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Building Science Identity Through Mentorship Vision Boards

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Building Science Identity Through Mentorship Vision Boards

Abstract
This qualitative study describes a novel intervention designed to build science identity in first-year civil engineering students. Science identity is associated with resilience and perseverance in STEM fields, yet practical teaching activities that support science identity are lacking in university classrooms. To address this need, we created a mentorship vision board (MVB) activity that prompted students to locate real people and projects that reflected facets of their identity, values, and interests. Student reflections on their MVBs were analyzed to identify salient themes about how the activity affected their science identity. Findings indicate that students reported greater clarity about who they wanted to be as engineers. By inviting first-year engineering students to see themselves as "engineering people," the MVB holds the potential to affirm their belonging as students, as professionals, and as future engineers serving their communities.

Cette étude qualitative décrit une nouvelle intervention conçue pour développer l'identité scientifique chez les étudiants et les étudiantes de première année en génie civil. L'identité scientifique est associée à la résilience et à la persévérance dans les domaines des STEM, mais les activités d'enseignement pratiques qui soutiennent l'identité scientifique font défaut dans les salles de classe universitaires. Pour répondre à ce besoin, nous avons créé une activité de tableau de vision du mentorat qui a incité les étudiants et les étudiantes à localiser des personnes et des projets réels qui reflètent des facettes de leur identité, de leurs valeurs et de leurs intérêts. Les réflexions des étudiants et des étudiantes sur leur tableau de vision du mentorat ont été analysées afin d'identifier les thèmes saillants sur la façon dont l'activité a affecté leur identité scientifique. Les résultats indiquent que les étudiants et les étudiantes ont indiqué plus clairement qui ils voulaient être en tant qu'ingénieurs. En invitant les étudiants et les étudiantes de première année en ingénierie à se considérer comme des « ingénieurs », le tableau de vision du mentorat a le potentiel d'affirmer leur appartenance en tant qu'étudiants/étudiantes, en tant que professionnels/professionnelles et en tant que futurs/futures ingénieurs au service de leurs communautés.

Keywords
science identity, engineering education, STEM pedagogy, mentorship; identité scientifique, enseignement de l'ingénierie, pédagogie des STEM, mentorat

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To face the world's most pressing and complex problems, a diverse workforce in science, technology, engineering, and math (STEM) is needed for their technical abilities and to steer innovation towards a future that is attentive to ethics, equity, empathy, and social justice. Despite the appeal of relatively secure, high paying, high demand jobs (Fry et al., 2021; Theobald et al., 2020), efforts to diversify STEM fields show patchy, inconsistent progress (National Center for Science and Engineering Statistics [NCSES], 2023). Although women have made gains in some areas such as the health sciences, in math and engineering fields progress has been more muted (Fry et al., 2021). For those from Black, Hispanic, Indigenous, and LGBTQ+ communities, and those that experience multiple, intersecting forms of marginalization, challenges to entering STEM and then persisting remain a concern (Cech & Waidzunasa, 2021; Engineers Canada, n.d.; National Academies of Science, Engineering and Medicine [NASEM], 2023; NCSES, 2023; Okrent & Burke, 2021). Reasons for why underrepresented groups choose not to enter certain STEM fields or leave once they are "in the pipeline" are complex and multifaceted (NASEM, 2023; Morelock, 2017; Wells, 2018); however, there is little doubt that the solutions require centering equity, diversity, inclusion, and anti-racism (EDI-R) at all levels of STEM including education and industry (NASEM, 2023).

In the STEM education literature, *science identity* emerges as a productive theoretical framework to consider underrepresentation in STEM. Buttressed by EDI-R commitments, the framework outlines key dimensions that shape one's sense of being a "science person" and thus persisting in STEM (Carlone & Johnson, 2007). The purpose of science identity research is to ensure science learning is not only meaningful but attentive to how identity is shaped, especially for those who experience oppression and exclusion in their social worlds (Avraamidou, 2020; Morelock, 2017).

Despite widespread agreement that science identity is strongly associated with success in STEM, few practical, course-based interventions for developing science identity are discussed in the literature. Our paper addresses this gap by reporting on a novel intervention: the Mentorship Vision Board (MVB). The MVB is a low-stakes activity that asked first-year engineering students to represent aspects of their identity through images of real engineering people and projects. In this paper, we analyze students' written reflections on their MVB to gauge the impact of the intervention and its potential to build science identity. In what follows, we summarize the literature on science identity as it is integral to our activity's design. In our methodology, we describe the MVB in more depth and outline the process for collecting and analyzing the data. Next, we examine four salient themes in the data and show how those themes relate to science identity. We conclude by discussing how the MVB supports science identity with attention to the sound pedagogy woven into the intervention's design. While EDI-R goals underpin the project, and we highlight the perspectives of underrepresented students in our analysis, our qualitative research design limits our ability to make claims about how the MVB affects specific identity groups.

Science Identity Literature Review

Science identity is a productive concept that helps us understand how one comes to develop their sense of *being* a "science person" and *belonging* to their field (Carlone & Johnson, 2007; Espinosa, 2011; Simpson & Bouhafa, 2020; Trujillo & Tanner, 2014). Researchers point to the following intersecting dimensions that shape one's identity as a "science person" (Carlone & Johnson, 2007; Hazari et al., 2020):

1. *Competence*: One's understanding and knowledge of science material.
2. *Performance*: One's ability to *do* science and demonstrate scientific knowledge.
3. *Recognition*: One's sense of being a "science" person, which is shaped by the symbiotic dynamics of *self*-recognition and the affirming recognition from significant others.
4. *Interest*: One's desire and curiosity for the subject.

While the first two domains are crucial for acquiring the technical skills needed to progress in STEM fields, and certainly a place of emphasis in STEM curriculum, particularly in those first years, the more affective domains of *recognition* and *interest* have salience for underrepresented students who may face greater obstacles in their effort to persist and succeed in STEM (Carlone & Johnson, 2007; Hazari et al., 2020; Meyers et al., 2012). *Interest* is a late addition by Hazari et al. (2020) to the original science identity framework. They define interest as student's desire or curiosity to learn the subject. Intrinsic motivation is cultivated through personal interests and desires including the desire to have a greater impact on society and to help others (McGee et al., 2016; Lakin et al., 2020).

Role models and mentors play an important role in building the *recognition* component of science identity (Estrada et al., 2018). For underrepresented students in particular, quality mentorship has been shown to have an overall positive impact on professional development (Ong et al., 2011) and mentorship within the first year could mitigate attrition rates (Apriceno et al, 2020). Beyond role models—individuals to look up to and emulate—mentors provide guidance and support that, ideally, delivers both emotional and material benefits (Wilson, et al. 2012). Research suggests that underrepresented students value mentors that match on many levels (e.g., values, beliefs, backgrounds, passions, personalities etc.) but also seek out mentors that share their racial/ethnic/gender identities (Atkins et al., 2020; Hernandez et al., 2017; Ong et al., 2011; Schinske et. al., 2016). Mentors who match on identity might be better positioned to support students through experiences of isolation, lack of belonging, and diminished self-efficacy, which are more common among marginalized students (Allen-Ramdial & Campbell, 2014, p. 616).

For our purposes, we have conflated "role model" and "mentor" somewhat to emphasize how both concepts imbricate to support recognition. Moreover, while a mentor is considered the "gold standard," we recognize that most students will not have a mentor in their first year and underrepresented students are less likely to find a mentor that match on identity. Thus, we see role models as a precursor or "first-step" to seeking out mentors in the future.

Strategies to bolster the affective domains of science identity is a growing area of research (Morelock, 2017). Addressing recognition, numerous studies describe formal mentorship programs and research opportunities (Carlone & Johnson, 2007; Estrada et al., 2018; Hazari et al., 2010; Robnett et al., 2018). The vast active learning umbrella (e.g., hands-on learning, project-based learning, and community-based learning) has been shown to develop interest and intrinsic motivation (Al-Hammoud et al., 2022; Asher et al., 2023; Ballen 2017). Lacking in this body of scholarship are flexible, applied assignments instructors can easily integrate in their courses. One exception is Asher et al.'s (2023) "utility-value intervention" in an introductory chemistry course where students wrote three short essays about how the chemistry material was both *personally* and *socially* meaningful. Their findings reveal that students who recognize the utility-value of challenging STEM courses are more likely to persist, which was especially impactful for marginalized students who demonstrate higher rates of attrition.

Another example of an adaptable assignment is "Scientist Spotlights." Over the term, instructors provided students with counter stereotypical profiles that expand "who scientists are and how science is done" (Schinske et al., 2016 p. 3; Metzger et al, 2023; Yonas et al., 2020). Students were then asked to respond to essay prompts about the profile including a prompt about the *relatability* of the scientist spotlighted; the question of relatability is meant to give students the opportunity to see themselves in the scientist being spotlighted. Notably, Aranda et al., (2021) adapted the Science Spotlight assignment by replacing instructor-authored profiles for student-authored ones, which significantly increased student awareness of diversity in science and relatability to scientists. This student-authored distinction, prominent in both Aranda et al.'s intervention and our own, goes beyond simply diversifying representation to give students agency in cultivating recognition and science identity more broadly.

Turning to vision boards specifically, very few studies explore their pedagogical value. For adolescents possessing fewer forms of social and economic capital, vision boards can be a creative tool to "explore their career and identity development and strengthen their self-efficacy in a way that is both intentional and flexible" (Waalkes et al., 2019, p. 206; Conderman & Young, 2021). Where it concerns undergraduate pedagogy, few documented cases of vision boards are found. One example comes from a Hispanic-serving community college that created an initiative to boost academic preparedness in students looking to transfer to a four-year STEM undergraduate degree program. The vision board activity, described in a category of "non-traditional" activities, was one small element in a three-day study skills workshop (Enriquez, et al., 2014; see also Brannis, 2016 and Cheney, 2016). To our knowledge, no studies have used vision boards as a way for students to build science identity.

As Morelock (2017) suggests, there is a notable absence of interventions that "ask students to connect their beliefs, values, or other aspects of identity to engineering" (p. 1255). In his systematic review of engineering identity, Morelock (2017) suggests that interventions are limited because of the assumption that identity will develop organically as students gain experiences in both academic and professional environments; however, this assumption does not fully consider the experiences of underrepresented students who often face distinct and systemic barriers. Even at the critical stage when underrepresented students have joined a post-secondary STEM program, their sense of identity continues to be vulnerable when faced with environments that are hostile, overly competitive, unwelcoming, or simply lacking in community supports and role models (Beasley & Fischer, 2012; Brown et al., 2015; Funk & Parker, 2018; Haverkamp et al., 2019).

As shown, the scholarship on science identity grounds the MVB in important ways. Our goal was to design an intervention that fosters students' recognition, interest, and belonging. On a practical note, we required an intervention that would be easy to integrate in a variety of undergraduate STEM courses. This was particularly relevant for the first author who routinely taught undergraduate communication courses for various STEM units. Their role prompted the need to create an impactful assignment that could fit seamlessly within existing course design and outcomes.

Methodology

The MVB was implemented in a required communication course for first-year civil engineering students at a Canadian university. A key objective of this course is to prepare students to communicate effectively when they are placed in professional environments during their co-op terms, which takes place in the first year of their engineering program. Data was collected in 2021 from three sections of the course taught by the same instructor (first author); the course was asynchronous and fully online. Out of 75 students, 51 agreed to participate in this research.

Our study received approval from the Office of Research Ethics. To minimize bias, the second author, a graduate research assistant (RA) hired through a grant and who was not a member of the teaching team, served as an intermediary to contact students and obtain their consent to share their MVB assignment for research purposes. Students were informed that their participation would not affect their grades; students were incentivized to complete the consent form and regardless of whether they consented, their names could be entered into a draw for a gift card. See Appendix A for a copy of the consent form.

Description of the MVB Assignment

The MVB was designed as a lightly graded low-stakes assignment, allowing students to engage in the spirit of the activity instead of being preoccupied with the "right" answer that would achieve a particular grade. The MVB had two parts. First, the vision board itself, a collage-type digital poster with images of inspiring engineering people and projects. Second, the written reflection on the vision board that discussed the images chosen and what they meant to the student. The latter is the focus of this paper. The activity guidelines provided to students can be found in Appendix B.

When constructing their MVB, students were prompted to draw on inspiring people and projects that spoke to their values. Importantly, these ideas were scaffolded into the course in various ways. For example, early in the course, students were asked to research what engineers said about communication in the field and share what they found on a discussion board; they were encouraged to talk to engineers they knew but were also given suggestions for other ways to find this information (e.g., Reddit's r/AskEngineers, a company blog). Later in the course, students were asked to write an e-mail to a real engineer that inspired them. Their major writing project, a research report, evolved from brainstorming topics related to the student's values and how those values were demonstrated in current engineering projects. By the time the MVB was introduced, towards the end of the term, students had some familiarity with ideas around values, identity, social impacts, and inspiring people and projects.

Thematic Analysis

This study engaged in a thematic analysis (TA) to identify patterns of meaning in the data (Braun & Clarke, 2006; Clarke & Braun, 2017; Joy et al., 2023). TA is a widely used, theoretically informed, approach to analyzing qualitative research systematically; it allows for an organic, iterative approach to code and theme development (Clarke & Braun, 2017). Importantly, employing a TA allows the researcher to *tell a story* about the themes and why they matter (Joy et al. 2023).

Both authors performed independent, close readings of the reflections, noting the words, phrases and topics that surfaced frequently so that they had a full understanding of the data and emerging patterns. The authors met several times to generate and refine inductive and deductive codes that would help meaningfully organize the data. These codes were as follows: *vision, goals, interest, social impacts,* and *role models/mentors.* The second author imported students' written reflections into NVIVO and manually coded 12 reflections. Using manually coded papers as a reference, the remaining reflections were automatically coded to predefined nodes. This step accelerated the coding process of the aggregated data in NVIVO while maintaining consistency with the initial criteria. The authors continued their iterative and collaborative process to establish the final themes, which are discussed next. Note that because we are analyzing reflections written by engineering students, at times we will refer to "engineering identity" instead of the broader category of "science identity."

Students' Reflections on the MVB

> "In order to complete this vision board I really had to think about what I wanted to do and who I wanted to be as an engineer."

In this section, we report on our findings by discussing excerpts from students' written reflections. The passages selected capture one of four salient themes in the data: Looking Back and Looking Forward; Exposure to the Field of Engineering; A Mixed Picture of Role Models; and Uncertainly Transformed. These themes reveal the ways in which students forged a pathway to their future professional selves.

Looking Back and Looking Forwards

The act of *looking back* emerged as a powerful lens through which to imagine future selves. Many students recalled memories from childhood as they wove together a narrative about who they wanted to be as future engineers. One student wrote: "while working on it [MVB], I really felt like I was drawn back into my passion of roller coasters… thank you for giving me the opportunity to look back on the past and fall in love with roller coasters once again." Here is another example where the student began with vivid memories of road infrastructure in Uganda:

> My first trip to Entebbe was when I was six months old. Since then, I've frequently gone back and forth between Kampala and Entebbe. As a child, I loved being in Entebbe which was peaceful compared to Kampala. What I didn't appreciate was the journey to get there. The roads we used were so bumpy and the journey didn't take less than two hours.

She went on to recount her memory of the Kampala-Entebbe expressway opening in 2018, describing it as "highly efficient" and "beautiful." Further in the reflection, she linked the activities she was participating in as a first-year engineering student (e.g., steel bridge design team, Women in Engineering group) as an investment in her long-term goal of bringing her engineering skills to her home country. Remarkably, we see the past, present, and future self thoughtfully intertwined in this reflection.

A feature of students' reflections that stood out was the concreteness, often an outcome of personal narratives. One student wrote at length about specific monuments in Cambodia, her home country, emphasizing how they documented the country's colonial history and fight for independence from French occupation, but also how they functioned to strengthen community and bolster tourism. Her understanding of social impacts, which can feel like a nebulous concept for many first-year students, now had meaning tied to her community: "I had never given too much thought to the impact of those buildings and structures when I was living back at home; however, this [MVB] project gave me a chance to reflect on the impact of those buildings." It is important to note here that for many international students, a vision of their future selves included engineering work in their home countries—Jamaica, Vietnam, Pakistan, India, Cambodia, and Uganda to name a few.

Another illustration of the sophisticated ways students found meaning across time, identity, and geography, can be seen in this next student who wrote about how she had always been passionate about law but when it came to deciding on a major in high school, engineering was also an option. A guidance councillor had helped her recognize that both careers, motivated by the student's passion for social justice, were achievable. In this section of her reflection, the student draws on her cultural background to describe the kind of work she saw herself doing:

> My background is Indian, and I was born and partially raised in India! I hate to say this, but in India, there is a lot of corruption that goes on and it affects people who have done absolutely nothing…I want to be able to help those who are affected by poor construction and be able to provide for them. After witnessing buildings collapsing and the builders living in perfect peace, it made me want to do something about it…If a civil engineer, who knows all the concepts and principles of building sciences, is on the case, it limits any chance of lies being spread, and a good sense of justice can most definitely overcome greed and corruption.

Although the student's full reflection suggests that the connection between law, engineering, and social justice had animated her thinking for some time, the MVB provided an opportunity to remember, reinforce, and crystalize her values and vision.

Exposure to the Field of Engineering

For many students, the MVB was an opportunity to gain a more expansive understanding of the field of engineering. One student wrote: "Before this assignment, I had no idea of any engineering firms that focus on the social impacts of engineering and helping people." Students reported enjoying the research process for the MVB, presumably because the research was informal and propelled by the *student's* interests (note that research was not a requirement for this assignment). This next student describes how the research process increased her awareness of the options she had as a civil engineer:

> Through my research, I was able to learn more about the Professional Engineering license as well as possible specializations I could take. Initially, I knew the main streams in civil engineering were structural and transportation. However, as I looked further into my research, I became more interested in water resources as well. While I was looking into the Global Engineering Brigade, I found that their organization helps to improve water quality and access to those in developing countries.

Along the same lines, this student wrote:

> At first, I knew I wanted to be a civil engineer, I wasn't sure in what region or subcategory would I prefer, actually I did not even know there was much beyond the structural aspect of civil engineering. I did not know there was environmental, geological, water ways, transportation as separate sub categories of civil engineering. This project helped me realize that even those these subcategories of civil engineering do exist, structural is what type of engineer I would like to become.

Many students engaged in self-directed research to learn more about a particular project or professional organization, which in turn sparked curiosity and interest, exposing them to career pathways in civil engineering that they were previously unaware of.

A Mixed Picture of Role Models

Prior to this assignment, students admitted to having thought little about mentors and role models in engineering, although some students mentioned experiences in other contexts such as sports. When asked to identify mentors and role models that inspired them and spoke to their values, goals, and identities, many students first thought of family. One student wrote a long paragraph listing the many impressive accomplishments of an engineer she knew, only to reveal at the end that this person was her mother. Here is another example:

> The most obvious choice for my mentor was my uncle. I was able to tour various construction sites back in Cambodia which sparked my interest in construction and structures. I was able to witness what his work could not only do for our family, but for Cambodia as a country.

Reflecting on mentors and role models required students to think more deeply about the characteristics of an engineer they valued. One student had always believed that engineers were “rigid and serious” types but when prompted by the assignment, she reflected on her favourite engineering professor who smiled and joked a lot. This role model—a real engineer within her local community—presented a new way to think of who she wanted to be, a “successful and funny engineer.”

For women, especially women of colour, finding engineers who reflected there racial/ethnic background was valuable. This student writes:

> [Name], in particular, is an inspiration to me because of her South Asian background because I can see a part of me in her and feel like I can see myself as part of the engineering community because of the representation she brings.

Not all students had role models they could identify with. One student who disclosed being gay wrote about how he lacked role models/mentors who could relate to his struggles. “I have a fear that my career may be impacted by my sexuality,” he wrote, going on to conclude:

> Overall though, I do not see many mentors which share my struggles. However, I am ready to be my own mentor in a way, instead being inspired by the people who will come after me that I can help. In other words, I am inspired by creating a better workplace for the people who come after me. This is my inspiration that will overcome my fears about my future in the workplace.

For this student, the absence of mentors that reflect an important part of his identity—his sexuality—created an opportunity to build a community and culture that he does not yet see in the field of engineering.

Uncertainty Transformed

Many students began their MVB with some uncertainty. They admitted giving little thought to their values, role models/mentors, communities, or the social impacts of their work. Opening sentences often read something like these examples:

> When I was first working on the vision board, I only had a very vague idea of what I wanted my future as an engineer to look like.
>
> Before going into this assignment, I did not have an idea of who I would consider an inspiration to me in the engineering field, much less who would make a good mentor."
>
> Prior to the first term of university, I wasn't connected with engineering communities or with the engineering field.

These statements highlight the subtle gaps in engineering identity that accompany many first-year students. Other students began with outright resistance:

> At first, when I saw the Mentorship Board assignment, I thought to myself, "how is finding a fake mentor supposed to motivate and guide me through my education and career path". I did not know of any famous successful engineers. I had convinced myself that there was no way this project could make a difference and I just wanted to get it over with. However, this was where I was wrong. The first couple weeks of working on the project off and on I struggled. I couldn't find anything useful, and I did not know where to start. After a while, I thought to myself, "what are some of the things that I care about?", "what was it in my life that caused me to believe that?". That is when the ideas started coming in.

Although this student was unusually frank, the turnaround she describes was echoed by many other students. Through the MVB assignment, we see reluctance give way to an engineering identity that is more clear-eyed and confident. As students reflected on the activity, many appreciated the space to think about their goals.

> I am glad to have a tangible goal to work for, that will motivate me throughout my undergraduate studies. The reason I needed one solid goal to think about so badly was because in the beginning, I didn't really know where I wanted to go with my life and career, which scared me a lot. Now, I feel that I have something to keep me grounded and even if I end up doing something completely different with my degree, I know that whatever I do will have something to do with sustainable living.

For some students, the creative aspect of the MVB is what they appreciated the most.

> This assignment was one of my favourite parts of the course. As a naturally creative, artistic person, I thoroughly enjoy anything to do with designing, colour working, and aesthetic mapping. It was a great break from formally writing, and an awesome opportunity to organize my thoughts and imagine myself in the field of engineering.

The largely positive, even transformative, experiences students convey suggest that the remembering, the reflecting, and the creating inherent in MVB helped fortify a picture of who they wanted to be as future engineers, a picture that was poorly developed at the start of the course.

Discussion

Our aim in creating the MVB assignment was to provide students with an impactful yet low-stakes intervention that developed their engineering identity. This study set out to understand the impact of the MVB by analyzing student reflections and the emerging themes. Our findings suggest that students were able to cultivate a more concrete and refined engineering identity, especially where it concerned *recognition* and *interest*.

The most prominent theme, "Looking Back and Looking Forward," brought to light how the past—whether the forgotten love of rollercoasters, a childhood memory of a trip, or the history of a building—can be accessed to bolster engineering identity and self-efficacy. For international students especially, looking back was a connection to their home country, a future where their skills could be used to address infrastructure concerns in that country and possibly the genesis of a *global* engineering identity. Significantly, the MVB gave students an opportunity to remember, reinforce and reflect, a process that benefits a range of students including students who had forgotten why they were drawn to civil engineering, students who were not quite sure, and students who had always known but appreciated the reminder. Finally, this theme revealed a sophistication in how students were able to navigate aspects of their histories, passions, values, and identities to shape a portrait of a future self.

The second theme, "Exposure to the Field of Engineering," demonstrated that students gained more awareness about civil engineering after completing the MVB. This knowledge was sometimes expressed in general terms (e.g., engineering companies care about the social impacts of their work) but also had a practical dimension. For example, students learned more about the Professional Engineering license and specializations in civil engineering, information that they would have typically be exposed to later in their academic careers. The self-directed nature of the research meant the research process was more enjoyable and relevant.

The third theme, "a mixed picture of role models," showed that students were unprepared to identify role models and mentors. Notably, this theme reflects an *a priori* coding process whereas the other themes came about more organically, further evidence of students struggling to find something concrete to say. We had hoped that prompting students to think about role models would be a "first step" in seeking out a mentor, but this is unlikely given that no student expressed a desire for a role model or mentor in the future.

Although this absence was disappointing, we see this as an opportunity to provide better scaffolding and resources, and facilitate more conversations, around mentorship, role models, and identity-affirming spaces. The fact that students often defaulted to family opens an avenue for accessing role models and mentors within their own communities, presenting a support system that students might not be fully aware of. Research shows that family role models are associated with success in STEM. In their review of scholarship on the experiences of women of color in STEM, Ong et al. (2011) write that "family and community support is perhaps the most salient and influential factor that women of color identify as encouraging to their completion of a STEM degree" (p. 186). Other research has found that "engineering persisters", unlike "engineering switchers" are more likely to have an engineer in the family, constituting a meaningful engineering experience (Pierrakos, et al., 2009). Although engineers in the family have likely functioned as informal mentors and role models, *fixing* their influence through the MVB has the potential to shape the student's engineering community in more tangible ways.

The final theme, "Uncertainty Transformed," captured students' overall experience with the MVB. Students began the activity skeptical of its value but by the end, expressed a clearer sense of what had guided them to the field of engineering and how their values, passions and identities were reflected in the field. For some students, the creative process was a refreshing aspect of this activity.

Overall, the findings suggest the MVB is a meaningful intervention that builds science identity through identification and reflection. In their narratives, students navigated the complexity and messiness of identity—across geographies; across familial relationships; across gender, race, and sexuality—connecting their personal selves to their professional selves with an impressive degree of clarity, concreteness, and elegance. The MVB encourages students' engineering identity by attending to the *self*-recognition component of recognition (versus the recognition *by significant others* component, as discussed by Carlone and Johnson). Students take an active role in carving out a material and conceptual space in engineering that reflects who they are, on their terms.

The MVB cultivates *interest* in engineering by expanding students' understanding of who engineers are and what they do. When students in highly technical fields like math, computer science, and engineering see how their work impacts people groups, communities, and society, their interest and connection to their field grows (Lakin et al., 2020). Through researching engineering through the lens of personal values, we see a (re)igniting of student's passion for engineering.

MVB as Good Pedagogy

Interventions that draw on the lived experiences of students and emphasize social impacts can improve students' science identity (Godwin, 2016). Lakin et al., (2020) assert that interventions should provide "multiple entry points" for students to think about their values, whether altruistic or individualistic, and how those values are reflected in the field of engineering (p. 228). By prompting students to reflect on their histories, identities, and values as they relate to the field of engineering and their future careers, the MVB answers the call for "new ways for educators to recognize students in the classroom" (Lakin, 2020, p. 330).

Importantly, the MVB invites reflective writing in technical fields. For the many students who might struggle through university-level math and physics, and need a reason to persevere, it is crucial that they connect with the *who* and *why* of engineering. The *Who am I* question, which underpins reflective writing, is a way for students to tap into the "non-technical, ethical, reflective aspects of the field so important to diversity in engineering and future engineering endeavors that acknowledge engagement with wider context" (Badenhorst, 2020, p.12). According to Sakellariou (2013), reflexivity for engineers is about showing awareness of, and taking responsibility for, the social dimensions of engineering such as social justice and community-led concerns, as well as the multidisciplinary and interdisciplinary approaches to solving complex social problems (p. 26). Arguably, the MVB provides first-year students the opportunity to practice reflexivity within the boundaries of a low-stakes, creative activity, thus building connections between the "more technical aspects of their work with a more socially aware professional identity as it expands their notions of what it is to be an engineer" (Badenhorst, 2020, p.12).

Although the MVP was not intentionally designed as an arts-based project, arts-based pedagogy (ABP) is evident. ABP emphasizes student-centered art processes (i.e., creating, responding, or performing) to achieve learning (Kraehe & Brown, 2011; Rieger et al., 2016) and has been shown to encourage self-transformation and critical awareness about social impacts and social justice (Kraehe & Brown, 2011). Moreover, in recent years, there has been an effort to bring more arts-based knowledge to STEM fields, reflected in the acronym STEAM (Science, Technology, Engineering, Arts, and Math) (Valk, 2022). Collage-type activities, like vision boards, have been shown to build cognitive-emotional outcomes through its emphasis on images, visual thinking, and reflexivity (Komarova et al., 2022, p. 308). In programs such as engineering, the creative and emotional dimensions of collage-work allow for pathways that develop soft skills, which are seen as increasingly valuable in technical fields (Komarova et al., 2022).

Our research does not untangle whether it is the process of creating a vision board or the process of reflection that supports science identity. We reason that *both* components are integral to the success of the intervention and, as discussed above, provide diverse pedagogical value. The act of obtaining an image of a real engineering person or project gives students something concrete to reflect on and often generated self-directed research. Moreover, some students responded positively to the creative aspect of the assignment. We speculate that a written reflection, without the vision board, would register as another writing task in a course replete with writing assessments, thus diminishing the novelty of the MVB.

The MVB contributes to enhancing the relatively small number of science identity interventions documented in the literature (Morelock, 2017), particularly those that focus on the domains of recognition and interest (Aranda et al., 20021; Asher et al., 2023). While the MVB was piloted in a first-year communication course for civil engineering students, versions of the activity subsequently ran in communication courses for computer science and life science students, which were not exclusively for first years. We believe the MVB is suitable for a range of STEM courses, including those in the hard sciences, and is flexible enough to support learning outcomes that speak to areas such as professionalization, social impacts, ethics, and EDI-R, just to name a few.

Finally, this qualitative study could be enhanced by quantitative approaches which could provide a more granular picture of which demographic groups benefited most from the MVB and in what areas. As undergraduate STEM programs prepare to recruit and welcome more diverse students, the kinds of experiences they have in university, in their programs, and in the classroom will shape their success.

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Appendix A
Consent Form to Access Students' Assignments (Online Form)

By providing your consent, you are not waiving your legal rights or releasing the investigator(s) or involved institution(s) from their legal and professional responsibilities.

Title of the study: "We all belong here": Building Science Identity Among First-Year Engineering Students

Research Team:

Principle Investigator: Rania Al-Hammoud
Principle Investigator: Andrea Jonahs
Graduate Research Assistant (GRA): Adama Olumo

I have read the information about the study presented in the Information Letter.

I have had the opportunity to ask questions related to the study and have received satisfactory answers to my questions and any additional details. If not, I know I can contact any member of the research team if I have questions.

I understand that participation in the study is voluntary and that I can withdraw this consent at any time up until March 2022 by informing any member of the research team.

I understand that my decision to participate in this study will not affect my grades in any way.

I understand that my name, as well as any identifying information, will not be shared with anyone outside of the research team. I understand that any use of quotations and/or images from my vision board will be done with explicit consent and will be for the purposes of illustrating salient themes; I understand that the research team will take care not to reveal any identifying information if they reference my work.

I understand that I may choose to enter my name into a draw for 1 of 10 $20 e-gift cards to the WStore. (Please note that if you decide to end your participation early, just click through to the end of the survey to still be entered into the draw.)

Please enter your student ID here

With full knowledge of this project, I agree, of my own free will, to participate in this study by sharing the following information (please check the boxes that you consent to):

For students enrolled in [course code redacted]

☐ I agree to share the following activities and assignments completed in [course code redacted]:

-start-of-term & end-of-term surveys on engineering identity
-community project proposal
-written reflection assignments

For students enrolled in [course code redacted]

☐ I agree to share the following activities and assignments completed in [course code redacted]:

- mentorship vision board including use of images from the vision board
- contribution to discussion boards
- written reflections

Use of anonymous quotations

☐ I agree to the use of anonymous quotations from my coursework in any paper or publication resulting from this study.

Focus Group Opportunity

We would like to invite women and racialized students to participate in focus groups. If you meet these criteria, would you like to be contacted with further information about the focus groups?"

☐ Yes
☐ No

Draw

In appreciation for your participation, you may choose to enter your name into a draw for 1 of 10 $20 gift cards to the WStore.

Please enter your name for the Draw

First **Last name**

☐ Yes, please enter my name in the draw

This study has been reviewed and received ethics clearance through a University of Waterloo Research Ethics Board REB #43426**.** If you have questions for the Board contact the Office of Research Ethics, at 1-519-888-4567 ext. 36005 or reb@uwaterloo.ca.
For all other questions contact any member of the research team.

Appendix B
Mentorship Vision Board Assignment Guidelines

Introduction

In this low-stakes assignment you will create a mentorship vision board (MVB). A vision board is simply a visual expression of who you are, what inspires and motivates you, and what you want to be or accomplish in the future. It's a way to imagine a future version of yourself.

The purpose of this activity is to help you see yourself as part of your engineering community and imagine how you might contribute to the field of engineering. Laying out your vision can build your confidence as a communicator and a professional in your field. By the end of this assignment, you should be able to:

- Identify personal values and goals that intersect with your profession.
- Identify real engineering people and projects in your field who you find motivating and inspiring.
- Expand your understanding of who an "engineer person" is (e.g., what they look like, what they do, what they care about).

Getting Started

To get started, reflect on some of these Big Questions:

- What kind of impact do I want to have on my community as a professional?
- What can I do in my field to make the world a better place?
- What personal values do I bring to the field?
- Where can I find professionals in my field that reflect aspects of my identity that are important to me?
- What are some cool projects that engineers in my field are working on that reflect the things I care about?
- What is it about_____professional that I find inspiring or motivating?
- What do I want from a mentor?
- What are some areas I need to build my confidence in? How might a mentor help in these areas?

What should I include in my MVB?

Your vision board adhere to the following broad guidelines:

- Images of real professionals in your field that inspire and motivate you. You want people who are accessible—think about someone you could e-mail or DM and likely receive a reply (so you wouldn't include Ada Lovelace, Nikola Tesla or Elon Musk).
- Images of real projects/research that speak to your goals and values.
- Images that convey something about who you are and what you want to accomplish in your field.

Apart from these guidelines, there is no "right" answer—be as creative as you want! Here are some ideas of where you can find inspiration:

- Professionals on social media.
- Professional organizations/societies that you find interesting. (e.g., ASCE, IEEE, Engineers Canada, Society of Women Engineers, National Society of Black Engineers)
- Clippings/screenshots from newspapers, magazines, blogs, or social media
- Headings, captions, quotes, or other motivational text. Just remember to keep text to a minimum!

Since your vision board is digital, you can make it more interactive by including hyperlinks, memes, video clips, and other types of media. Avoid clip art, stock images or other types of generic visuals. You may use any software you feel comfortable with as long as you can share your vision board electronically. Here are some options:

- PowerPoint/Google slides
- Canva
- Pinterest
- Notion
- Adobe Photoshop/InDesign, CorelDraw

Reflect on your MVB

In your written reflection, we are looking for the following:

- an explanation or "walk through" of your MVB
- insight into why you chose the images you did, why they were meaningful, how they spoke to your goals/values/identity etc.
- insight into how the activity might have changed your thinking about mentorship and/or who you want to be as an engineering professional (if nothing changed, you can say that).

Min. 500 words.

MVB Rubric

CRITERIA	POINTS
MVB -visuals show variety and diversity (min. 6 images) -visuals are of real people/projects related to civil engineering -conveys values and social impacts in engineering -captions/text provide necessary context for visuals -text is used purposefully and kept to a minimum	8
Creativity -MVB is visually pleasing, interesting, and attractive -demonstrates time, care, effort, and creativity -avoids generic images	2
Reflection -meets above criteria -writing is clear and concrete -writing has been proofread carefully	10