Undergraduate engineering students’ perceptions of research and researchers

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Abstract

Background: Participating in undergraduate research experiences (UREs) supports the development of engineering students’ technical and professional skills. However, little is known about the perceptions of research or researchers that students develop through these experiences. Understanding these perceptions will provide insight into how students come to understand knowledge evaluation and creation, while allowing research advisors to better support student development.

Purpose: In this paper, we explore how undergraduate engineering students perceive what it means to do research and be a researcher, using identity and epistemic cognition as sensitizing concepts. Our goal is to explore students’ views of UREs to make the benefits of these experiences more accessible.

Design/Method: We created and adapted open-ended survey items from previously published studies. We collected responses from mechanical and biomedical engineering undergraduates at five institutions (n = 154) and used an inductive approach to analyze responses.

Results: We developed four salient themes from our analysis: (a) research results in discovery, (b) research includes dissemination such as authorship, (c) research findings are integrated into society, and (d) researchers demonstrate self-regulation.

Conclusions: The four themes highlight factors that students perceive as part of a researcher identity and aspects of epistemic cognition in the context of UREs. These results suggest structuring UREs to provide opportunities for discovery, dissemination, societal impact, and self-regulation will help support students in their development as researchers.

KEYWORDS
epistemic cognition, identity, qualitative, undergraduate research
INTRODUCTION AND BACKGROUND

Studies have shown the importance of undergraduate research experiences (UREs) in helping students clarify career goals; persist in science, technology, engineering and mathematics (STEM); develop research skills; gain an understanding of disciplinary practices; and grow technical knowledge (Gentile, Brenner, & Stephens, 2017). The purpose of this paper is to investigate undergraduate engineering students’ perspectives of research and what it means to be a researcher to gain insights into their researcher identity and factors influencing that identity. This paper is part of a larger project that seeks to make the benefits of UREs more accessible to students, with the understanding that, currently, a limited number of students have the opportunity to participate in UREs because of cost, time, grade point average (GPA) requirements, and availability of opportunities (Gentile et al., 2017).

1.1 How UREs are defined

UREs are defined and distinguished by several factors, including the mentor’s role, length of experience, student compensation, cost, and process of selecting research topics. The most recognized type of URE is the apprentice-style experience in which an undergraduate student works in a faculty member’s research group; however, other types of UREs include capstone experiences, internships or co-ops, course-based undergraduate research experiences (CUREs), project-based programs, and community-based research programs (Gentile et al., 2017). In these experiences, students perform a variety of tasks ranging from mundane (e.g., cleaning lab equipment and tallying data) to advanced (e.g., running experiments and writing publications). These current definitions of UREs are from the perspective of faculty and/or experienced researchers. While these definitions are important, to make the benefits of UREs more accessible to students, we need to explore the definitions and perceptions of research from the student perspective. As stated by Bandura (1997), “people’s level of motivation, affective states, and actions are based more on what they believe than on what is objectively true” (p. 2). Building on Bandura’s perspective, we aim to look across experiences that students perceived to be research, whether or not those experiences align with our definitions of research.

1.2 Prior studies on UREs

While there are a variety of URE types, many prior studies have focused on evaluating program outcomes and characteristics of summer experiences. Studies that examined students participating in summer research programs reported gains in technical and personal skills, including gains in understanding laboratory techniques, readiness for more demanding research, and tolerance for obstacles (Lopatto, 2004). Participating in summer research also impacted course choice; participants took more classes in the same department that facilitated their URE and reported an increase in motivation to learn, engagement in their own learning, and independent thought in these classes as a result of participating in an URE (Lopatto, 2007).

While UREs have been shown to increase persistence in STEM fields (Nagda, Gregerman, Jonides, von Hippel, & Lerner, 1998), past research makes the distinction that UREs tend to confirm or clarify students’ career goals and do not act as recruitment mechanisms into STEM majors (Linn, Palmer, Baranger, Gerard, & Stone, 2015; Seymour, Hunter, Laursen, & DeAntoni, 2004). However, it is unclear if this result extends to all STEM undergraduate students since the selection process for UREs is competitive and the decision to participate in an URE is self-directed. Most students who participate in UREs have relatively high GPAs (Linn et al., 2015; Russell, Hancock, & McCullough, 2007) and are reported to have decided on a STEM career during childhood (Russell et al., 2007). While most URE participants have already decided to pursue STEM careers, not all have completely solidified their STEM career pathways. Participating in UREs encourages undergraduate students to consider graduate studies in pursuit of a PhD (Russell et al., 2007). Increased interest in pursuing STEM careers and graduate studies is likely the result of students’ gains in research skills and self-efficacy (Adedokun et al., 2013).

Due to the demonstrated benefits of participating in UREs, there have been increasing calls to expand student access to these benefits (Gentile et al., 2017; Kuh, 2008). There are a number of approaches that could be taken to expand access, such as ensuring consistency in the quality of research experiences or incorporating impactful aspects of research experiences into other curricular or cocurricular experiences. Regardless of the approach, broadening access to the benefits of UREs requires a deep understanding of undergraduate students’ perceptions of both research and
researchers. UREs are complex and dynamic experiences, with individuals fulfilling a variety of roles that can produce useful insights for ongoing and newly encountered learning experiences. Prior studies of capstone experiences have shown that exploring student perspectives yielded unique insights into students’ development of their engineering identity in a way that is more nuanced and profound than would be possible from the perspectives of other individuals (e.g., faculty mentors) (Lutz & Paretti, 2017). Therefore, this study focuses on undergraduate engineering students’ perspectives of research and what it means to be a researcher to gain insights into their researcher identity and factors influencing that identity in ways that can effectively expand access to the benefits of UREs.

2 | THEORETICAL PERSPECTIVES AND SENSITIZING CONCEPTS

Our research was influenced by critical realism, which stratifies ontology (i.e., the nature of reality) into three components: objective observations (actual), subjective experiences (empirical), and mechanisms that underpin those objective observations and subjective experiences (real) (Case, 2013). As such, we focused on understanding the complex experience of undergraduate researchers through the perspective of the student including their observations of research and experiences as an undergraduate researcher. Characterization of students’ perceptions is important for two reasons: (a) students’ perceptions directly influence students’ identities and their epistemic cognition (i.e., ways of knowing) and (b) students’ perceptions do not necessarily align with the perceptions of professionals (i.e., faculty members), which have guided much of the current knowledge of undergraduate research. Based on these two reasons, there is need to capture the student perspective related to undergraduate research. Building on the work of Hunter et al. (2006) and our previous studies (Faber, Benson, et al., 2016; Faber & Benson, 2015a, 2015b), this study aimed to answer the research question: How do undergraduate engineering students perceive research and what it means to be a researcher?

While we allowed participants to dictate the definition of a research group or laboratory, we adopted the viewpoint that a “traditional” research laboratory is the physical space along with the instruments, devices, and specialized equipment used (Osbeck, Nersessian, Malone, & Newstetter, 2011). It is also “an organized social group with [a] shared agenda that undergirds the particular problem-solving goals undertaken by any researcher at any given time” (Osbeck et al., 2011, p. 32). We did not use this framing to narrow our view of what counts as research to students but rather to bring attention to the idea that research is inherently situated within a community of practice with shared beliefs and practices (Lave & Wenger, 1991). As students participate in UREs, situated learning suggests that perceptions, identities, beliefs (which includes epistemic cognition), and interactions with others will be shaped by participation (Lave & Wenger, 1991). In this study, situated learning, specifically communities of practice, broadly frames our investigation of how students perceive research (epistemic cognition) and what it means to be a researcher (identity). Figure 1 captures our initial perspective on how these three concepts overlap. Our research focus is the intersection of epistemic cognition and researcher identity within a community of practice (i.e., UREs).

More specifically, epistemic cognition and identity in research served as the sensitizing concepts in that they were “points of departure for studying the empirical word while retaining [our] openness to exploring it” (Charmaz, 2014, pp. 30–31). Based on our past work (Faber, Benson, et al., 2016) and readings of the literature, as described below, we identified connections between ways of building knowledge in a domain and views of one’s self in that space. Subsequently, we started with epistemic cognition and researcher identity, but our research participants’ perspectives further defined and guided those topics, including their connections. Our approach allowed us to focus, while also remaining open to potential findings from our participants.

2.1 | Researcher identity

In a study by Hunter, Laursen, and Seymour (2006), faculty mentors of students in UREs identified students’ gains in attitudes and behaviors connected with becoming a scientist (their researcher identity). Students recognized the same shift in behavior and attitudes; however, they did not identify themselves as becoming researchers (Hunter et al., 2006). Laursen, Hunter, Seymour, Thiry, and Melton (2010) state, “Students … did not fully realize the extent to which they were being exposed to, then adopting and becoming adept in, professional practice. … In contrast … research advisors readily recognized these developing behaviors and attitudes as novice versions of their own professional practice” (p. 53). Based on their study, it is unclear how students saw themselves as researchers and whether the students felt they were becoming part of the research community of practice. While faculty projected a researcher identity upon the
students, it is unknown whether these students experience identity formation themselves. This distinction is important, as identities can be projected upon an individual; however, the individual can accept or reject that identity (Gee, 2000). One approach to conceptualizing identity includes four dimensions: interest, recognition, performance, and competence (Carlone & Johnson, 2007; Hazari, Sonnert, Sadler, & Shanahan, 2010). Table 1 details the dimensions. Three of these dimensions (recognition, performance, and competence) were originally operationalized by Carlone and Johnson (2007) as key components to the science identity of practicing scientists. Hazari et al. (2010) added interest to Carlone and Johnson’s model. This four dimensional approach has been extended to quantitative measures of engineering identity (Godwin, Potvin, Hazari, & Lock, 2016; Prybutok, Patrick, Borrego, Seepersad, & Kirisits, 2016; Verdin & Godwin, 2018). This identity perspective provides an outline to understand how and the extent to which students in UREs develop researcher identities. While our work is situated in a different context (URE) than the studies described above, these studies share the common thread of investigating individual’s identity development in communities of practice (science, physics, engineering, and research).

In our previous work (Faber & Benson, 2015a, 2015b), we developed open-ended survey items based on the four dimensions of the identity described above (Carlone & Johnson, 2007; Hazari et al., 2010). Analysis of the responses to the open-ended questions revealed interest, competence, recognition, character traits, and research experience as themes that influenced student perception of their researcher identity (Faber & Benson, 2015a, 2015b). The themes of interest, competence, and recognition also aligned with the work of Carlone and Johnson (2007), Hazari et al. (2010), and Godwin et al. (2016). Character traits and research experience likely emerged because of how students defined what is needed to be a researcher. The goal of this study is to investigate how students define research and what it means to be a researcher beyond a predetermined framework to inform our emerging understanding of researcher identity as it relates to epistemic cognition.
2.2 | Epistemic cognition

Epistemic cognition includes ideas, practices, and processes that individuals use to gain knowledge, understanding, and accuracy in explanations (Chinn, Buckland, & Samarapungavan, 2011; Chinn, Rinehart, & Buckland, 2014). Epistemic cognitions are context and situation dependent, meaning that epistemic processes and beliefs individuals access and develop will be influenced by the situation and context surrounding them. To investigate students' epistemic cognitions in the context of undergraduate research, we began with Chinn et al.'s (2014) AIR model.

The AIR model includes three main components of epistemic cognition: epistemic Aims and value, epistemic Ideals, and Reliable processes for achieving epistemic aims. Epistemic aims are goals that individuals adopt related to gaining knowledge, understanding, and/or true beliefs. Epistemic ideals are standards individuals use to evaluate if an epistemic aim has been achieved. These align with explanatory ideals from philosophy of science, which are defined as properties that make a good explanation (Toulmin, 1972). In science, an example of an epistemic ideal is that an assertion is supported by experimental evidence. Scientists use this standard to conduct and assess research in their field. Reliable processes (including reliable and unreliable) are methods that may be used to achieve an epistemic aim. Chinn et al. (2014) provide the following example: “When scientific research is conducted, true beliefs are more likely to be produced when scientists employ the reliable process of carefully recording data (rather than relying only on memory)” (p. 437). A goal of this study was to understand students’ epistemic cognitions in research in order to explore their definitions of research and researchers, perceptions of the purpose of research, and beliefs about if/how they feel they are adding to knowledge.

3 | METHODS

We investigated students’ perceptions by administering an open-ended survey adapted from an instrument developed from previous work (Benson et al., 2018; Faber, Benson, et al., 2016; McAlister et al., 2017). Participant responses were collected through Qualtrics and coded to establish a codebook that was refined during analysis. Once all surveys were analyzed, the researchers organized the codes into groups and constructed themes by describing the relationship between grouped codes.

3.1 | Open-ended survey

Our survey included 16 open-ended prompts (see the Appendix) that were part of a larger survey (Benson et al., 2018; Faber, Benson, et al., 2016; McAlister et al., 2017). The prompts were informed by our previous work (Faber & Benson, 2015a, 2015b), where we developed and tested open-ended survey prompts to explore how students identify as researchers. We used open-ended surveys rather than interviews to collect a large number of responses from students with different research experiences across a range of institutions. The prompts aimed to capture participants’ perception of research, their views of themselves as researchers and their epistemic cognition in research (see Figure 1, which shows how we integrated our sensitizing concepts). Example items designed to capture each of these aspects are included in the list below.

- “Describe three ways in which you see yourself as a researcher.” (Researcher Identity)
- “In what ways do you feel like you are adding to the current knowledge in your field of research?” (Epistemic Cognition)
- “What is the purpose of research?” (Perception of Research)

We also included four demographic items to gain information about the participants’ backgrounds and to identify the extent to which our sample reflects our population in terms of race, gender, and major. The survey was distributed to potential participants through Qualtrics.

3.2 | Participants

We distributed our survey to mechanical engineering (ME) and biomedical engineering (BME) students at five institutions (Table 2) following our IRB-approved protocol.
ME and BME students were selected for recruitment because these programs are commonly available at universities across the United States and represent an older, more established discipline versus a newer, emerging one. These differences can manifest as different beliefs and assumptions about doing engineering and being an engineer (Godfrey & Parker, 2010). We recruited students who identified as having research experience from institutions that have a range of Carnegie Classifications™, settings, and profiles to capture responses about different types of research experiences. Department representatives at each institution distributed the survey via email to all undergraduate students in their department asking for students with research experience to participate. We allowed students to self-identify as having a research experience using their own definitions of research. As such, we did not include a definition of a research experience in the email script or survey. This allowed us to capture perceptions of students doing less formal UREs in addition to those who had participated in formal programs.

As documented in Table 2, a total of 154 participants submitted at least one answer to the open-ended survey, with 113 participants (73% of the 154 participants) completing the entire survey. However, responses from all 154 participants were used in our analysis regardless of survey completeness. In other words, we did not exclude the surveys of participants who did not respond to every item. This approach allowed us to capture the broadest representation of experiences from our sample and did not negatively impact our analysis since we did not analyze at the individual student level. A majority of the 113 completed responses were from Institution 1 (15%) and Institution 2 (50%). Institutions 3–5 represented 12, 11, and 12% of the responses, respectively. Demographic questions were located at the end of the survey; therefore, we do not have that information for those who did not complete the entire survey. Demographic information (gender, race, ethnicity, major, and year in school) for the 113 completed surveys is provided in Table 3. Comparing demographics of our study sample to demographics of the BME and ME departments at the institutions, we have an overrepresentation of females and BME majors. Reporting similar metrics for race and ethnicity is more difficult because of the differences in how we collected data compared to how each institution collects the same data. For example, we did not include Hispanic as an option, so participants who identified as Hispanic selected “other” and wrote in Hispanic. Likewise, the institution data we had access to did not break Asian into the subgroups (e.g., South Asian, East Asian, and Other Asian). Despite these differences, it appears that in our sample White and Asian are overrepresented, while Black and Hispanic are underrepresented. It is important to note that we compared our study sample to the demographics of BME and ME programs from which we recruited and not the demographics of the students participating in research in those programs as those
demographics were not available. We provide this demographic information to give context to our findings based on our sample. The demographics did not influence our interpretation of the data as all analysis was done on de-identified data.

### 3.3 Analysis

Qualitative data collected from open-ended survey prompts were analyzed using initial coding (Charmaz, 2014), also known as open-coding (Saldaña, 2015). Coding was performed by three team members: two graduate researchers and

| Demographic Information for our survey sample (n = 113) and the BME and ME programs that participated in our study (n = 113) |
|---|
| **Gender** | Percentages based on survey responses (%) | Percentages based on institution data (%) |
| Male | 59.3 | 81.1 |
| Female | 40.7 | 18.9 |

| **Major** | percent based on survey responses (%) | percent based on institution data (%) |
| ME | 37.2 | 74.6 |
| BME | 57.5 | 25.4 |
| Other | 4.4 | — |

| **Year** | percent based on survey responses (%) | percent based on institution data (%) |
| First year | 4.4 | — |
| Second year | 20.4 | — |
| Third year | 23.0 | — |
| Fourth year | 38.9 | — |
| Fifth year | 9.7 | — |
| Sixth year + | 3.5 | — |

| **Race and ethnicity** | Percentages based on survey responses (%) | Percentages based on institution data (%) |
| White | 68.1 | 53.0 |
| Black/African American | 1.8 | 4.4 |
| South Asian | 12.4 | 5.2 |
| East Asian | 11.5 | — |
| Other Asian | 2.7 | — |
| American Indian/Alaskan Native | 1.8 | 0.2 |
| Hispanic | — | 25.4 |
| Native Hawaiian/Pacific Islander | 0 | 0.12 |
| None given | — | 1.6 |
| Two or more races | — | 2.3 |
| Other a | 11.5 | — |

Note: Participants were able to select multiple race and ethnicity options, so the percentages add up to more than 100%. One participant did not indicate their major so the percentages do not add to 100%. The percentages based on institution data include data from 4 of the 5 institutions. One of the institutions does not collect demographic data for their students. “—” indicates that these data were not available.

Abbreviations: BME, biomedical engineering; ME, mechanical engineering.

aHispanic was not included in the race and ethnicity options on our survey. Participants who identified as Hispanic selected the “Other” option and wrote “Hispanic.”
one undergraduate researcher. The goal of the initial coding was to capture the range of ideas found in the responses related to epistemic cognition and identity. All coders read foundational literature regarding each of the concepts to ensure they had common understanding before coding. This approach allowed the coders to focus on the sensitizing concepts while being open to new ideas and theories that emerged from the data. To establish an initial codebook, the coders independently coded six randomly selected surveys containing completed responses to all survey questions. For these surveys, the coders first read through the participants’ responses to the open-ended survey prompts to familiarize themselves with each participant. Next, the researchers identified key phrases, or codes, related to students’ identity and epistemic cognition and developed in vivo codes, when appropriate, based on the participant’s own words, such as “studying unknown” and “problem-solving” (Charmaz, 2014; Saldaña, 2015). Each participant’s response to the open-ended prompts was examined individually. Once the coders finished coding the six transcripts, they compiled a list of codes and definitions. The coders then had multiple discussions to develop their understanding of the codes and their definitions. This round of coding resulted in an initial codebook.

To refine the initial codebook, the coders individually analyzed five additional surveys noting any questions and additional codes. Before discussing these questions and additional codes, the coders measured inter-rater reliability (IRR) to inform the discussion of specific codes and determine the consistency of code application among coders. Following measurement of IRR, the coders discussed the questions and additional codes noted during coding until they reached agreement, then modified the codebook as necessary. The IRR for this initial codebook refinement was lower than 80%; however, after two additional iterations, each including five new surveys, the coders were able to consistently achieve 80 to 90% IRR. Thus, a total of 21 surveys were used to refine the initial codebook (Figure 2). A detailed description of the refinement process for this initial codebook can be found in McAlister et al. (2017).

Once the refined codebook was established, all 154 surveys were analyzed using a collaborative coding approach. The first coder applied codes to the survey, the second coder checked the code applications including marking passages where there was disagreement with the code application, and the third coder reconciled disagreements by referring to code definitions and code application examples described in the codebook. If there was a clear code mis-application, the coders discussed proper application of the code and modified the codebook when necessary. If disagreements in coding were not a result of code mis-application, the third coder would discuss with the first two coders until they reached agreement. Throughout the coding process, each coder kept records of their thoughts and questions as recommended by Corbin and Strauss (2007) and Charmaz (2014) to document how codes were further developed. These records were invaluable for the reconciliation of disagreements in code application.

The process of subsequent code development was iterative and involved discussions between the coders and other members of the research team with the goal of eliminating inconsistencies. This resulted in the final codebook, which included 68 codes, 28 of which are directly aligned with the research questions that are the focus of this paper. Other research questions were explored in the larger research project using all 68 codes. A sample of the codebook with example codes, how they were applied, and sample quotes can be seen in Table 4, and a full list of codes is in Table 5. When codes are used in the text of this manuscript, they are italicized so they can be distinguished from participants’ quotes.

Once all open-ended survey responses were coded, the coders grouped codes into categories based on relationships or commonalities they observed. A summary of the theme generation process is shown in Figure 3.
The process of theme development was informed by axial coding to identify connections and relationships between the codes (Charmaz, 2014) and a constant comparison approach to identify similarities and differences across students (Corbin & Strauss, 2007). Through the processes of constant comparison and axial coding, the coders grouped codes into categories that they felt were related and aligned to the research question (Figure 3). These categories were refined through cross-comparison among survey responses. Coders gained some sense of the salient themes emerging from the data through describing the relationship between codes within each group. The coders developed themes by examining the relationship between code categories, the saliency of each code and category to our research question, and the frequency each code was used. In addition to coder discussions, the coders met with the larger research group to narrow the scope of the themes. This process resulted in the development of four themes that capture students’ perceptions of research and what it means to be a researcher: (a) research results in discovery, (b) research includes dissemination, (c) research findings are integrated into society, and (d) researchers demonstrate self-regulation. When used in the text of this paper, the themes will appear in bold italics. Table 5 shows how the codes mapped to our four themes. We will discuss each of these themes through the lenses of epistemic cognition and identity in the following sections.

| Code | Definition | What it is | What it is not | Sample quotes |
|------|------------|------------|----------------|---------------|
| Developing something novel/new | Discussion of ideas or technology that is novel or new | Developing ideas, theories, processes, devices, etc. that directly follow the words novel, new, or synonyms of those words; creating something | Not the improvement of a current idea, process, device, etc.; not unknown; not working with or on equipment that was recently purchased | “The purpose of research is to advance human knowledge of a concept or to develop a new idea that will be useful to humanity” [Participant 2-7] “A person who investigates new areas of interest.” [Participant 3-4] |
| Contributing to scientific community | Student discussion of making knowledge contribution to science | Contributing to the field of study or knowledge in general; propelling field forward; making progress in field or their own research | Not writing a paper or making a presentation; not helping the general community or society; not making progress in the context of a specific experiment | “To uncover the unknown and contribute to the current field of knowledge.” [Participant 3-3] “Research is the study and testing of a new, or already known technology, technique, etc. that will help progress a certain field of science.” [Participant 5-4] |
| Utility of research | The application of information, data, or ideas gained from research. Discussion of what student’s want to contribute to society | Solving current problems, or treatments; helping society | Not knowledge for knowledge’s sake | “In a university setting - the purpose [of research] seemed to be solely to gain knowledge, though the big picture was the curing of diabetes” [Participant 1-1] “To deepen the human body of knowledge for the benefit of humanity” [Participant 5-5] |

Table 4 Sample codes, definitions, and examples of their application from the codebook

3.4 Quality considerations

We used the Quality Framework (Q3) (Walther, Sochacka, & Kellam, 2013) to establish quality throughout the research process. This framework emphasizes establishing quality during data collection (making the data) and data analysis (handling the data). It also provides language to describe different types of quality considerations. We considered six
**Table 5** Summary of how codes mapped to specific themes related to students’ perceptions of what it means to do research and be a researcher

| Codes                                      | Research results in discovery | Research includes dissemination | Research findings are integrated into society | Researchers demonstrate self-regulation |
|--------------------------------------------|-------------------------------|---------------------------------|-----------------------------------------------|----------------------------------------|
| Having curiosity                           | X                             |                                 |                                               |                                        |
| Analyzing/comparing                        | X                             |                                 |                                               |                                        |
| Fit with current knowledge                 | X                             |                                 |                                               |                                        |
| Confirming what is known                   | X                             |                                 |                                               |                                        |
| Asking questions                           | X                             |                                 |                                               |                                        |
| Knowing more                               | X                             |                                 |                                               |                                        |
| Studying unknown                           | X                             |                                 |                                               |                                        |
| Constructing knowledge                     | X                             |                                 |                                               |                                        |
| Developing something novel/new             | X                             |                                 |                                               |                                        |
| Synthesizing ideas                         | X                             |                                 |                                               |                                        |
| Critical thinking                          | X                             |                                 |                                               |                                        |
| Being creative/innovative                  | X                             |                                 |                                               |                                        |
| Authorship                                 | X                             |                                 |                                               |                                        |
| Having communication skills                | X                             |                                 |                                               |                                        |
| Presenting to others                       | X                             |                                 |                                               |                                        |
| Contributing to scientific community       | X                             | X                               | X                                             |                                        |
| Wanting to apply knowledge/theory          | X                             |                                 |                                               |                                        |
| Improving process/product                  | X                             |                                 |                                               |                                        |
| Utility of research                        | X                             |                                 |                                               |                                        |
| Being focused                              | X                             |                                 |                                               |                                        |
| Being responsible                          | X                             |                                 |                                               |                                        |
| Exerting effort                            | X                             |                                 |                                               |                                        |
| Working hard                               | X                             |                                 |                                               |                                        |
| Having resilience and patience             | X                             |                                 |                                               |                                        |
| Challenging self                           | X                             |                                 |                                               |                                        |
| Working independently                      | X                             |                                 |                                               |                                        |
| Being meticulous                           | X                             |                                 |                                               |                                        |

**Figure 3** Overview of the process used to develop themes
quality types: theoretical validation, procedural validation, process reliability, communicative validation, pragmatic validation, and ethical validation.

### 3.4.1 Quality considerations embedded in making the data

The open-ended survey items were developed and assessed during a previous study (Faber & Benson, 2015a, 2015b). During that study, the questions were developed iteratively to ensure they provided information the researchers were interested in (communicative and procedural validation). All participant email addresses and other identifying information, such as advisor names, were removed from responses and replaced with pseudonyms to maintain the confidentiality of participants (ethical validation).

### 3.4.2 Quality considerations embedded in handling the data

Survey responses were analyzed using our sensitizing concepts of identity and epistemic cognition (process reliability, theoretical, and communicative validation). The collaboratively developed codebook was presented to research team members at multiple stages (refined and final) to gather feedback as a means of establishing reliability (theoretical, pragmatic, communicative, and procedural validation, and process reliability). The collaborative coding process included the coders challenging one another to more fully understand interpretations and explanations to ensure reliability and validity. These discussions resulted in the coders reaching consensus on the codebook (theoretical, pragmatic, communicative, and procedural validation, and process reliability). As an additional means to ensure reliability and validity, the coders measured IRR during codebook refinement (theoretical, communicative, and procedural validation, and process reliability). Codebook refinement was not considered complete until IRR was at least 80% across the coders (McAlister et al., 2017). Once complete, coders continued to ensure consistency in code application through collaborative coding.

### 3.4.3 Statement of the coders’ UREs

Two of the coders were graduate students and two were undergraduates at the time of this study. One graduate coder participated in undergraduate research in their third and fourth year in a molecular biology laboratory. This coder performed experiments, analyzed data, and presented research at national conferences. The second graduate coder did undergraduate research for 4 years in a ME laboratory. They were responsible for preparing samples, performing material tests, analyzing test results, and calculating test parameters. One of the undergraduate coders had a formal summer Research Experience for Undergraduates (REU) funded by the National Science Foundation at a different institution before joining this project. That experience was a traditional REU in a BME lab. The second undergraduate coder’s only experience with undergraduate research at the time of the coding was on this engineering education project.

### 3.5 Statistical analysis of themes across demographics and institutions

A common assumption about UREs may be that they are different across institution type, student’s academic year, academic major, and/or gender. To address this assumption, we examined our data for trends in the themes for various groups using chi-squared tests for independence and Fisher’s exact tests. While this analysis approach is in contrast to the interpretive analyses described in this study, we believe it is the most appropriate method to check our assumptions about our participants’ experiences. We started the analysis by mapping our qualitative codes to each theme (shown in Table 5) and used them as indicators of the presence of themes in each student response. For example, if the code *authorship*, which was mapped to the theme *research includes dissemination*, was applied to a participant response, that theme was considered present in that participant's response. Once a theme was identified as present in a participant's response, we did not look for evidence of that theme in their response again. The theme was either present or not present in a participant's response; there was no weight nor quantification of the number of times it was present for a single participant. Themes were considered independent of each other as the presence of one theme did not influence the presence of another. As some of the counts within specific groups were low (fewer than five participants within a
specific group), Fisher's exact tests were also run for each theme and demographic combination (Ott & Longnecker, 2010). Analyses were run using JMP statistical software (JMP®, 2019).

The p-values for the chi-squared tests for independence across all themes and all demographics were not significant except for the theme research findings are integrated into society by years in college (p = 0.028). However, Fisher’s exact test for this combination indicated that this was not statistically significant at the α = 0.05 level (p = 0.103). The results from chi-squared and Fisher's exact tests indicated that the presence of any of the themes was not dependent on the participants' institution, major, years in college, or gender. Thus, no statistical relationships were observed between students' perceptions and their institutions or demographics; therefore, we have no evidence to suggest that there are differences across our themes based on these characteristics of our participants.

3.6 | Limitations

Although participants identified factors that affect their researcher identity formation, how they constructed these ideas remains unclear. While participants described what they believe a researcher is and numerous instances where they felt like a researcher, our data did not include descriptions of how they came to these realizations. Furthermore, due to the inherent one-way communication of a survey, we were unable to clarify ambiguous or vague answers provided by participants. Therefore, complex concepts like the origins of students' perceptions of a researcher and their epistemologies were difficult to discern.

Given the goal of this study to better understand how undergraduate BME and ME students conceptualize what it means to do research and be a researcher, some aspects of this study may not transfer to other engineering programs or elements may be missing from our data. Additionally, because not all institutions have centralized undergraduate research programs and often students participate in experiences at other institutions, it is difficult for us to know the exact response rate on this survey (number of respondents out of the total possible number of students participating in UREs) or how our study sample compares demographically to the population of students who participate in a URE at each institution. Given the lack of students who identified as Hispanic and/or Black in our data and the influence of salient social identities on other identities (Jones & Mcewen, 2000), it is important to note that our results may not translate to these or other nonrepresented populations. Furthermore, we cannot speak to how the social identities of the individuals with whom the participants worked or interacted with in research (e.g., research mentors, peers, individuals at conferences) may influence our participants' perceptions of researchers and themselves as researchers, a consideration which may be especially important for participants who have a salient social identity that is underrepresented, such as a woman of color. A majority of the participants (67%) were from the two Research University/Very High (based on the Carnegie Classification™ shown in Table 2) institutions, which could lead to a biasing of results toward the types and amount of research conducted at these institutions. We attempted to address this limitation by identifying the institutions for participants whose responses are quoted in the results to demonstrate the breadth of types of research experiences represented by those quotes (Participant [participant number]—[institution number]; e.g., Participant 5-3 is the fifth unique participant from Institution 3 mentioned in the text). Finally, since response to the survey was voluntary, those who responded may not be representative of the general population of ME and BME students with research experience. This may have introduced volunteer bias, wherein individuals with strong opinions are overrepresented, and those with low interest in the topic of the survey may be underrepresented (Salkind, 2010).

4 | RESULTS

Through our analysis of the open-ended survey responses, we identified four themes that encompass how students conceptualize research and what it means to be a researcher. In the following section, we describe each of the themes: (a) research results in discovery, (b) research includes dissemination, (c) research findings are integrated into society, and (d) researchers demonstrate self-regulation. As a reminder, when codes are used in the text, they are italicized so they can be distinguished from participants' quotes, and themes appear in bold italics.

4.1 | Research results in discovery

Participants described research in a way that expressed the importance of discovery which included developing something novel/new, studying the unknown, confirming what is known, and constructing knowledge. These
descriptions included mentions of new methods, techniques, products, ideas, or theories. Participants described the purpose of research as discovery, or as Participant 1-3 stated “doing something never done before.” Likewise, other participants conceptualized research as a process of generating new knowledge in the field through novel results. As Participant 1-4 said, the purpose of research is “to establish or generate new facts or conclusions.” Furthermore, Participant 3-2’s statement, “the purpose of research is to explore a field and to offer new information to the scientific community, be it correct or not,” highlights the idea that there is value in new information independent of its correctness.

The theme research results in discovery was not isolated to participants’ descriptions of the purpose of research but also showed up in their explanations of when they first felt like a researcher. For example, Participant 4-3 felt like a researcher “after completing [their] second research experience and generating new scientific data.”

Additionally, we saw the theme present in two different ways in participants’ explanations about whether they were contributing to the field. The first was that participants expressed that they did not feel like they were contributing to the field because they were staying within what is already known or repeating experiments rather than seeking something new. Participant 2-3 expressed this sentiment by stating that they “feel like [their] research has probably been done already on a similar scale elsewhere.” Similarly, Participant 2-5 explained: “I’m not doing any groundbreaking work, simply applying previously discovered phenomena to new setups. I’m simply experimentally validating what we already know exists.” Other participants identified repeating experiments and confirming what is known as ways to contribute to the field. For example, Participant 2-4 stated, “I feel as I am adding to my field of research because when I did my experiments, I got similar results or data as those who did the experiment previously.”

Research results in discovery was a salient theme because of its prominence in students’ perceptions of research, views of themselves as researchers, and beliefs about their contribution to the field. This theme was not present in a singular manner across all participants, with some viewing new or novel as a requirement and others recognizing the value in verifying existing knowledge.

4.2 Research includes dissemination

Another theme that appeared throughout participants’ responses was research includes dissemination. Within this theme, participants discussed the importance of presenting to others, authorship of research results, and contributing to the science community. These ideas were present in participants’ descriptions of the purpose of research. For example, Participant 1-2 described that the purpose of research is “to provide descriptive accounts of investigations in order to allow for someone else to be able to repeat those finding[s].” This example demonstrates how dissemination of research is a way to carry out a core element of the research process: repeatability.

We also saw this theme present in participants’ descriptions of how or when they felt recognized as a researcher. The opportunity to present research provided participants an opportunity for others to see their work and their accomplishments. Participant 1-5 described how presenting provided a space for others to see and recognize their work and for them to communicate results, which is part of the purpose of research: “I worked really hard on [my presentation] and it was nice that other people saw how hard I worked and I was able to communicate what I did. The communication of research results is as important as the research itself.” Participants felt recognized through disseminating their work, from both those who were and were not familiar with it. For example, Participant 2-6 described, “I believe I felt recognized as a researcher when I was allowed to present at the spring expo. Presenting gave me a new perspective on my work and helped me think of ways to convey the information to people who might not be familiar with it.”

Additionally, we saw the theme research includes dissemination in participants’ descriptions of their contributions to knowledge in their field. Participant 3-1 stated simply, “Presentations at conferences and publications are the bridge between me and the scientific community.” Participants who had not been able to publish or present their work did not feel like they were contributing to the field because there was no way for others in the field to know about their work. For example, Participant 1-2 stated, “I haven’t published anything yet, so no one knows what I’m doing besides those in my lab.”

Research includes dissemination was a salient theme across participants’ responses because it was identified throughout participants’ descriptions of the purpose of research, how they were recognized as researchers, and their beliefs about their contribution to the field. This theme presented in a similar manner across all participants; there were no cases in which participants described dissemination in a way that was counter to other participants.
4.3 | Research findings are integrated into society

The theme *research findings are integrated into society* expands on the previous theme, *research includes dissemination*, but is more focused on who benefits from the research and to whom the work is disseminated.

Participants described the purpose of research as contributing to society, whether through the *utility of their research, improving a process or product*, or that they *contribute to the science community*. They believed research should be shared not only with the scientific community but with society more broadly. Participant 4-2’s statement exemplifies these altruistic goals of the participants: “The purpose of research is to better humanity.” In participants’ descriptions of the purpose of research, we also saw cases of overlap between participants’ views of research as novel or new and their belief that is should be integrated with society. For example, Participant 2-7 believed that the purpose of research is to “advance human knowledge of a concept or to develop a new idea that will be useful to humanity.”

Additionally, we saw *research findings are integrated into society* in participants’ descriptions of themselves as researchers. Participant 1-6 saw themselves as a researcher because “I work to make a product/difference.” We also saw counter examples in which participants did not feel like researchers because they did not see their work contributing to society. Participant 1-8 described not feeling like a researcher because the work they are doing had already been done before: “I didn’t do much to help society, I was more confirming what was known.”

Finally, we saw this theme in participants’ descriptions of how much they saw their work making a contribution to the knowledge in the field based on the type of experience (e.g., academia, industry, confirmatory study, etc.). For example, Participant 1-1 described that their work might not benefit society as much as it could because it is in the context of industry:

> Unfortunately because I work in industry, the knowledge gained by work in my department does not leave the company. Because of patents, secrecy, and the over-arching goal of maximizing profit, the customer who needs our products doesn’t benefit as much as say if we had been working in academia, where published findings become public knowledge and may directly benefit other researchers working in a similar area.

The theme *research findings are integrated into society* was salient across participants’ descriptions of the purpose of research, views of themselves as researchers, and beliefs about their contribution to knowledge in the field. Like *research includes dissemination*, this theme was presented in a similar manner across all participants in that there were no cases in which participants described integrating research into society in a way that was counter to other participants.

4.4 | Researchers demonstrate self-regulation

The final salient theme that we identified across participants’ responses was *researchers demonstrate self-regulation*, which included specific traits needed by researchers. This theme appeared in participants’ descriptions of a researcher, from which we generated a list of character traits including *having a desire/motivation to learn*, *being meticulous, being studious, having resilience and persistence*, and *working independently*. All of these traits align with descriptions of self-regulated learners who are highly motivated to learn, exhibit vigilance in the strategies they use, and independently seek out and benefit from opportunities to learn (Zimmerman, 1990). For example, Participant 1-1 described a researcher as “Curious. Problem-solving. Ambitious. Always eager to learn new things. Not easily deterred by failure. A willingness to ask questions.” This theme also appeared in participants’ descriptions of their research project. For example, Participant 2-8 stated, “It is a very ambiguous process of defining what you want to get done. It takes a lot of self-motivation and time management skills. There are no deliverables like in the classroom; you have to make your own.”

We also identified this theme in participants’ descriptions of when they started feeling like a researcher, primarily through autonomy and independence. Participants perceived researchers as making autonomous decisions, a perception which made a direct connection between participants’ level of independence and how participants viewed themselves as researchers. Participant 5-1 focused on the independence they are given in lab: “I started feeling much more like a researcher when I reached a level where I was much more independent in my work. When you are not independent, you feel much more like a student instead.” In the same way, when a participant is not given the autonomy to regulate their own research, they often do not identify themselves as researchers. Participant 1-7 said they do not feel
like a researcher because “[a]t this point, I do a lot of what my supervisors tell me to do.” To a lesser extent, we also saw participants connect their own researcher identities to other aspects of self-regulation. For example, in response to “In what way do you see yourself as a researcher,” Participant 5-4 responded, “I work hard for what I want in life.”

**Researchers demonstrate self-regulation** is a salient theme in participants’ descriptions of who researchers are, what research is, and the ways they see themselves as a researcher. Within this theme, the most prominent idea was the connection between a participant’s independence and autonomy in their research to their researcher identity.

5 | DISCUSSION

Prior studies of student perspectives of research primarily focus on their awareness of opportunities (Bangera & Brownell, 2014; Healey, Jordan, Pell, & Short, 2010) and perceived benefits or challenges to participating (Kardash, 2000; Laursen et al., 2010; Sadler, Burgin, McKinney, & Ponjuan, 2009). Additionally, other studies of UREs focus on the needs of students from the perspective of research mentors, for example, the skills and knowledge students need to conduct research (Kardash, 2000; Linn et al., 2015). These studies have called for research mentors to support students in their development of research capabilities through specific activities like reading the literature and presenting their work, recognizing that “students need guidance to understand the rationale, research design, and contribution to the field” (Linn et al., 2015, pp. 1261757–4). While these approaches will affect students’ interpretations of what it means to do research and be a researcher, these studies do not capture students’ resulting perceptions of research because the studies took a research mentor-driven approach to defining research and the research process. To date, few studies explore students’ perceptions of what research is and what it means to be a researcher. A study conducted by Woodcock, Graziano, Branch, Ngambeki, and Evangelou (2012) quantitatively assessed students’ beliefs about research and researchers to inform their model predicting students’ intentions to pursue research-related careers. These researchers created survey items that reflected various aspects of research and researchers, and, through factor analysis, developed seven composites of characteristic beliefs about the nature of research: innovative and transformative, collaborative and creative, repetitive analysis and lab work, practical and imaginative, detailed and systematic, working toward an end goal, and a process of discovery. Our findings align with one of Woodcock et al.’s (2012) findings, namely that one of the most commonly held student beliefs about research is that it involves discovery. However, a key difference between their study and ours is that we did not pre-determine characteristics of students’ beliefs about research and researchers. An additional study exploring undergraduate chemistry students’ perceptions of research activities and outcomes of research focused on students’ misconceptions and to what extent those misconceptions change over the course of a summer URE (Cartrette & Melroe-Lehrman, 2012). This work focused on science students currently in a summer 10-week URE, and as such, the students viewed research as being similar to what they do in their laboratory courses. Our study builds on this work in two ways: (a) our population was not limited to summer URE participants as students self-identified as participating in research, allowing for a broader range of types of research experiences and (b) the context of our study was engineering students who may not identify the same connection as science students between the ability to conduct research and the skills and knowledge they are developing for their future careers. This relationship parallels the ongoing tension perceived in engineering education between including professional training and research in engineering curricula (Magnell & Geschwind, 2019). Our study complements Cartrette and Melroe-Lehrman’s (2012) research in that it sought to further fill the gap related to student perceptions of research through a focus on researcher identity and epistemic cognition.

Within the theme **research results in discovery**, many participants perceived research as getting new results and identifying something in the field that no one else has discovered. These perceptions connect to epistemic resources from physics education. Within that research, epistemologies are made up of a combination of fine-grained epistemic resources, which are activated in response to specific contexts (Hammer & Elby, 2003). In the context of their research experiences, participants activated the epistemic resource “research knowledge is novel or new.” These participants’ researcher identities were tied to this epistemic resource; therefore, if their work was not novel or new, they felt they were not researchers. Given participants were relatively new to their research fields, they may not have developed the epistemic resources to determine if and how their work was novel, potentially limiting how they saw themselves as researchers.

Certain participants who perceived research as novel or new only saw themselves as contributing to the field if they produced new results. In many ways, this is a limited view of the value and purpose of research; confirming others’ results is a critical aspect of scientific studies. These ideas relate to epistemic cognition as they reveal that some participants may have a limited view of how knowledge is constructed in their discipline, believing that only one research
group needs to produce a result for it to be considered knowledge in the field. Students whose perception of research included confirming what is known felt they were contributing to the knowledge in their field by repeating studies that had already been done, indicating a more expansive view of how knowledge is constructed (i.e., through consensus or confirmation). This idea is similar to the epistemic resource of “checking” (Hammer & Elby, 2003) in which the participant is checking the knowledge of others by repeating their experiments. In summary, research results in discovery demonstrates connections between a student’s epistemic cognition (the idea that new knowledge has more value than knowledge that reinforces or confirms what is already known), their perception of research (research as novel or new), and their researcher identity (the extent to which their research contributes to knowledge in their field).

The theme of research includes dissemination demonstrates how research practice can impact students’ researcher identities and provides insight into students’ epistemic cognitions in the context of research. Perceived recognition from others is a key component of identity development that has been included in engineering identity research (Godwin, 2016; Tonso, 2006). Our participants saw dissemination as a way of presenting their research findings to the scientific community and actively contributing to it. Participant 3–2’s earlier quote shows they recognize the value of presenting both positive and negative results to the research community because it allows other researchers to evaluate the work and build from it. This is an example of how dissemination can be a process to achieve the epistemic aim of having one’s work evaluated for validity or expanded on by others. Subsequently, it leads to recognition of one’s work and identity development as a researcher.

The theme research findings are integrated into society suggests that these participants see research as a way of adding knowledge to society (an epistemic aim) and as something that should be presented to others such that results can reach a broader audience. If this is not being done, these participants think less of themselves as researchers because their identity as a researcher is related to how well they are meeting their perceived purpose of research. This is another example of the interactions between epistemic cognition and researcher identity as participants’ researcher identity was affected by how well they meet the epistemic aims of research. It is possible that these notions are also linked to the participants’ engineering identity. Engineering is often defined and differentiated from other activities based on its orientation to serve the public which is captured in documents such as the National Society of Professional Engineers (2019) Code of Ethics for Engineers. It is possible that our participants coupled their researcher and engineering identity in this theme.

The final theme, researchers demonstrate self-regulation, suggests that participants understand that researchers need to have specific traits and/or skills that align with the research environment. Additionally, we see evidence that some participants identify core differences between research and classroom environments, differences which influence the traits and/or skills that are needed to be a researcher. This finding about the importance of context aligns with theories of situated learning (Lave & Wenger, 1991) and epistemic cognition (Berland & Crucet, 2016; Chinn et al., 2014; Faber, Vargas, & Benson, 2016), which also reflect the importance of context and situation for student development. More specifically, research in epistemic cognition suggests that differing contexts activate and reinforce specific epistemic practices, processes, and/or ideas (Elby & Hammer, 2010; Sandoval, 2005). For example, in the context of undergraduate research, students are given the opportunity to construct knowledge, a situation which is different from many classroom environments where knowledge is transferred to students by an authority. By their nature, these two contexts require that students activate different epistemic practices, processes, and ideas to be productive.

Related to identity and self-regulation, if students perceive an intersection of their identities with being a researcher, self-regulation can increase; however, if the intersection creates a place of dissonance, self-regulation may decrease. This concept relates to the self-determination theory (SDT) perspective of self and identity. Through the lens of SDT, the self represents a growth trajectory for an individual, and identity includes different characteristics that are both dispositions and reactions to social contexts (Soenens & Vansteenkiste, 2011). If identity and the self align, there will be optimal functioning (i.e., self-regulation) in whatever context the alignment occurs (Soenens & Vansteenkiste, 2011). The same is true for our participants: identity congruence (alignment between one’s identity and self) as researchers can lead to self-regulation in the research environment.

5.1 Implications for practice

Our participants often conceptualized research as acquiring new knowledge and making new discoveries and developments. Thus, it may be helpful in building students’ researcher identities for mentors, advisors, and engineering educators broadly to highlight aspects of discovery in their academic pursuits, including research experiences, course work, and internships. To expand students’ perceptions of research and researchers, mentors and advisors could foster projects that help students
find value in research practices beyond discovery, such as replicating and validating previous results (Price, 2011), and in turn supporting students’ development of new epistemic standards with which to evaluate research.

Many participants felt more like researchers when they disseminated their results, thus having access to forums for presenting their work is an important part of students’ research experience. This suggests that mentors should provide opportunities for students to present research findings at national conferences and departmental seminars, or in their research group meetings. Some participants felt that disseminating research findings should clearly impact society to fulfill the purpose of research. Therefore, to help build stronger researcher identities and to reinforce student attitudes about societal benefits of engineering more broadly (a key goal in engineering education; Litchfield & Javernick-Will, 2015), research mentors should help undergraduate students identify the impacts of their research results by mapping how the research will directly or indirectly affect specific groups or communities. In large or complex research groups, it may be appropriate for the principal investigator to explicitly inform those working with undergraduate students such as graduate students or postdoctoral researchers of the importance of connecting the students’ work with the broader context or motivation for their research.

Finally, participants believed that a researcher should embody many aspects of self-regulation. Participants discussed how being given independence to make their own decisions or to do their own research was a key aspect of developing their researcher identity. Participants also discussed how a lack of autonomy leads them to not feel like a researcher. Subsequently, it is important to allow students some independence during their research experiences for them to develop strong researcher identities. There are several options available to research mentors to provide this independence, including allowing students to either develop or codevelop their own research questions at the beginning of their URE and to develop additional research questions.

Beyond the laboratory research experience, this study has implications for instructional practice as well. These findings, particularly because they are from the student’s perspective, address the need to translate high-impact practices into traditional classroom environments (Kuh, 2008) to realize the benefits that students are identifying from UREs. Aspects of the themes observed in this study could be introduced into assignments, projects, and in-class activities to better align the goals of the scientific and classroom communities so that students can meaningfully engage in scientific practices in the classroom (Berland, 2016). For example, within the theme research includes dissemination, students described the importance of presenting to others, authorship of research results, and contributing to the science community. With this in mind, instructors could incorporate cooperative learning opportunities such as a jigsaw activity that allow students to present what they have learned to their peers. Exercising autonomy is included in the theme researchers demonstrate self-regulation, which, based on self-determination theory, can enhance students’ academic achievement (Pintrich & DeGroot, 1990). Instructors might consider allowing students to choose from a list of potential project topics or to develop project topics of their own from the course content. To address the theme research findings are integrated into society, open-ended engineering problems could incorporate current topics, for example, modeling data or developing a design related to a local infrastructure project. When introducing such projects, the instructor should explicitly point out how course content and skills needed to complete the problem can benefit society.

5.2 Implications for future research

The implications for research relate to the questions that arise from examining students’ beliefs about knowledge in research and descriptions of themselves as researchers. Future research should focus on how students develop their ideas about knowledge in their field—what it means to know something, where knowledge comes from, and who can create that knowledge. Through this study, we identified different ways that students conceptualize research; however, future research should aim to understand why and how these different conceptualizations emerge. It would be particularly helpful to understand how aspects of research group interactions combined with research practices and types of research contribute to a student’s beliefs about knowledge in their field. These findings could then be translated to inform training associated with UREs and classroom practices to begin to align these experiences with the epistemic practices and beliefs within the larger field.

Additionally, this study and other work in engineering education (Danielak, Gupta, & Elby, 2014) have begun to show the connections between students’ identities and epistemology. Future research should continue exploring the connections to further define this specific relationship and investigate differences that might emerge based on context (e.g., classroom environment vs. research environment). Such investigations would provide insights into designing learning experiences that help students see themselves as contributing to their field and to society in general.
Another important aspect of our findings, which extends beyond epistemology and identity, relates to students’ ideas about the importance of negative research results. In typical educational practices, students are conditioned to focus on success through grades, recognition for achieving a positive project or research result, or confirming results from previous experiments. This finding has implications for ongoing research into students’ responses to failure (Kapur, 2014) academic shame (Huff, Shanachilubwa, & Secules, 2018; Turner & Husman, 2008), and resilience (Hernandez, Schultz, Estrada, Woodcock, & Chance, 2013). These future research directions will extend this study and the potential impact of undergraduate research on the student experience.

6 | CONCLUSIONS

UREs are multifaceted experiences with the potential to impact students’ researcher identities and epistemic cognition. Through our research, we developed four themes that include how students conceptualize research and what it means to be a researcher: (a) research results in discovery, (b) research includes dissemination, (c) research findings are integrated into society, and (d) researchers demonstrate self-regulation. Within these themes, our participants expressed a range of perceptions of research and researchers. Some students’ perceptions of research directly related to how they see themselves as discovering something new, and others recognized their role in confirming what is already known. Disseminating research findings was seen as a way to benefit society as well as feel recognized as a researcher. Focusing on these aspects of UREs could help to enhance research experiences for students, allowing them to develop epistemic cognition and identities as researchers. Additionally, as described previously, there are opportunities to translate these findings into other student experiences so that the benefits of UREs are more accessible as UREs have traditionally been limited.

Across the four themes, we see multiple connections between students’ perceptions of research, of themselves as researchers (researcher identity), and of knowledge (epistemic cognition). Our team is continuing this work to further explore how students develop as researchers through research experiences as it relates to their identities and epistemic cognition in hopes of making the benefits of UREs more accessible. Specifically, we are seeking ways to translate and propagate our findings into traditional classrooms to the benefit of all students, including those who are not afforded the opportunity to be involved with formal UREs. The benefits of UREs are vast (e.g., increasing persistence in STEM, developing research skills, growing knowledge of a discipline, etc.), and through our research, we hope to expand the reach of their impact.

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APPENDIX A.: OPEN-ENDED SURVEY PROMPTS

1. When did you start doing research?
2. Why did you start doing research?
3. How would you describe the research projects you have worked on to a classmate who is unfamiliar with the work?
4. What is research?
5. What is the purpose of research?
6. What makes someone a researcher?
7. Describe the characteristics of a researcher.
8. Do you see yourself as a researcher? (7-point anchored scale from “No, not at all” to “Yes, very much”)
   a. If participant selected “No, not at all,” the following question appeared
      i. Why don’t you see yourself as a researcher?
   b. If participant selected anything other than “No, not at all,” the following questions appeared
      i. When did you start feeling like a researcher?
      ii. Describe three ways in which you see yourself as a researcher.
      iii. Describe a scenario/experience in which you felt recognized as a researcher. (If you haven’t had a scenario/experience where you have been recognized as a researcher, state so.)

   iv. Please describe the three most crucial influences on your development as a researcher in order of most to least important.
9. Do you feel like you are adding to the current knowledge in your field of research? (7-point anchored scale from “No, not at all” to “Yes, very much”)
   a. If participant selected “No, not at all,” the following question appeared
      i. In what ways don’t you feel like you are adding to the current knowledge in your field of research?
   b. If participant selected anything other than “No, not at all,” the following questions appeared
      i. In what ways do you feel like you are adding to the current knowledge in your field of research?