A Review of Agentic Frameworks in Engineering Education

Ms. Brianna Shani Benedict, Purdue University

Brianna Benedict is a Graduate Research Assistant in the School of Engineering Education at Purdue University. She completed her Bachelor's and Master's of Science in Industrial and Systems Engineering at North Carolina Agricultural & Technical State University. Her research interest focuses on interdisciplinary students' identity development, belongingness in engineering, and agency.

Mrs. Kayla R. Maxey, Purdue University-Main Campus, West Lafayette (College of Engineering)

Kayla is a doctoral student in the School of Engineering Education at Purdue University. Her research focuses on creating and sustain a culture of inclusion in engineering. She investigates the the cultural ideologies produced and reinforced by engineering education structures (e.g. departments, courses, policies) to determine the influence on initiatives to recruit, retain, and support diverse students. Her current work explores the cultural productions of institutional leadership to develop improve departmental and institutional climates.

Ms. Dina Verdín, Purdue University at West Lafayette

Dina Verdín, PhD is an Assistant Professor of Engineering in the Polytechnic School of the Ira A. Fulton Schools of Engineering at Arizona State University. She graduated from San José State University with a BS in Industrial Systems Engineering and from Purdue University with an MS in Industrial Engineering and PhD in Engineering Education. Dina is a 2016 recipient of the National Science Foundation's Graduate Research Fellowship and an Honorable Mention for the Ford Foundation Fellowship Program. Her research interest focuses on changing the deficit base perspective of first-generation college students by providing asset-based approaches to understanding this population. Dina is interested in understanding how first-generation college students author their identities as engineers and negotiate their multiple identities in the current culture of engineering. Dina has won several awards including the 2018 ASEE/IEEE Frontiers in Education Conference Best Diversity Paper Award, 2019 College of Engineering Outstanding Graduate Student Research Award and the Alliance for Graduate Education and the Professoriate (AGEP) Distinguished Scholar Award. Dina's dissertation proposal was selected as part of the top 3 in the 2018 American Educational Research Association (AERA) Division D In-Progress Research Gala.

Dr. Allison Godwin, Purdue University at West Lafayette

Allison Godwin, Ph.D. is an Assistant Professor of Engineering Education at Purdue University. Her research focuses what factors influence diverse students to choose engineering and stay in engineering through their careers and how different experiences within the practice and culture of engineering foster or hinder belongingness and identity development. Dr. Godwin graduated from Clemson University with a B.S. in Chemical Engineering and Ph.D. in Engineering and Science Education. Her research earned her a National Science Foundation CAREER Award focused on characterizing latent diversity, which includes diverse attitudes, mindsets, and approaches to learning, to understand engineering students' identity development. She has won several awards for her research including the 2016 American Society of Engineering Education Educational Research and Methods Division Best Paper Award and the 2018 Benjamin J. Dasher Best Paper Award for the IEEE Frontiers in Education Conference. She has also been recognized for the synergy of research and teaching as an invited participant of the 2016 National Academy of Engineering Frontiers of Engineering Education Symposium and the Purdue University 2018 recipient of School of Engineering Education Award for Excellence in Undergraduate Teaching and the 2018 College of Engineering Exceptional Early Career Teaching Award.

A Review of Agentic Frameworks in Engineering Education

Abstract

This theory paper focuses on how agency is framed and used in engineering education concerning faculty and students. There is a diverse landscape of how agency has been defined and studied in social science, which presents challenges in understanding the breadth of how agency has been defined and studied in higher education. As a result, this narrative review highlights possible uses of agency as a framework to examine innovation in engineering education across multiple levels of the educational system. Furthermore, this paper supports the importance of agency in facilitating diverse pathways into engineering, promoting a liberal approach to engineering education, and supporting individual diversity as a way to potentially shift dominant mindsets, cultures, and structures that disrupt the ability to make change in engineering education.

Introduction

A recent editorial discussed the need for a third Morrill Act for the 21st century to provide guidelines for increasing pathways into STEM education. The editorial highlighted the role engineering education may play in addressing issues of access and engagement, reasserted the value of STEM literacy integrated with liberal arts, and emphasized the need for universities to be prepared to support diverse learners [1]. Unfortunately, the solicitations advocated in this report mirror requests made for at least two decades for undergraduate engineering education. This gradual sense of change demonstrates how transforming engineering education from a local and systemic perspective is indeed difficult [2].

However, despite the difficulty and perceived resistance to change, this call for innovation in higher education highlights the critical need for change agents—individuals within academia and outside of it willing to enact a transformation in STEM education at the curricular, institutional, and national levels. A core piece of ensuring a change in educational systems is the ability of these agents to exercise their agency (i.e., free will or choice to act). However, the dominant norms in higher education can limit opportunities for students, faculty members, or higher education administrators to enact their agency [3], [4]. A deeper understanding of how agency is defined and used in this context for research and policy changes can provide useful ways of catalyzing change in engineering education.

Agency is an emerging theory within engineering education; however, historically, it has a deep lineage and debate among the social sciences. Researchers have investigated various perspectives of agency through multiple lenses such as the structure agency dialectic prioritized by sociologists, which is often rejected by psychologists who support the idea of personal agency where individuals influence their actions [5], [6]. Often, anthropologists straddle the line between an individualized and dialectic conceptualization of agency [7]. These fundamental understandings of agency have been extended into research areas in STEM education to understand student learning, engagement, equitable learning experiences, and critical agency [8]. Only recently have engineering education researchers begun to explore the ways agency may situate and expand our understanding of student and faculty agency to understand change in the classroom, curriculum, pathways into and throughout engineering, and systemically throughout engineering education.

This narrative review provides a starting point for researchers who are interested in studies focused on agency in engineering education, to date. We intend for this paper to be used as a tool for understanding the current perspectives and methodologies used to examine student and faculty agency in engineering. Including an initial conversation concerning how the engineering education community can consider how agentic frameworks can be leveraged or extended to investigate change in engineering education. To begin, we briefly present a few fundamental definitions of agency. The following sections comprise a synthesis of existing perspectives of agency in engineering education and a discussion of how agency can provide breakthroughs in engineering education.

Definitions of Agency

At a surface level, agency can be understood through associated terms such as will, purposiveness, intentionality, choice, initiative, freedom, and creativity [9]. Agency is the exercise or manifestation of an individual's capacity to act [10]. This construct is presumed to be present in all fundamental human actions; that is, every individual (actor) possess agentic (or internal behaviors) capabilities and can exercise these capabilities at any time. Agency is thought to be "the ability to exert influence on one's life" [11, p. 38]. Anthony Giddens [12] stated that agency, while encompassing an individuals' intention, also involves the individuals' capability of acting on an intention and producing consequences (or change) from their actions [p. 9]. From a psychological perspective, agency is "people's beliefs about their capabilities to exercise control over events that affect their lives" [5, p. 1175], and agentic actions involve "exploring, manipulating, and influencing the environment" [13, p. 4]. Individuals possess varying degrees of capabilities, and in turn, they possess different perceptions of agentic potential. Present in all these definitions is the idea that agency is individual behavior and behavior through interaction between the self and society.

An individual's agency has been theorized and used in studies in fields such as anthropology [14], psychology [6], [15], life course studies [11], [16], and the social sciences [12], [17]. In the realm of STEM education research, where our narrative review focuses, agency has been prominent among scholars concerned with issues of equity and social justice in-and-out of the classroom setting, specifically in science education [8], mathematics education [18], and engineering education [19], [20]. Below, we provide an in-depth account of studies concerning student and faculty agency in engineering education.

STEM Education Agentic Frameworks

Multiple definitions of agency proposed in engineering education research based upon the traditions from which researchers have framed their studies. We identified twelve studies using search terms such as "agency" and "engineering education" in available databases (Education Resources Information Center, Education, and Education Full Text) and ASEE PEER document repository. Most studies discussed are in the context of the United States; however, two studies are within a South African context, and one is in a Norwegian context. Studies focused on K-12 engineering education, and early career engineers were excluded based on the scope of this paper to synthesize the literature for undergraduate engineering education. We also found that these

studies used both qualitative and quantitative research methods. Once we identified studies that used agency as central to their studies, we examined how agency was used to study undergraduate engineering education.

We identified three themes among study outcomes: student learning, persistence, and positioning. Below, we organize our review by these themes to illustrate the range of applications of agential frameworks in examining how students may feel empowered or constrained to enact agency in engineering education. We discuss how agency has been defined in each study, what the findings of each study show, and how these findings may fit within a broader characterization of change initiated by students in engineering education.

Student Learning

Scholars in science education have framed "learning as agency" from a critical perspective to understand how students engage in science learning, and how students use their knowledge to transform their communities and world at large perception of their ability to change their world through everyday actions as well as his/her broader goals in life [42]. Later, we discuss how students are positioned and position themselves influences how students learn, navigate engineering, and develop their identities as engineers. However, in this section, we focus on how agency is useful for assessing how agency enhances engineering learning as an outcome.

The studies focusing on student learning were grounded in sociology and varied in methodological approaches [21]–[23]. Drawing on an analytic framework for empowerment, Svihla and colleagues [21] defined *agency* as the "autonomy to make decisions," concerning students' learning how to enact their agency when engaging in problem scoping and solving [p. 2]. In addition to agency, this work draws on the idea of opportunity structures, which may constrain an individual from enacting agency (i.e., purposeful choices) to result in a desired or unintended outcome. Similarly, Gynnild [22] drew directly from Gidden's structuration theory to examine change in engineering education, specifically concerning enhancing teaching and learning. The structuration theory suggests there is a relationship between human agency and structures, where structures constrain individuals as well as enable individuals to influence social practices.

In contrast, Case's study [23] was based on Archer's morphogenetic theory, which differs slightly from Gidden's theory by collapsing structure into two dimensions, structure and culture, when examining agency. Structure is defined as the goods, social positions, and roles in society, while culture is defined as the ideas and beliefs in engineering and science. Agency is defined as human action and interaction. This conceptualization of agency was used to understand how students' agency changed over time to enable them to "leave higher education with different knowledge and capacity for action" [p. 843]. This analytic framework also includes an element—situational logic, which refers to a belief where change arises in the opposition between structure and culture, which relates to how Gynnild [22] discussed how the "nature of recursive social practices that help us conceive both stability and change" [p. 302]. Lastly, student agency has been defined as "the ways students develop personally through engagement with knowledge" [24]. This characterization of student agency is similar to Svihla et al. [21]. Both studies focused on students developing agency as an integral piece for navigating pathways into their career as an engineer.

Along with varying theoretical underpinnings of agential frameworks, multiple approaches were used to investigate student learning, such as a multiple case study, narrative analysis, and phenomenography. The narrative analysis conducted by Case [23] highlighted how the students felt constrained by the curriculum, which in turn influenced their interactions with faculty and peers. This research also highlighted the importance of students' ability to see themselves, in relation to the knowledge that is legitimized in the classroom. More importantly, Case [23] suggested there is a need to make structural and cultural changes to institutions and curricula, including pedagogy and assessment, to enable students to build "radically new perspectives on the world [p. 850]," including a change in who students are becoming personally and professionally through their engagement with knowledge. Similarly, using a multiple case approach, Svihla et al. [21] emphasized how students' perceptions of the design problem influenced their attitudes towards learning and task completion. Connections between discourse patterns about agency were found. Their findings suggest students are willing to negotiate problems based on their perception of the authenticity of the design problem, and making considerations for the context of the problem is essential for students learning design. Students who claimed the design problem as an assignment had low agency, in comparison to their peers who took ownership of the design. As a result, students who demonstrated *framing agency* had orientations towards learning based on their willingness to explore and test ideas outside of the task, instead of focusing on task completion. These findings inform how educators can begin to support students sense of agency in design by encouraging students to take ownership of their work, as opposed to approaching the design with intent to find the right answer. Also, their findings inform later studies that discuss how there is a paradox between how engineers are positioned by society and how engineering education often constrains student's ability to enact and develop attitudes that result in change.

Although Gynnild [22] presented a case using phenomenographic methods, this article was primarily focused on the translation of Gidden's structuration theory into an engineering education context to understand change in how students approach learning from a surface, deep, or strategic approach. Both surface and strategic learning were considered superficial. As a result, the learning environment was modified to incorporate visual media and a take-home midterm assessment to illustrate the related phenomena and the mathematical equations to stimulate a more in-depth approach to learning. Eleven students were interviewed and asked to write in a journal about their learning. Students who had a predisposition towards deep learning reported how the visual media and assessment were helpful; however, the students who held superficial values about learning reported a small impact on their learning. These results illustrate how social change is influenced by individuals who are willing to adopt the new practices imposed by the structure; in this case, the lecturers who implemented strategies to improve student learning. These articles are concerned with the ways structure and culture shape student agency.

Persistence

Concerns regarding persistence and engagement in engineering have been tied to constraints imposed by institutional structures and cultures on students [25]–[27]. Ahmed and colleagues [29] combined elements from two theoretical frameworks, Bourdieu's ideas about cultural capital [28] and Archer's [17] beliefs about structures, to understand why students who are "academically eligible to continue" leave engineering [29, p. 133]. Bourdieu's assumption of capital refers to the cultural resources that influence society, as well as the power dynamics that influence students' decision-making. Whereas Archer's perspective recognized the interwoven nature between

structure and agency, as opposed to solely prioritizing the role of structure. Irrespective of competing ideas among Bourdieu and Archer, their work aims to focus on the relationship between structure and agency by examining the power dynamics between the student (as an agent) and the institution (as a structure).

Additionally, this study used Archer's agentic reflexivity, which involves understanding the "internal conversation" that justifies their withdrawal. With influences from grounded theory, their findings indicated how students primarily withdrew from engineering based on a lack of interest in engineering. Also, some students stated tension, which resulted in the students temporarily withdrawing from the program to receive more "on-site experience" or transferring to a new program. Additional rationales for leaving engineering include financial and academic barriers (i.e., performance in courses). Ahmed et al. [29] emphasized the value of integrating initiatives to mediate concerns related to structural constraints such as providing financial assistance to students and providing supplemental information to support students to make informed decisions about their pathways.

This work presents a focus on the internal processes (i.e., thoughts) in addition to external behavior in examining student agency. A similar concept is used in higher education research focused on understanding graduate student agency through two concepts: agentic perspectives and agentic actions [30]. Agentic perspectives involve understanding how students "make sense of situations and concepts to advance their personal goals" [p. 2], which results in strategic actions towards the student's goals (i.e., agentic actions). This view of agency highlights how multiple factors are influencing how students navigate into or out of engineering.

Positioning
In this review, positioning is used as an umbrella term to represent the process of how individuals place themselves and are placed within social contexts. Several studies across different themes utilized this perspective, including identity development, diversity support, and critical views of agency. From a social psychological perspective, positioning theory is used to understand how people are "positioned" concerning discursive acts such as "conversation, institutional practices, and societal rhetorics" [31, p. 51]. Also, discursive practices are used to explain the ways people "produce social and psychological realities" [32, p. 45]. This view of positioning can be used to understand how students position themselves as well as how others position them according to discourse and social structures as a way to make sense of identity, belonging, and how students imagine themselves within a particular role such as an engineer.

Using narrative research methods, Greene et al. [33] combined ecological systems theory, critical race theory, and narrative identity framework to understand how Black men who participate in makerspaces form their identities as engineers. Ecological systems theory consists of four levels: microsystem, mesosystem, exosystem, and macrosystem [34]. The microsystem is the first level of the environment, which contributes to the student's development through close interactions in one setting, such as the classroom, home, or work. The mesosystem involves the relationship between multiple microsystems (i.e., classroom experiences and internship). The exosystem is an environment where the student isn't an active participant but affects the student. Macrosystems involve the cultural values, norms, and belief systems that have indirect influences on the student.

Each environmental level has an indirect or direct impact on the development of the student. However, in the context of the study, their work defined the makerspace as a microsystem based on the students' interactions within the setting. Greene et al. [33] suggested that makerspaces have the potential to influence how Black men form their identity as engineers, since makerspaces provide freedom and flexibility, as opposed to traditional learning environments [33]. The authors did not explicitly describe a definition of agency; instead, their findings suggest that Black men express how makerspaces serve as "a solidifying agent in their decision to pursue engineering" [p. 11]. This study also highlights the importance of examining how non-traditional learning approaches facilitate identity development by validating students' various ways of engaging in engineering, including the association between identity development and developing a sense of agency. Although agency was not a primary concern in the study, ecological systems theory may be useful for further examining how students develop an understanding of agency with the other environmental levels that influence how they engage in the makerspace, including institutional structure and culture. More importantly, this research study emphasizes how providing students access to co-curricular spaces (i.e., makerspaces) informs their positioning to author their identity as an engineer [35].

Similar to Green et al. [33], Secules et al. [36] examined agency among students who are traditionally marginalized in engineering. Their work was informed by bell hook's style of theorizing to make sense of how an underrepresented student navigated an oppressive system. In their work, agency is defined as "who controls the narrative of experiences in marginalization" [p. 189]. In addition to controlling the narrative, the idea of theorizing involves a process of "understanding one's situation in terms of existing oppressive social norms, questioning those norms, and eventually opening up our imagination to liberation from them" [p. 190]. This framing of agency relates to other scholars who assume a sense of agency involves actively processing mentally and through actions. Narrative research methods were used to identify three intertwined narratives were identified as a part of Emilia's stories, specifically emphasizing racial and gender inequities in STEM: Vulnerability and Strength Regarding Math, Women in STEM: Conflicting Feminisms and Self-determination, and The Nature of Engineering: Authoring Disciplinary Narratives. Within the "Vulnerability and Strength Regarding Math" narrative, the Emilia exercised her agency by pursuing engineering as a career choice, despite her low mathematics self-efficacy, discouraging conversations with family members, and rigor culture that suggested that students must excel in mathematics to be a good engineer. In addition to rejecting the "cultural motif" associated with engineering, the student also made a conscious effort to network with professional engineers to understand what aspects of engineering required math. The student demonstrated their agency by asking questions and taking action to resist the dominant narrative of what it means to be a "real engineer," stereotypical gendered roles in engineering, and positioning her weaknesses regarding technical skills as developmental, as opposed to fixed. Key elements of this framing of agency are about empowering the participant to tell their story as a source of support and agency as well as shifting from a perspective that encourages women to be more like male engineers considering there are additional attributes of engineering that are suppressed in the dominant narrative.

While the student in [36] pushed back on the culture of engineering by theorizing, Chua and Cagle [37] emphasized the disconnect between how students are positioned in recruitment efforts as "change-makers" with reality where curricula and pedagogy constrain students. Engineering

agency is often framed in rhetoric that emphasizes the need for engineers to negotiate the type of problems they solve and how they approach those problems. However, the discourse in engineering education curricula and classrooms positions students in ways that limit agency when solving problems. Such as fostering a culture that reinforces epistemic beliefs (i.e., certainty of engineering knowledge) that there is one right way to solve a problem or no choice in decisions. Drawing on the theory of structural power, critical pedagogy, and epistemic rhetoric analysis, Chua and Cagle [37] used critical discourse analysis to understand how engineering education text artifacts may be limiting students' sense of agency. Students' sense of agency is limited by the ways undergraduate assignments are structured in a manner that doesn't allow students to negotiate or reframe the assignment. Chua and Cagle [37] suggest how these limitations may influence whether students develop a sense of agency to modify or push back on the constraints or requirements given in future context, which contradicts the messaging from discourse that position "engineers as powerful agent" [p. 3]. This preliminary study begins to highlight how there needs to be coherence between public messaging of what it means to be an engineer and engineering curricula and pedagogy.

Critical engineering agency, another framework used in engineering education described "agency beliefs" as beliefs that "are focused on how students perceive their empowerment rather than on their explicit actions, as is typically the case with research on agency" [19, p. 317]. The use of agency in this framework is heavily focused on students' epistemological understandings and application of concepts within engineering. Agency is tied to the students' capabilities to shape their environment through engineering "(e.g., using their knowledge of science/engineering to design solutions for their community) and in their broader goals (e.g., pursuing a career in a service-related engineering field)" [38, p. 442]. Engineering agency beliefs in this framework are closely tied to developing a critical thinking mindset about science, engineering, and what they can do for the world. The authors wrote, "Students' agency beliefs involve how students see and think about STEM as a way to better themselves and the world along with being a critic of themselves and science in general [20, p. 939]. The critical thinking perspective is intimately tied to engineering agency beliefs, where students become "evaluator[s] of STEM as well as become critics of themselves and the world around them through self-reflection" [39, p. 13]. In essence, agency beliefs in this framework are based on a spectrum of how students view engineering as a way to change their world or the world at large.

Most agentic frameworks in engineering education used qualitative research methods. However, Godwin and colleagues [40] and Verdín and Godwin [41] used quantitative measures to understand students' agency beliefs in engineering education. Godwin et al. [40] developed and validated items to measure critical engineering agency by drawing on Basu and Barton's [42] agentic framework in science education. Basu and Barton [42] situate "learning as agency" as a way to account for positioning and power in learning. Godwin and colleagues [40] are drawing on the idea of how students' can "use science as a context for change, such that identity develops, their position in the world advances, and they alter the world towards what they envision as more just" [41, p. 389]. Similarly, Godwin et al. [40] were concerned with understanding how engineering students' use engineering knowledge, skills, and processes to inform their "perception of their ability to change their world through everyday actions as well as his/her broader goals in life". Along with how agency can be used to predict choice in engineering, their findings suggest agency

within a disciplinary domain is a relevant construct for examining undergraduate engineering students' pathways and identity development.

Continuing with the idea of personal agency, Verdín and Godwin [41] developed and validated a personal agency scale to understand what influenced first-generation college students' goal in making a difference in their community using their engineering knowledge and skills. Verdín and Godwin [41] drew on Bandura's social cognitive theory to frame student agency by focusing on the reciprocation between personal, environmental, and behavioral factors. Including four personal agency constructs (i.e., forethought, intentionality, self-reactiveness, and self-reflectiveness; [41]). Using confirmatory factor analysis, their results indicated two groupings of personal agency (i.e., intentionality with self-reactiveness and forethought with self-reflectiveness) instead of four that were identified in prior work [41]. They used these two latent constructs of personal agency to theorize how first-generation students navigate engineering. This operationalization of personal agency in engineering education was used to understand how students enact their agency in relation to personal, environmental, and behavioral factors.

Together, these studies emphasize how there are several ways to understand how students enact agency in engineering education. Beyond the three overarching student outcomes identified as a result of examining agency, some studies emphasized the importance of students developing a sense of agency [21], [24], [33]. In contrast, others like Chua and Cagle [37] highlighted how engineering education discourse might be resulting in a lack of agency. Some studies affirmed the importance of empowering students to enact agency or developing a sense of agency as an essential skill to engineering [21], [36]. In addition, the majority of the articles discussed the relationship between structure (or culture) and agency; however, there were a few studies which described the internal processes associated with agency or how it can be supported and developed for the student outcomes studied. More importantly, in addition to discussing how to empower students to enact change, several studies recognized the need for institutional structural and cultural change [22], [23], [36], [37]. Below, we discuss the role of faculty as it relates to change in engineering education through faculty agency.

Faculty Agency

In our analysis of studies evaluating student agency, we noticed that several studies briefly mention the potential influence of institutional structures (e.g., policies, norms, cultures) on how students' develop and exhibit their agency in engineering education learning environments [23], [29], [33], [36]. The researchers' acknowledgment of institutional constraints highlights the complexity of the engineering education infrastructure and emphasizes the importance of engaging all agents of change across the leadership hierarchy [2], [43]. Although the leadership hierarchy of engineering institutions include faculty, administrators, industry professionals, governing boards, and federal agencies, faculty's roles and responsibilities uniquely position them to influence curriculum design and delivery, policies, practices, and cultures [44]. As a result, faculty can be a bridge between student agency and the institutional structures, positioning them as a critical component for ensuring change in engineering education [43], [45]–[47].

Similar to our analysis of student agency, we identified a few studies evaluating faculty agency using search terms of "agency," "faculty," and "engineering education" in available databases

(Education Resources Information Center, Education, and Education Full Text) and ASEE PEER document repository. Although the available research on faculty agency in engineering education is limited in comparison to student agency, the few studies highlighted in this review demonstrate the diverse conceptualization of faculty agency in engineering education and the methodological approaches. Also, we outline how the authors define agency, what we learned, and how these findings may fit in a broader characterization of how change can be promoted by faculty in engineering education.

Local Transformation

In our search for studies evaluating faculty agency in engineering education, we found that a great deal of previous research emphasizes instructional changes. In the engineering education community, the emphasis on instructional improvements was a response to gaps identified in the research to practice cycle in the 2009 report, *Creating a Culture for Scholarly and Systematic Innovation in Engineering Education* [48]. As a result, many engineering education researchers use motivation theories to evaluate faculty's willingness to engage in instructional change [43], [49], [50]. These motivation theories included Self Determination Theory [50], Self-efficacy [51], and Expectancy Value Theory (EVT) [53]. These studies evaluated faculty agency by exploring the relationship between their beliefs, values, and goals and the larger academic structure [50]–[54].

Matusovich, Paretti, McNair, and Hixson [50] investigated faculty's motivation to implement research-based instructional strategies (RBIS). Although Matusovich et al. [50] did not explicitly define agency, they suggested that faculty's willingness to act or not determined their agency. The authors argued that faculty engagement with transformation initiatives is influenced by what motivates faculty to act. As a result, the study is grounded in Expectancy Value Theory (EVT). EVT posits that an individual's belief of success determines individual engagement and the value they associate with the activity [53], [54]. In the context of faculty engagement with the research to practice cycle, faculty's expectancy of success includes their beliefs about their abilities to translate theory into classroom practices and successfully enact those practices in their teaching [49]. They used a concurrent mixed-method study design to gather data at two engineering education conferences. Qualitative data (e.g., field notes, open-ended survey responses) were the primary data sources, which was supported by descriptive statistics from a quantitative survey. The team identified individual and social factors that encouraged or discouraged faculty's motivation and, ultimately, their agency. For example, a common theme among participants influencing their expectancy of success and inhibiting engagement was the participant "not knowing how to do something" [p. 31]. On the other hand, the research suggested that when participants perceived cost value of implementation was small (e.g., easy to implement), then their likelihood of enacting their agency to engage with the RBIS increased [50]. Although the authors evaluated faculty agency at the individual level, the EVT lens supported the identification of individual and systemic factors of engagement.

Similarly, Finelli, Daly, Richardson [49] used the lens of EVT to evaluate faculty's motivation to adopt effective teaching strategies. In addition to EVT, Finelli et al. [49] integrated organizational change and instructional development in their approach to institutional transformation. The authors implicitly defined faculty agency as faculty's willingness to act and subsequent actions in a similar fashion as Matusovich et al. [50]. The study used faculty focus groups to elicit factors that

promoted or hindered the adoption of particular teaching strategies: student-centered, groups, and authentic context. In these focus groups, they specifically asked about faculty's expectancy of success and task value. The analysis of this work resulted in 26 individuals' themes grouped into seven categories. The categories that promoted adoption included infrastructure and culture, knowledge and skills, and flexible classroom and curricular structures. Whereas, the categories that hindered adoption included concerns about student learning experience and time. Depending on the faculty member, their disposition, professional goals, network, and community could be an aid or detract from their agency to implement. These findings informed subsequent faculty and administrative change plans. The change plans were ultimately implemented at the local level, and student and faculty data were collected to evaluate effectiveness, attitudes, and behaviors. As a result, the authors were able to accelerate the adoption of RBIS at their institution.

Other authors like Cruz et al. [43] built upon the work of Matusovich et al. [50] and Finelli et al. [49]. Cruz et al. [43] also incorporated additional elements of the system (e.g., cultural factors, change management processes, pedagogical knowledge, and student experiences to understand faculty motivation to implement effective teaching strategies. This study explored the complexity of institutional change by focusing beyond the actions of faculty to understand their position within the higher education system. In particular, Cruz et al. [43] concluded that an individual change agent could not address all aspects of institutional change at once; however, they did emphasize the importance of institutional influencers to consider the complexity of departmental or institutional transformation.

Systemic Transformation

Although Finelli et al. [49] and Cruz et al.'s [43] studies explore faculty agency in a way that considers the systemic structures within institutions, they do not examine broader policy in higher education. Researchers Smith-Orr, Bodnar, Lee, Faber, Coso Strong, and McCave [43] begin to explore the influence of faculty agency on their goals for systemic transformation of local and national agendas. They used Campbell and O'Meara's [3] faculty agency framework to explore the impact of faculty on systemic transformation within their leadership positions. Campbell and O'Meara's [3] framework defines agency as "taking strategic or intentional actions or perspectives towards goals that matter to oneself" [3, p. 52]. The previously discussed motivation theories define agency through faculty's willingness to take action, which links to Campbell and O'Meara's framework through the concept of agentic perspectives. Smith-Orr et al. [44] used collaborative inquiry and collaborative autoethnography to explore early-career faculty transitions to academic careers. Also, they used reflections to inform a quantitative survey to evaluate the strategic actions taken and their impact on local and national change agendas. As a result, they identified that early-career faculty's agency resulted in the greatest impact of change through their dissemination actions. On the other hand, their findings suggested that their agency had the least prevalent impact on national agendas.

These studies lay the groundwork for future work on exploring faculty agency in engineering education to understand better how to create and sustain local and national change. For example, analyzing faculty agency through motivational theories, like Matusovich et al. [50], could be applied to research evaluating faculty's impact to create and sustain change through their non-teaching responsibilities similar to Smith-Orr et al. [44]. However, despite the application, more work needs to be done to understand faculty agency and its influence across the engineering

education ecosystem if we are going to engage in the transformation to support the next generation of engineers.

Conclusion

In this narrative review, we examined the ways agency has been used in engineering education. This paper has shown how student agency has been explored to address a variety of student outcomes through varied definitions and methodological approaches. Some studies were not designed to investigate agency directly; however, agency emerged as a student outcome during the analysis. These studies focused on how students have been constrained or empowered to learn engineering, persist through the structural and cultural barriers imposed, and how they are positioned in engineering. In terms of faculty agency, this review illustrated the importance of faculty beliefs about their ability to influence institutional and systemic change in engineering education is essential for large-scale change; however, an understanding of the organizational and structural issues supporting these change efforts need to be more deeply examined.

Transformations in engineering education have been criticized for not considering a systemic perspective when considering ways to enact change beyond curricula, departmental, and institutional change [2], [55]. However, issues concerning integrated learning, accessibility, and individual diversity "requires change at different levels in engineering education" [1], [2], [55, p. 265]. One important consideration that was raised across studies was the interplay between students, faculty, and external actors (i.e., industry, government, and accrediting boards) to shape change in engineering education. As a result, all actors must be motivated to adjust to new practices that will ensure STEM literacy is prioritized in a manner that is accessible and enables students to develop a sense of agency to navigate the ambiguity and complexities associated with the societal demand for engineers. Moreover, further studies that build on these agentic frameworks in engineering education can potentially facilitate the identification and deconstruction of mechanisms that hinder diverse pathways into engineering, promote a liberal approach to engineering education, and support individual diversity.

References

[1]   J. B. Main, K. A. Smith, A. W. Fentiman, and K. L. Watson, "The next Morrill Act for the 21st century," *J. Eng. Educ.*, vol. 108, no. 2, pp. 152–155, 2019.
[2]   A. F. Mckenna, J. Froyd, and T. Litzinger, "The complexities of transforming engineering higher education: Preparing for next steps," *J. Eng. Educ.*, vol. 103, no. 2, pp. 188–192, 2014.
[3]   C. M. Campbell and K. A. O'Meara, "Faculty Agency: Departmental Contexts that Matter in Faculty Careers," *Res. High. Educ.*, vol. 55, no. 1, pp. 49–74, 2014.
[4]   S. Billett, "Relational Interdependence Between Social and Individual Agency in Work and Working Life," *Mind, Cult. Act.*, vol. 13, no. 1, pp. 53–69, 2006.
[5]   A. Bandura, "Human agency in social cognitive theory," *Am. Psychol.*, vol. 44, no. 9, pp. 1175–1184, 1989.
[6]   B. Albert, "Toward a Psychology of Human Agency," *Perspect. Psychol. Sci.*, vol. 1, no.

2, pp. 164–180, 2006.

[7] K. Frank, "Agency," vol. 6, no. 3, pp. 281–302, 2006.

[8] J. Arnold and D. J. Clarke, "What is 'Agency'? Perspectives in Science Education Research," *Int. J. Sci. Educ.*, vol. 36, no. 5, pp. 735–754, 2014.

[9] M. Emirbayer and A. Mische, "What is agency?," *Am. J. Sociol.*, vol. 103, no. 4, pp. 962–1023, 1998.

[10] M. Schlosser, "Agency," *Stanford Encyclopedia of Philosophy*, 2015. .

[11] S. Hitlin and G. H. Elder, "Agency: An Empirical Model of an Abstract Concept," *Adv. Life Course Res.*, vol. 11, no. 06, pp. 33–67, 2007.

[12] A. Giddens, "Elements of the Theory of Structuration," in *The Constitution of Society: Outline of the Theory of Structuration*, Berkeley and Los Angeles: University of California Press, 1984, pp. 1–28.

[13] A. Bandura, "SOCIAL COGNITIVE THEORY : An Agentic Perspective," *Annu. Rev. Psychol.*, vol. 52, no. 1, pp. 1–26, 2001.

[14] D. Holland, W. J. Lachicotte, D. Skinner, and C. Cain, *Identity and Agency in Cultural Worlds*. Havard University Press, 2001.

[15] L. Vygotsky, *Thought and Language*. Massachusetts Institute of Technology, 1986.

[16] A. Eteläpelto, K. Vähäsantanen, P. Hökkä, and S. Paloniemi, "What is agency? Conceptualizing professional agency at work," *Educ. Res. Rev.*, vol. 10, pp. 45–65, 2013.

[17] M. S. Archer, *Structure, Agency, and Internal Conversation*. Cambridge: Cambridge University Press, 2003.

[18] E. E. Turner, "Critical mathematical agency: Urban middle school students engage in mathematics to investigate, critique, and act upon their world," 2003.

[19] A. Godwin, G. Potvin, Z. Hazari, and R. Lock, "Identity, Critical Agency, and Engineering: An Affective Model for Predicting Engineering as a Career Choice," *J. Eng. Educ.*, vol. 105, no. 2, pp. 312–340, 2016.

[20] A. Godwin and G. Potvin, "Fostering female belongingness in engineering through the lens of critical engineering agency," *Int. J. Eng. Educ.*, vol. 31, no. 4, pp. 938–952, 2015.

[21] V. Svihla, J. R. Gomez, M. A. Watkins, and T. B. Peele-Eady, "Characterizing framing agency in design team discourse," *Proc. ASEE 126th Annu. Conf. Exhib.*, 2019.

[22] V. Gynnild, "Agency and structure in engineering education: Perspectives on educational change in the light of Anthony Giddens' structuration theory," *Eur. J. Eng. Educ.*, vol. 27, no. 3, pp. 297–303, 2002.

[23] J. M. Case, "A social realist perspective on student learning in higher education: the morphogenesis of agency," *High. Educ. Res. Dev.*, vol. 34, no. 5, pp. 837–852, 2015.

[24] N. Pitterson, J. Case, A. Agrawal, and I. Hasbun, "Investigating the ways in which student agency develops through engagement with knowledge," in *Proceedings - Frontiers in Education Conference, FIE*, 2018, pp. 1–5.

[25] M. W. Ohland, S. D. Sheppard, G. Lichtenstein, O. Eris, D. Chachra, and R. A. Layton, "Persistence, engagement, and migration in engineering programs," *J. Eng. Educ.*, vol. 97, no. 3, pp. 259–278, 2008.

[26] C. E. Brawner, M. M. Camacho, S. M. Lord, R. A. Long, and A. W. Ohland, "Women in industrial engineering: Stereotypes, persistence, and perspectives," *J. Eng. Educ.*, vol. 101, no. 2, pp. 288–318, 2012.

[27] M. H. Forbes, A. R. Bielefeldt, J. F. Sullivan, and R. L. Littlejohn, "Low-Choice Culture in Undergraduate Engineering and Autonomy-Supportive Exceptions," *J. Prof. Issues*

Eng. Educ. Pract., vol. 144, no. 1, pp. 1–8, 2018.

[28] P. Bourdieu and J.-C. Passeron, "Reproduction: In education, society, and culture," in *Theory, culture & society*, 2nd ed., R. Boyne, M. Hepworth, S. Lash, R. Robertson, and B. S. Turner, Eds. London: Sage Publications, 1990.

[29] N. Ahmed, B. Kloot, and B. I. Collier-Reed, "Why students leave engineering and built environment programmes when they are academically eligible to continue," *Eur. J. Eng. Educ.*, vol. 40, no. 2, pp. 128–144, 2015.

[30] K. O'Meara, "Advancing Graduate Student Agency," *High. Educ. Rev.*, vol. 10, no. 10, pp. 1–10, 2013.

[31] D. Howie and M. Peters, "Positioning theory: Vygotsky, Wittgenstein and social constructionist psychology," *J. Theory Soc. Behav.*, vol. 26, no. 1, pp. 51–64, 1996.

[32] B. DAVIES and R. HARRÉ, "Positioning: The Discursive Production of Selves," *J. Theory Soc. Behav.*, vol. 20, no. 1, pp. 43–63, 1990.

[33] M. L. Greene, "Black Men in the Making : Engaging in makerspaces promotes agency and identity for Black males in engineering An Investigation of the Engagement of Black Men in Engineering Academic Makerspaces," 2019.

[34] A. J. Onwuegbuzie, K. M. T. Collins, and R. K. Frels, "Foreword: Using Bronfenbrenner's ecological systems theory to frame quantitative, qualitative, and mixed research," *Int. J. Mult. Res. Approaches*, vol. 7, no. 1, pp. 2–8, 2013.

[35] D. Holland, "A practice theory of self and identity," *Identity Agency Cult. Worlds*, 2001.

[36] S. Secules, A. Gupta, A. Elby, and E. Tanu, "Supporting the Narrative Agency of a Marginalized Engineering Student," *J. Eng. Educ.*, vol. 107, no. 2, pp. 186–218, 2018.

[37] M. Chua and L. E. Cagle, "You can change the world, but not this homework assignment: The contradictory rhetoric of engineering agency," in *Proceedings - Frontiers in Education Conference, FIE*, 2017, vol. 2017-Octob, pp. 1–4.

[38] A. Godwin and G. Potvin, "Pushing and pulling Sara: A case study of the contrasting influences of high school and university experiences on engineering agency, identity, and participation," *J. Res. Sci. Teach.*, vol. 54, no. 4, pp. 439–462, 2017, doi: 10.1002/tea.21372.

[39] A. Godwin, "Understanding female engineering enrollment: Explaining choice with critical engineering agency (Unpublished doctoral dissertation). Clemson University, & Modeling engineering choice using student attitudes and self-beliefs.," Clemson University, 2014.

[40] A. Godwin, G. Potvin, and Z. Hazari, "The development of critical engineering agency, identity, and the impact on engineering career choices," in *ASEE Annual Conference and Exposition, Conference Proceedings*, 2013.

[41] D. Verdín and A. Godwin, "Board 51 : An Initial Step Towards Measuring First-Generation College Stu- dents ' Personal Agency : A Scale Validation An Initial Step Towards Measuring First-Generation College," in *American Society for Engineering Education*, 2019.

[42] S. J. Basu and A. Calabrese Barton, "Critical physics agency: Further unraveling the intersections of subject matter knowledge, learning, and taking action," *Cult. Stud. Sci. Educ.*, vol. 4, no. 2, pp. 387–392, 2009.

[43] J. M. Cruz and V. Tech, "A System Approach to Instructional Change in Academia," 2019.

[44]   C. Smith-Orr, C. A. Bodnar, A. Coso Strong, W. C. Lee, and E. J. McCave, "Collaborative Research: Supporting Agency among Early Career Engineering Education Faculty in Diverse Institutional Contexts: Developing a Framework for Faculty Agency.," *Am. Soc. Eng. Educ. Annu. Conf. Expo.*, no. 1, 2019.

[45]   E. J. McCave, C. J. Faber, C. A. Bodnar, A. C. Strong, W. C. Lee, and C. S. Smith-Orr, "Collaborative research: Supporting agency among early career engineering education faculty in diverse institutional contexts," *ASEE Annu. Conf. Expo. Conf. Proc.*, vol. 2018-June, 2018.

[46]   S. A. Bjorklund and C. L. Colbeck, "The View from the Top: Leaders' Perspectives on a Decade of Change in Engineering Education*," *J. Eng. Educ.*, vol. 90, no. 1, pp. 13–19, 2001.

[47]   M. Besterfield-Sacre, M. F. Cox, M. Borrego, K. Beddoes, and J. Zhu, "Changing engineering education: Views of U.S. faculty, chairs, and deans," *J. Eng. Educ.*, vol. 103, no. 2, pp. 193–219, 2014.

[48]   L. H. Jameison and J. R. Lohmann, "Creating a Culture for Scholarly and Systematic Innovation in Engineering Education: Ensuring U.S. engineering has the right people with the right talent for a global society," 2009.

[49]   C. J. Finelli, S. R. Daly, and K. M. Richardson, "Bridging the research-to-practice gap: designing an institutional change plan using local evidence," *J. Eng. Educ.*, vol. 103, no. 2, pp. 331–361, 2014.

[50]   H. M. Matusovich, M. C. Paretti, L. D. Mcnair, and C. Hixson, "Faculty motivation: A gateway to transforming engineering education," *J. Eng. Educ.*, vol. 103, no. 2, pp. 302–330, 2014.

[51]   R. M. Ryan and E. L. Deci, "Self-Determination Theory and the Facilitation of Intrinsic Motivation, Social Development, and Well-Being," *Am. Psychol.*, vol. 55, no. 1, pp. 68–78, 2000.

[52]   A. Bandura, *Self-Efficacy: The exercise of control*. New York: W. H. Freeman, 1997.

[53]   J. S. Eccles and A. Wigfield, "Motivational Beliefs, Values, and Goals," *Annu. Rev. Psychol*, vol. 53, pp. 109–32, 2002.

[54]   J. S. Eccles *et al.*, "Expectancies, values, and academic behaviors," in *Achievement and achievement motivation*, J. T. Spence, Ed. San Francisco: W. H. Freeman, 1983, pp. 75–146.

[55]   A. Jamison, A. Kolmos, and J. E. Holgaard, "Hybrid Learning: An integrative approach to engineering education," *J. Eng. Educ.*, vol. 103, no. 2, pp. 253–273, 2014.