# Engagement in Practice: Lessons Learned About the Emotional Outcomes of Co-Designing Accessible Engineering Education Tools

**Mirelys Mendez Pons, Stanford University**

Mirelys Mendez Pons is an undergraduate student at Stanford University studying Product Design with a focus on physical design and manufacturing, and a minor in Modern Languages (Spanish and Portuguese). She completed an interdisciplinary honors thesis at Stanford's Graduate School of Education on making electrical engineering education more accessible for blind and low-vision learners, emphasizing usability, confidence, belonging, and emotional engagement.

**Aya Mouallem, Stanford University**

Aya Mouallem (she/her) is a PhD candidate in Electrical Engineering and MA candidate in Education at Stanford University. She received a BEng in Computer and Communications Engineering from the American University of Beirut. Aya is a graduate research assistant with the Designing Education Lab at Stanford, led by Professor Sheri Sheppard. Her research designs, develops, and evaluates education technology and pedagogy to broaden the accessibility of engineering education and fundamentally transform how we prepare future engineers. She is supported by the Knight-Hennessy Scholars program and the DARE and RAISE doctoral fellowships.

**Shima Salehi, Stanford University**

I am an assistant faculty at Stanford Graduate School of Education, and my research focus on improving STEM education effectiveness and accessibility for all students leveraging learning and cognition theories as well as educational technologies.

**Dr. Sheri D. Sheppard, Stanford University**

Sheri D. Sheppard, Ph.D., P.E., is professor of Mechanical Engineering at Stanford University. Besides teaching both undergraduate and graduate design and education related classes at Stanford University, she conducts research on engineering education and

# Engagement in Practice: Lessons Learned About the Emotional Outcomes of Co-Designing Accessible Engineering Education Tools

**Abstract**
Electrical engineering (EE) education remains largely inaccessible to blind and low-vision (BLV) learners due to its reliance on visual representations such as circuit diagrams and simulations. Disability is a critical but often overlooked dimension of diversity in engineering education. This Engagement in Practice paper explores the co-design and evaluation of an accessible, multi-sensory circuit simulation tool developed in partnership with the BLV community through a collaboration with a nonprofit serving BLV individuals in Northern California. In particular, this study examines how the availability of an accessible engineering education tool influences the emotional and psychological engagement of BLV learners in EE.

Eight BLV participants joined a community engagement program that we organized at Stanford University over 2.5 years. The program revolved around the use of tactile circuit-building tools and an accessible digital simulator to complete introductory electrical engineering activities. Post-program mixed-methods surveys combined open- and closed-ended questions to evaluate the BLV participants. Inductive thematic analysis, through open, axial, and selective coding, identified emotional and cognitive patterns related to engagement and self-efficacy. Quantitative data from the survey were analyzed using statistical methods. Findings show that accessible, hands-on learning experiences using the tool fostered an increased self-efficacy and persistence in problem-solving, while reducing frustration and emotional barriers to participation in engineering educational activities. Participants also described a stronger sense of belonging and motivation to continue exploring STEM-related learning after engaging with and helping design the accessible simulator. Consequently, this study elucidates insight into how accessible engineering education tools for BLV learners show strong promise for promoting longer-term motivation and broadening equitable participation in STEM, particularly through transferable elements such as co-design with BLV learners, multisensory scaffolding, and attention to emotional engagement. Notably, these outcomes stem not only from the tool itself, but also from participant involvement in its iterative refinement. At the same time, elements such as tactile circuit representations remain more specific to EE contexts. This work emphasizes the importance of inclusive participatory design practices, alongside consideration for emotional and psychological outcomes, in developing accessibility-focused engineering education resources.

## 1 Introduction

Electrical engineering (EE) relies heavily on visual representations such as diagrams, schematics, and prototyping, making it largely inaccessible for blind and low-vision (BLV) learners [1][2]. This limits BLV participation in engineering and perpetuates their underrepresentation in STEM [3][4]. BLV students face challenges conceptualizing abstract concepts, navigating spatial layouts, and applying knowledge practically [5][6], often resulting in exclusion, reduced confidence, and lower persistence [7][8]. Existing tools like tactile diagrams and screen readers provide partial support but fall short on spatial reasoning and circuit abstraction, requiring extra cognitive and emotional effort and underscoring the need for multisensory approaches.

This paper addresses the lack of accessible, non-visual EE tools by co-designing multisensory circuit-building resources with BLV participants, emphasizing not only functional access, but also affective outcomes, confidence, belonging, and independence, which are critical yet underexplored for STEM persistence. It forms part of a greater collaborative effort by the DEL research team at Stanford University [9], [10], focusing on physical tactile tools, co-design processes, and participant emotional experiences. **The guiding question for this effort is:** *How do accessible circuit-building tools influence the affective states of blind and low-vision students when learning electrical engineering, and how do these affective responses shape learners' motivation and interest in participation in STEM?*

## 2 Literature Review

Traditional methods for teaching electrical engineering such as diagrams, schematics, and prototyping assume sighted learners, posing unique challenges for BLV learners [12]. While computer science offers accessible text-based entry points via screen readers [13], spatially and visually heavy disciplines like EE are harder to adapt for BLV users due to abstract, non-tactile visualizations [14] [15]. Significant gaps persist in how BLV learners navigate EE coursework. Research on tactile schematics and auditory systems focuses on usability and task completion, not broader psychological experiences like belonging, confidence, or emotional responses; critical for STEM persistence [16]. Belonging is essential; in [17] Bulk describes it as involving affiliation, familiarity, acceptance, trusting connections, interdependent relationships, and equity. BLV students often experience non-belonging or belonging uncertainty due to ableist structures, dependence, burden perceptions, and lack of representation [18]. Confidence here refers to self-efficacy, beliefs in one's ability to succeed in specific situations [19], and is tied to perceived competence in challenging STEM environments [20].

Accessible co-design actively includes BLV learners in shaping tools to meet their needs, fostering ownership and empowerment and serving as a mechanism that can support belonging and confidence development [21] [22]. This research bridges gaps by examining how accessible tools shape belonging, confidence, and emotional responses in EE coursework and factors influencing persistence, engagement, and success in STEM [23].

## 3 Positionality

The first author is a sighted student in an undergraduate Design program with a background in design research. The second author is a graduate student researcher in Electrical Engineering and established a nonprofit community partnership to involve the BLV community in Northern California in the broader research project. The third author is an engineering educator whose research focuses on increasing accessibility to engineering education for all learners, with a particular emphasis on underrepresented communities. The fourth author is a learning scientist, with a background in Electrical Engineering whose research focus is on promoting evidence-based effective and accessible engineering and science education.

## 4 Methods

This mixed-methods study investigated tactile, digital, and co-design resources for EE education with BLV learners. Eight diverse participants (in terms of varying engineering tool exposure and circuit knowledge) were recruited via a community partnership with Lighthouse for the Blind Visually Impaired in San Francisco, which provided ongoing co-negotiation of goals, shared decision-making and responsibilities, and iterative evolution over the years in response to participant feedback and organizational priorities. IRB approval was obtained. Given the small sample size, methods were primarily exploratory and reflective, aimed at understanding participant experiences rather than making generalizable claims.

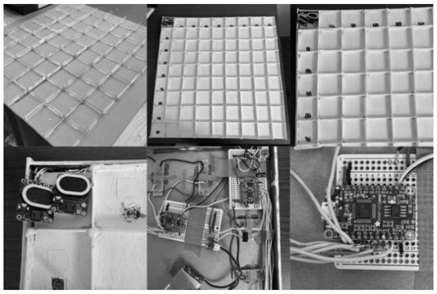

**Figure 1**. Design of grid board

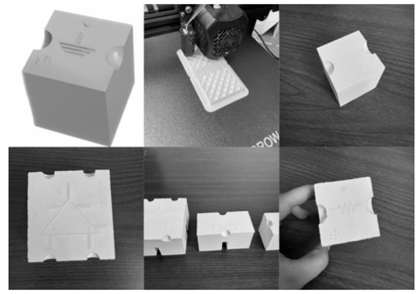

**Figure 2.** Design of tactile blocks.

This co-design process led to the development of a tactile grid board with acrylic dividers and audio feedback, Braille-labeled circuit blocks, a reference guide using pipe-cleaners and audio buttons, and a screen-reader-compatible digital simulator. Two iterations of the same tool were developed and tested in partnership with the BLV community. Activities combined workbook-based circuit building, panel discussions on BLV STEM experiences, and co-design sessions entailing journaling, "5 Whys," "How Might We?," and presentations [24]. Post-program surveys captured accessibility, usability, educational value, and emotions (frustration, enjoyment, curiosity, empowerment, confidence). Data were analyzed via grounded theory [25][26], thematic coding (open, axial, selective) [27], and descriptive statistics for Likert responses. Research quality was improved via triangulation with qualitative and quantitative data, iterative engagement with participants, and grounding interpretations in participant-generated feedback.

## 5 Findings

Participants described consistent confidence growth through repeated tool engagement, iteration, and support. **P1** said, *"Once I had that grid and key in front of me… I grew more confident. I felt especially secure once I understood how the grid [transferred] directly to the simulator."* **P2** shared, *"The more I used the tool, the more confident I became in completing tasks. It is [logic]-based, so I gained more confidence as I continued to use the tool."* **P6** noted, *"My comfort level definitely increased dramatically as soon as I completed my first circuit and understood the notation system."* **P5** commented, *"After a few attempts, I became more comfortable and began to comprehend the activity, so the hands-on experience was helpful for me."*

Seven of eight participants reported increased confidence in designing circuits and using formulas (Figures 3–4) after the first session. Confidence also rose in explaining design ideas, empathizing with co-design partners, identifying problems from multiple angles, and believing in positive impact through design (Figures 5–8). Initial frustration stemmed from tool unfamiliarity (e.g., Google Docs navigation barriers), difficulty feeling block shapes, and time constraints. Participants shifted from anxiety to affirmation through exploration, support, and iteration. **P1** explained: *"I couldn't swipe or tab through content… It felt very affirming to be able to troubleshoot with the blocks and learn what I did wrong and why."* **P2** struggled with shapes initially, but repeated use built confidence. Curiosity and motivation surged—**P4** embraced the "squirminess" of discovery, **P7** reported a *"newfound interest in electrical engineering,"* and **P5** expressed, "*I actually surprised myself that I feel I did better than I expected of myself.*" Pride in co-design contributions reinforced ownership, sparking agency and transforming uncertainty into self-assuredness through tactile engagement, problem-solving, and iteration.

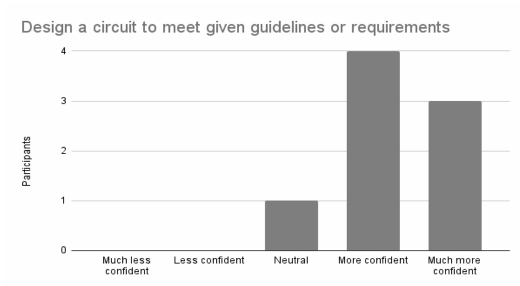


**Figure 3**. Change in confidence in designing circuits to meet requirements.

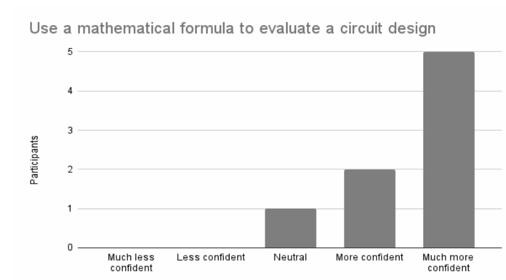


**Figure 4**. Change in confidence in applying mathematical formulas in design.

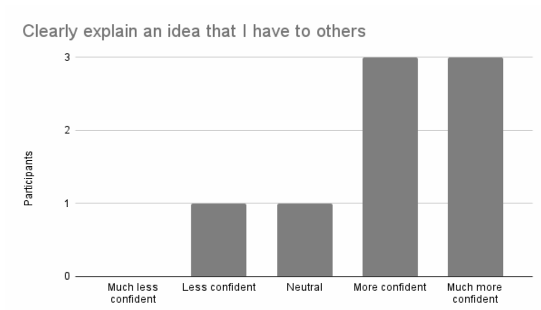


**Figure 5**. Change in confidence in explaining design ideas.

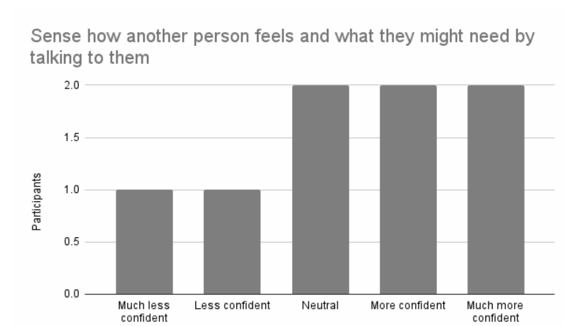


**Figure 6**. Change in confidence in empathizing with co-design partners.

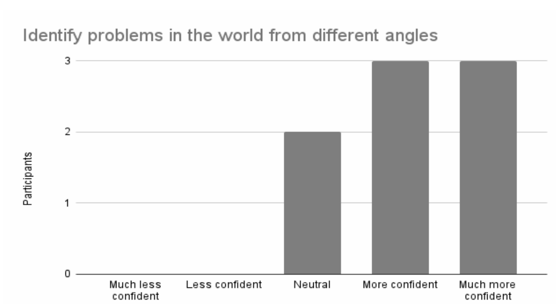


**Figure 7**. Change in confidence in identifying problems from multiple angles.

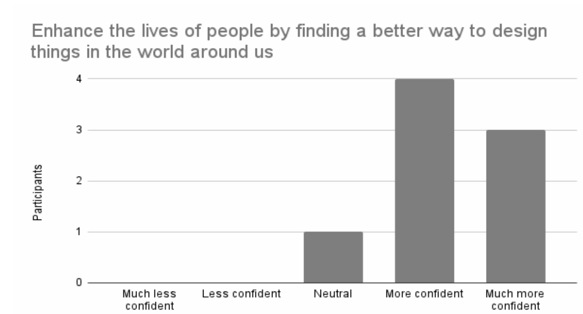


**Figure 8**. Change in confidence in creating a positive impact through design.

## 6 Discussion

Emotions like confidence, frustration, and curiosity are core to BLV engagement with EE. Traditional visual reliance creates barriers [11] [12]; multisensory translations fostered positive affective reactions, transforming anxiety into capability and highlighting emotional support as essential to accessibility [16]. Confidence progressed from initial self-doubt to positive self-efficacy via scaffolded exploration, error correction, and feedback [22]. Co-design reduced barriers, enhanced ownership, and extended agency beyond technical skills [20]. These emotional shifts, reduced frustration, increased persistence, curiosity, and belonging, indicate that accessible tools reshape BLV identities as capable STEM participants. Quantitative trends (most reporting higher confidence across skills) align with qualitative descriptions of "early wins" and psychological safety. Limitations include a small sample (N=8), restricting generalizability and statistics, and reliance on post-session self-reports. Future work could add video recordings, interviews, or observations for deeper insights into engagement over time. The approach transfers to other STEM fields (e.g., mechanics) through similar partnerships and multisensory tools, emphasizing emotional outcomes alongside cognitive ones for equity.

## 7 Conclusion

This research study examined how accessible circuit-building tools influence affective states of BLV students during EE learning and shape their motivation and interest in participation in STEM. Multimodal tools fostered confidence, reduced frustration, sparked curiosity, and strengthened belonging and self-efficacy. Co-design empowered participants as contributors, deepening emotional connection to engineering. When BLV learners engage with intentionally designed tools in supportive environments, emotional experiences become foundational to equitable STEM participation. These multimodal and co-design approaches are also transferable to broader efforts in educational reform aimed at expanding participation and access across diverse learner populations, where disability should be recognized as a core dimension of diversity alongside race, ethnicity, and gender.

***References:***

[1] J. A. Miele and E. J. Kennedy, "Accessible STEM education for students with visual impairments," J. Visual Impairment Blindness, 2021.
[2] D. Ting, K. Nguyen, and D. Tindall, "Accessibility in engineering education," in Proc. SIGCSE, 2022.
[3] National Science Foundation, Women, Minorities, and Persons with Disabilities in Science and Engineering, NSF 23-315, 2023.
[4] R. N. Brewer, M. R. Morris, and A. M. Piper, "'Why would anybody do this?' Understanding older adults' motivations and challenges in crowd work," in Proc. CHI, 2014.
[5] T. Coughlan, T. Ullmann, K. Lister, and A. Johnson, Technology and Inclusion: Implications for Open and Distance Learning. Milton Keynes, U.K.: Open Univ., 2019.
[6] W. Erickson, C. Lee, and S. von Schrader, Disability Statistics Annual Report. Ithaca, NY, USA: Cornell Univ. Yang-Tan Institute, 2021.
[7] J. Woods, A. Tietjen, and J. P. Bigham, "Improving non-visual access to engineering diagrams," in Proc. ASSETS, 2018.
[8] E. Hasper, D. Kim, and A. Stefik, "Investigating how visually impaired students learn computing and engineering concepts," ACM Trans. Comput. Educ., 2020.
[9] A. Mouallem et al., "IncluSim: An accessible educational electronic circuit simulator for blind and low-vision learners," in Proc. CHI, 2025, pp. 1–18.
[10] A. Mouallem et al., "'Nothing about us, without us:' Co-designing an accessible engineering education tool," in Proc. ASEE, in press.

[11] B. Beck-Winchatz and M. A. Riccobono, “Advancing participation of blind students in science, technology, engineering, and math,” Adv. Space Res., vol. 42, no. 11, pp. 1855–1858, 2008, doi: 10.1016/j.asr.2007.05.080.

[12] J. U. Davis et al., “TangibleCircuits: An interactive 3D-printed circuit education tool for people with visual impairments,” in Proc. CHI, 2020, pp. 1–13, doi: 10.1145/3313831.3376513.

[13] L. Shi, Y. Zhao, and S. Azenkot, "Designing interactions for 3D printed models with blind people," in Proc. ASSETS, 2017, pp. 200–209, doi: 10.1145/3132525.3132549.

[14] R. Chang et al., “AccessibleCircuits: Adaptive add-on circuit components for people with blindness or low vision,” in Proc. CHI, 2021, pp. 1–14, doi: 10.1145/3411764.3445690.

[15] T. Kulkarni, G. S. Kim, and A. Mouallem, “A case for improving the accessibility of electrical and computer engineering education,” in Proc. ASSETS, 2023, pp. 1–8, doi: 10.1145/3597638.3614551.

[16] L. M. Jackson, K. McGuire, and L. L. Espinosa, Minority Serving Institutions: America’s Underutilized Resource for Strengthening the STEM Workforce. Washington, DC, USA: Nat. Acad. Press, 2019.

[17] L. Y. Bulk, Being Blind and Belonging in Academia, Ph.D. dissertation, Univ. of British Columbia, Vancouver, BC, Canada, 2020.

[18] S. Zhang et al., “Beadwork bridge,” in Proc. ASSETS, 2024, pp. 1–14, doi:10.1145/3663548.3675623.

[19] A. Bandura, Self-Efficacy: The Exercise of Control. New York, NY, USA: W. H. Freeman, 1997.

[20] R. W. Lent, S. D. Brown, and G. Hackett, “Toward a unifying social cognitive theory of career and academic interest, choice, and performance,” Journal of Vocational Behavior, vol. 45, no. 1, pp. 79–122, 1994, doi: 10.1006/jvbe.1994.1027.

[21] C. L. Bennett and D. K. Rosner, “The promise of empathy: Design, disability, and knowing the ‘other,’” in Proc. CHI, 2019, pp. 1–13, doi: 10.1145/3290605.3300528.

[22] O. Labattaglia, Accessible Co-Design, M.S. thesis, Auckland Univ. of Technology, Auckland, New Zealand, 2019.

[23] J. Seo and G. T. Richard, “SCAFFOLDing all abilities into makerspaces,” Inf. Learn. Sci., vol. 122, no. 11/12, pp. 795–815, 2021.

[24] M. Estrada, P. R. Hernandez, and P. W. Schultz, “A longitudinal study of how quality mentorship and research experience integrate underrepresented minorities into STEM careers,” CBE—Life Sci. Educ., vol. 17, no. 1, ar9, 2018, doi: 10.1187/cbe.17-04-0066.

[25] Interaction Design Foundation, “5 Whys.” [Online]. Available: https://www.interaction-design.org/literature/topics/5-whys

[26] K. Charmaz, “The grounded theory method: An explication and interpretation,” in Contemporary Field Research, 1983, pp. 109–126.

[27] A. Strauss and J. Corbin, “Grounded theory methodology,” in Handbook of Qualitative Research, 1994.