

Transformation through Research: Undergraduate Research Experiences and Learning Pathways in Electrical Engineering

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Abstract

In this exploratory pilot study, we apply Transformative Learning Theory to examine how undergraduate electrical engineering students describe learning through research that either reshapes how they understand engineering practice or strengthens skills without substantially changing prior expectations. Undergraduate research experiences are widely valued, but existing studies often rely on self-reports and provide limited theoretical explanation for why similar opportunities may produce different kinds of learning. We draw on two semi-structured interviews and descriptive survey context from nine submitted responses (four complete and five partial/background-only) to examine two learning pathways: transformative learning and informative learning. We offer a theory-informed interpretation of how these pathways appeared in this preliminary sample and identify tentative implications for equitable undergraduate research integration within an R1 electrical and computer engineering department engaged in an NSF Revolutionizing Engineering Departments initiative.

Introduction

Undergraduate research experiences are often positioned as a high-impact pathway for skill development, career self-efficacy, and identity development. At the same time, reviews of existing research note that much of what we know about undergraduate research rests on student self-reports, with fewer studies validating reported gains with direct measures or longitudinal evidence. This leaves open a practical question for departments: when students describe research as life-changing, what is changing, and why do some students leave research with new ways of thinking while others leave with strong skills and steady perspectives? Linn and colleagues highlight these methodological and design challenges and call for more systematic studies that can distinguish effective and ineffective aspects of research experiences. [1]

We are motivated to address this problem by using Transformative Learning Theory (TLT) to interpret how students make sense of learning through research. TLT distinguishes informative learning, which adds knowledge and skills to an existing frame, from transformative learning, which changes the frame itself. Mezirow describes transformation as beginning with disorienting dilemmas that surface limits in current assumptions, followed by critical reflection and integration of new meaning perspectives. [4] Hoggan extends this view by describing transformation across domains such as epistemology, self, behavior, and capacity. [5] Engineering education scholarship has begun to consider TLT, but Tong and colleagues note that empirical applications in engineering remain limited. [6]

This study is a pilot implementation of Transformative Learning Theory to examine UREs and is initiated by an undergraduate researcher at the University of South Florida within a Participatory Action Research (PAR) initiative to promote student-led educational research. Our focus is on undergraduate electrical engineering researchers at the University of South Florida, a large public R1 university engaged in a department change initiative. The contribution of this pilot is not to estimate the prevalence of learning pathways across the department, but to show how TLT can help distinguish qualitatively different forms of learning reported within undergraduate

research and to identify contextual conditions that may shape them. We ask: (1) How do students describe learning through research in ways that align with transformative or informative learning? (2) What conditions appear to shape which pathway students experience? and (3) What access patterns and barriers matter when research opportunities may support deep shifts, not only skill building?

Literature Review

Large-scale, multi-institutional studies consistently report that students value undergraduate research and associate it with confidence, persistence, and career intentions. For example, Lopatto reports that students commonly describe gains in understanding and motivation, and Russell et al. report broad impacts on participation and career-related benefits [2], [3]. At the same time, the evidence base remains constrained by the dominance of self-report approaches and by limited theorization of mechanisms. [1] Work examining multi-year participation suggests that duration and experience level can relate to the kinds of gains students report, but it also points to the need to understand trajectories and developmental conditions rather than assuming uniform outcomes. [7]

Within this literature, questions about how research becomes transformative are rarely addressed directly. TLT provides language for examining whether students are adding to what they already know or reconstructing how they understand engineering work. Hoggan's typology is useful here because it allows analysis of transformation across domains, including epistemological shifts in how knowledge is produced, as well as shifts in self and behavior. [5] This study uses TLT to interpret undergraduate researchers' accounts as a way to contribute a process-oriented perspective to undergraduate research.

Theoretical Framework

We use Transformative Learning Theory to differentiate two kinds of learning outcomes in undergraduate research. Following Mezirow, we attend to moments students describe as disorienting, the forms of reflection they report, and whether they describe adopting new meaning perspectives that reorganize how they interpret research and engineering practice. [4] We also use Hoggan's domains to describe where transformation appears to occur, such as epistemology, self, behavior, and capacity. [5] Our analytic intent is not to label participants as transformed or not, but to describe how their narratives reflect different learning pathways and what conditions appear to support each pathway.

Context and Research Methodology

Institutional and Program Context

This study is situated within the Electrical and Computer Engineering (ECE) department at the University of South Florida, a large public R1 university. The department is engaged in a multi-year NSF Revolutionizing Engineering Departments (RED) initiative examining departmental culture, structures, and learning pathways. Undergraduate research occurs through faculty-led laboratories, externally funded REUs, and informal extracurricular arrangements, but access to these opportunities is uneven. In practice, students often enter research by emailing individual faculty members directly or by learning about openings through peers, class exposure, or

department communication, and participation may be paid, credit-bearing, or unpaid depending on lab resources.

The study was conducted within a Participatory Action Research (PAR) initiative that supports student-led inquiry into educational practices. This framing shaped the study's focus on student meaning-making and access rather than programmatic inquiry.

Research Design

This paper reports findings from a qualitative pilot study examining how undergraduate electrical engineering students describe learning through research and how those descriptions align with transformative or informative learning pathways. Transformative Learning Theory (TLT) provides the analytic framework, allowing attention to changes in students' assumptions about engineering practice, knowledge production, and professional identity.

The pilot design prioritizes depth and theory development over generalizability and is intended to inform a subsequent, larger-scale study. Ethical approval was obtained from the university's Institutional Review Board for the PAR program, and this specific study was determined by the university's review board to be a quality improvement project.

Participants and Data Collection

Participants were undergraduate ECE students recruited through departmental mailing lists and informal research networks. A brief survey was distributed to collect background information on research participation, awareness of opportunities, and perceived barriers. The survey yielded nine submitted responses, including four complete responses and five partial responses that still provided usable background information. Survey data were used in two ways in this paper: first, to inform interview sampling and question design; and second, to provide limited descriptive context for the qualitative findings. Because of the small sample and partial-response pattern, survey results are reported descriptively only and are not used for inferential claims.

Table 1. Descriptive survey context for submitted responses.

Measure	Count	Notes
Submitted survey responses	9	4 complete; 5 partial but usable for background context
Interview participants	2	Both had undergraduate research experience
Faculty-led research selections	5	Across all submitted survey responses
Course-based research/service-	2	Across all submitted survey responses

learning selections		
Complete respondents agreeing research helps career	4 of 4	Descriptive only
Complete respondents disagreeing research is easy to find/apply for	3 of 4	Descriptive only

Two students with undergraduate research experience participated in semi-structured interviews lasting 45–60 minutes. Interview questions elicited expectations of research, descriptions of research activities, moments of challenge or surprise, mentoring interactions, and perceived impacts on thinking, identity, and future plans. Interviews were audio-recorded and transcribed verbatim by the first author (undergraduate student researcher).

Data Analysis

Interview transcripts were analyzed using theory-informed thematic analysis. In a first stage, the first author coded each transcript for expectations, challenge, mentoring, reflection, reported skills, and perceived impacts on identity or future plans. In a second stage, these codes were interpreted through Mezirow's concepts of disorienting dilemmas and perspective transformation and Hoggan's domains of transformation, including epistemology, self, behavior, and capacity. Cross-case comparison was then used to examine how similar features of research experience, such as ambiguity, troubleshooting, and mentoring, were interpreted differently by the two participants. The first author discussed emerging interpretations with the research mentor (second author) and peer undergraduate researchers leading their own studies, who acted as 'critical friends' [8] to question assumptions and refine theme boundaries.

Rather than categorizing participants as simply transformed or not transformed, the analysis examined patterns of meaning-making that were more consistent with transformative or informative learning pathways and the contextual conditions shaping those pathways. Survey results were summarized descriptively to contextualize the interview themes related to access, participation patterns, and perceived barriers.

Trustworthiness

Analytic memos were used to document interpretive decisions and support reflexivity, particularly given the first author's insider status as an undergraduate researcher within the department. Direct quotations were used to ground interpretations in participants' language. Emerging interpretations were also discussed with the research mentor and peer undergraduate researchers acting as critical friends to question assumptions and refine theme boundaries.

Results

Across two interviews, students described research as valuable, but in qualitatively different ways. One student described an epistemological shift in how they understand research practice, while another described strong skill development and informed career decision-making without a comparable shift in their underlying expectations. Descriptive survey results provide limited context for these accounts. Across the nine submitted surveys, five respondents reported faculty-led research, two reported course-based research or service-learning, and one reported independent or extracurricular research; among the four complete responses, all agreed that undergraduate research would help their careers, while three of four disagreed that finding and applying for research was easy. These descriptive patterns do not establish prevalence, but they do align with the interview emphasis on value, uneven access, and differing developmental outcomes. Below, we identify four themes that capture these differences and the conditions students associated with them.

Two legitimate learning pathways: transformative and informative

Both participants described positive research experiences, yet their accounts diverged in whether research reshaped their frame for engineering practice. Participant 1 described a shift from viewing research as primarily intuitive to seeing it as systematic, and that shift carried into how they approached technical problems. Participant 2, by contrast, described the research as largely matching prior expectations and emphasized skill development, interview confidence, and clearer career decision-making rather than a reconstructed view of engineering knowledge.

I didn't think researchers did [methodical work], I think it was just something like 'Oh I have an idea, so I'm just gonna try it and hopefully it works' [P1]

Now it's kind of like it's very methodical trial and error. It's like you do some research, like you do like literature review and you like start to read stuff and you know you come up with like ideas and theories and then you test it. [P1]

I would say pretty much what it was... pretty much working on my own most of the time, which was that and figuring out stuff, reading a lot of research papers... So yeah, it was pretty much what I was expecting. [P2]

Disorienting dilemmas only matter when they create cognitive dissonance

Both students described challenges, ambiguity, and iterative troubleshooting. What appeared to distinguish their trajectories was whether those challenges contradicted their starting assumptions about how research works. Participant 1 entered with little understanding of research, and early struggles unfolded alongside exposure to more systematic research practices. Participant 2 entered expecting research to be uncertain and iterative, so moments of being stuck were interpreted as normal rather than disorienting.

I honestly had no clue what to expect because all I knew about research was what I've seen on like Instagram reels. [P1]

I knew it's part of the process. It's not it was not frustrating. It was it's just it's part of the research. [P2]

This contrast matters analytically. Both participants encountered troubleshooting, conceptual gaps, and incomplete knowledge. However, only Participant 1 described these experiences in a way that destabilized an earlier understanding of research and contributed to a revised framework for action. Participant 2 explicitly rejected the idea that being “lost” had changed assumptions about research, describing that state instead as something anticipated and manageable. In other words, challenge by itself did not appear sufficient for transformation in this pilot; challenge appeared to become transformative when it produced cognitive dissonance relative to the learner’s prior frame and invited reflection on that frame.

Seeing expert thinking made new frameworks visible

Participant 1 connected their shift to opportunities to observe how others reasoned about research problems. Group meetings and interactions with more experienced researchers made expert thinking visible, and that visibility created a comparison point for reflecting on their own approach. In contrast, Participant 2 emphasized independent work with weekly check-ins and described mentors as highly supportive, but included fewer moments of explicitly comparing their reasoning to others’ reasoning.

I think it happened around the time I started attending group meetings because I was learning more about how the other like undergrads and graduate students approach their research and like how they present it and talk about it. [P1]

This theme extends beyond the idea that mentoring is simply helpful. Participant 1’s account suggests that seeing expert practice enacted, through presentations, explanations, and discussion of next steps, helped make the logic of research visible. The important mechanism here may be not only access to advice, but access to how more experienced researchers justify, sequence, and communicate their work. Participant 2 also described supportive faculty energy and regular meetings, but the narrative focused more on encouragement and guidance than on a newly visible model of how knowledge is produced. In this pilot, visible expert thinking appeared especially relevant to the participant who reported an epistemological shift.

Access is shaped by informal knowledge, resources, and departmental signaling

Both participants described research discovery as uneven and often reliant on informal networks. They also noted material constraints, such as time, funding, and eligibility requirements, that can limit who can participate. These access patterns matter because research can support either pathway, and in both interviews research was tied to major decisions about graduate school and career direction.

If you know that people do research, then you know about it. But if you don't, it's kind of like they don't really... I feel like they don't do very much like promoting research... If you know people that do research, then you know about research kind of thing. [P1]

They're trying to find a paid position and most, like a lot of research labs, they don't have the funding... they would have to volunteer. And a lot of them don't want to put in the time to volunteer because, you know, they need to go to work. [P2]

The survey context reinforces this theme in a limited way. Among the four complete survey responses, three respondents disagreed that finding and applying for research was easy, and responses to the awareness item were mixed rather than uniformly positive. Across the nine submitted responses, faculty was the most commonly selected discovery pathway, with additional respondents identifying peers, department email, or student organizations. Taken together, these results suggest that access in this context may depend heavily on informal exposure and available resources rather than on a transparent, consistently visible pathway into research.

Limitations

This study has several limitations that should guide interpretation and future replication. First, the interview sample was very small and included only two students, both of whom had research experience, so the findings should be read as exploratory rather than representative of all ECE students. Second, the survey component was limited by both small size and partial completion, which means the quantitative results serve only as descriptive context. Third, because the study focused on one department at the University of South Florida, access patterns, mentoring structures, and departmental signaling may differ in other institutional settings. Finally, the study relied on retrospective self-report, so the analysis captures how students narrated their learning rather than directly measuring change over time. Future replications would benefit from a larger sample, more systematic recruitment across research and non-research participants, and longitudinal data that can track shifts in expectations and meaning-making as they unfold.

Discussion and Conclusion

These preliminary findings offer a way to interpret undergraduate research outcomes that complements prior work documenting benefits by introducing a theory-informed distinction between learning that changes the frame and learning that strengthens capacities within the frame. Consistent with prior studies, both participants described research as valuable for confidence, skill development, and career thinking. [2], [3] The more modest contribution of this pilot is a mechanism-oriented interpretation of why qualitatively similar research experiences may be narrated differently.

First, the results suggest that disorienting dilemmas were not sufficient on their own in this small sample. Both participants encountered ambiguity and setbacks, yet only one described a clear epistemological reframing. In Mezirow's terms, challenge appears to become a catalyst for transformation when it destabilizes an existing meaning perspective and invites reflection and reorganization. [4] When a student enters with a more accurate mental model of research,

challenge may be absorbed as expected, and learning may remain informative while still substantial.

Second, the results point to the possible importance of social learning structures that make expert practice visible. Participant 1 located their shift in moments of observing how others reasoned, presented work, and justified methodological choices. This aligns with Hoggan's emphasis on epistemological transformation and suggests, at least tentatively, that simply placing a student on a project may not be enough. Opportunities to observe group meetings, collaborative troubleshooting, and presentations may help novice researchers compare their initial assumptions to disciplinary practice. [5]

Third, the access theme reframes a familiar issue in undergraduate research. Prior work documents broad benefits and calls for more rigorous, systematic studies and better aligned program design. [1], [7] In our interviews, and to a limited extent in the survey context, access depended on informal knowledge and resource constraints such as unpaid labor expectations, time, and eligibility barriers. If research can shape decisions about graduate school and future career directions, then unequal access may matter not only for skill building but also for who gets to encounter experiences that could alter trajectories.

These points should be read as tentative implications rather than as firm departmental recommendations. In a RED context, they suggest several design considerations worth examining in broader studies: increasing transparency about how students enter research, reducing unpaid participation barriers where possible, and creating more opportunities for novices to see how research reasoning is enacted in practice.

Finally, our findings also caution against treating transformation as the only desired outcome. Participant 2's account shows that informative learning can produce strong preparation and informed choice, even without a reframed worldview or epistemology. For program design and future research, this suggests the value of attending to multiple legitimate outcomes and to the fit between student goals, prior frameworks, and available mentoring structures.

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