Identity-based motivation: Connections between first-year students' engineering role identities and future-time perspectives," *J of Engineering Edu*, vol. 109, no. 3, pp. 362–383, Jul. 2020.

[22] J. Huff and M. Ross, "Advancing an Integrative Perspective of Identity in Engineering Education," in *International handbook of engineering education research*, A. Johri, Ed. New York, NY: Routledge/Taylor & Francis Group, 2023, pp. 183–198.

[23] Z. Hazari, G. Sonnert, P. M. Sadler, and M.-C. Shanahan, "Connecting high school physics experiences, outcome expectations, physics identity, and physics career choice: A gender study," *J. Res. Sci. Teach.*, pp. 978–1003, 2010.

[24] H. B. Carlone and A. Johnson, "Understanding the science experiences of successful women of color: Science identity as an analytic lens," *J. Res. Sci. Teach.*, vol. 44, no. 8, pp. 1187–1218, Oct. 2007.

[25] E. Treadway, J. E. S. Swenson, and M. Caserto, "Development of a Survey Instrument for Measuring Affective Pathways," in *American Society for Engineering Education*. Minneapolis: ASEE, 2022.

[26] E. Treadway, K. Tubbs, M. Caserto, M. Lee, and J. Swenson, "Assessment of a Survey Instrument for Measuring Affective Pathways," in *2023 ASEE Annual Conference & Exposition Proceedings*. Baltimore: ASEE, 2023, p. 42328.

[27] G. A. Goldin, "Affective Pathways and Representation in Mathematical Problem Solving," *Mathematical Thinking and Learning*, vol. 2, no. 3, pp. 209–219, Jul. 2000.

[28] I. M. Gómez-Chacón, "Affective influences in the knowledge of mathematics," *Educational studies in Mathematics*, vol. 43, no. 2, pp. 149–168, 2000.

[29] M. Magee and J. Swenson, "Characterizing Student Work while Solving Ill-Defined Statics Problems in Groups," in *2023 ASEE Annual Conference & Exposition Proceedings*. Baltimore , Maryland: ASEE Conferences, Jun. 2023, pp. 1–20. [Online]. Available: http://peer.asee.org/43190

[30] K. Churakos, J. Mitchell, and J. E. S. Swenson, "An Autoethnography of the Student Experience Solving an Open-Ended Statics Problem," in *American Society for Engineering Education Annual Conference*. Portland: ASEE, 2024, pp. 1–21.

[31] G. A. Goldin, "Affect, Meta-Affect, and Mathematical Belief Structures," in *Beliefs: A Hidden Variable in Mathematics Education?*, G. C. Leder, E. Pehkonen, and G. Törner, Eds. Dordrecht: Kluwer Academic Publishers, 2002, vol. 31, pp. 59–72, series Title: Mathematics Education Library.

[32] J. Radoff, L. Z. Jaber, and D. Hammer, ""It's Scary but It's Also Exciting": Evidence of Meta-Affective Learning in Science," *Cognition and Instruction*, vol. 37, no. 1, pp. 73–92, Jan. 2019.