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Exploring the Evolution of Graduate Engineering Student Identity-Based Motivations as They Conduct AI Engineering Research

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Exploring the Evolution of Graduate Engineering Student Identity-Based Motivations within an AI Engineering Research Group

Abstract

This study explores how six doctoral engineering students' identities and motivations evolve through participation in a Graduate Research Group (GRG) researching AI-related engineering (AI engineering) for cyber manufacturing applications at a private Northeastern university and a public Southeastern university through a center grant. Using Identity-Based Motivation (IBM) theory, which includes Action Readiness, Dynamic Construction, and Interpretation of Difficulty, this research examines the interplay of subthemes related to these three components of IBM within an interdisciplinary graduate research environment.

Thematic analysis of narratives revealed how graduate-student participants' sense of purpose drove them to take action to engage in graduate research, which was continually shaped by interdisciplinary collaboration. Similarly, their identities were seen to be dynamically constructed as they transitioned from learners to contributors or leaders as they developed a sense of belonging within the research group, consistent with IBM theory. Moreover, the students interpreted challenges as opportunities for growth, strengthening their determination to solve research problems.

The relationships between the subthemes revealed an interconnectedness between the three IBM components. The graduate students' responses reflected a reinforcing cycle, where purpose-driven actions influenced identity development, shaping how difficulties were perceived and addressed. Emerging findings further highlight the importance of supportive, interdisciplinary research environments in fostering graduate students' identities and motivations.

Introduction

Integrating Artificial Intelligence (AI) into engineering has revolutionized how engineering problems are tackled and solved across disciplines [1], [2], [3], [4], [5], [6]. In a Graduate Research Group (GRG) at a private Northeastern university in collaboration with a public Southeastern university, engineering graduate students work with AI, defined as machine learning models and computer-guided tools to optimize engineering processes. The GRG employs AI in its lab for cyber manufacturing applications, particularly in the scalable production of polymer microparticles with controlled size, shape, and chemical functionalities. The six graduate students, who are doctoral students in this study, are directly involved in developing and applying these AI technologies to solving engineering problems by participating in different projects.

Although the GRG encompasses two distinct universities, we consider the GRG as a unified research environment where students conduct research in an interdisciplinary context as a result of weekly meetings the graduate students and advisors participate in to discuss projects, progress, and future research directions. This weekly meeting is completely virtual, so every team interaction is equal across sites. Graduate students collaborate across sites by mailing

samples and engaging in an exchange effort. This paper addresses the following research question:

RQ: *How do graduate students' identities and motivations evolve over time as they engage in interdisciplinary AI engineering research within the Graduate Research Group (GRG)?*

The following section, discusses related engineering education literature and introduces Identity-Based Motivation (IBM) theory, highlighting how studying participants who work in AI engineering graduate research is a new area to explore through the lens of IBM theory. Then, in the Project Approach section, we discuss details about the project's participants, their recruitment process, and data collection and analysis approaches. This section also describes the GRG's context further as well as discusses our scope and emerging subthemes. After that, the next section presents the project's emerging findings, which are organized around IBM theory's three core components. Finally, the Discussion section connects these emerging findings back to IBM theory, and the Conclusion and Future Research address key insights, limitations, and future directions.

Background and Significance

Despite significant advancements in artificial intelligence (AI), which have transformed graduate engineering research into technology-driven, multidisciplinary, and collaborative [7], gaps remain in engineering education literature regarding how graduate students' identities and motivations develop within AI engineering research contexts. This gap highlights the need to understand how working with and developing these dynamic technologies to solve engineering problems can influence graduate students' identity formation and motivation, which are also dynamically developing alongside the technologies. Building upon Stryker and Burke's [8] definition, identity can be defined as the internalized meanings and role expectations that individuals associate with themselves while taking on certain positions within social contexts. Applying that definition to this study, graduate students at the GRG form their identities through the roles they assume as they engage in AI engineering research. Moreover, identity, in this sense, is shaped by their interactions and the social structures of which they are a part [8].

By exploring the graduate students' identities and motivations, which are not fixed, as Tsugawa [9] argued, researchers can learn more about graduate students' experiences to foster more student-centered graduate programs [9]. Previous research also highlighted the importance of identity in engineering education and research. Godwin [10] developed a measure of engineering identity, emphasizing its role in student success for undergraduate students, and highlighted how engineering identity had been shown as an indicator of educational and professional persistence in previous studies [11], [12], [13], [14]. Similarly, Litzler and Young [15] found that students' experiences—such as their confidence and sense of community—impact their commitment to an engineering degree, highlighting the important role a supportive educational environment plays in students' success. At the graduate level, Bahnson et al. [16] used an intersectional approach to explore engineering graduate students' identities and academic advisor relationships, further revealing that social factors play a critical role in shaping students' professional identities.

Building on Oyserman's [17] Identity-Based Motivation (IBM) theory, which is comprised of three components—Action Readiness, Dynamic Construction, and Interpretation of Difficulty [17], utilizing updated literature by Oyserman and Destin [18]—this study investigates how the GRG facilitates the identity development and motivation of graduate-student participants within the context of AI engineering research. Action Readiness refers to how identities influence individuals to be ready to act and interpret the world according to the norms, values, and behaviors relevant to who they are [18]. Moreover, the specific actions individuals consider important and how they understand situations depend on the content of their identity, which is constantly being shaped. This leads to the second component of IBM, Dynamic Construction, which states that identities, what they mean to individuals, and which behaviors align with them, are formed in a contextual manner, even if their identities often feel stable and separate from their surroundings [18]. Essentially, identities are not fixed; they are continuously shaped and reshaped by the situations individuals encounter and their interactions. The third component, Interpretation of Difficulty, suggests that when a behavior feels aligned with one's identity, any difficulties one faces while engaging in that behavior indicate that the behavior is important rather than impossible [18]. As a result, individuals can perceive their efforts as meaningful rather than pointless. Furthermore, this way of interpreting challenges influences one's judgment, choices, and actions because it affects how one perceives and responds to difficulties [17], [18].

IBM theory is fitting for exploring how graduate students' identities and motivations evolve or develop within the GRG while conducting AI engineering research. IBM theory posits that identity is not singular but multiple, comprising various internalized roles and expectations that individuals hold based on their interactions in different social and professional contexts. This also aligns with the work of Stryker and Burke [8], who argue that individuals possess multiple identities linked to their roles within structured networks [8]. This study highlights how students, as graduate researchers, GRG participants, and future academics or industry professionals, balance and integrate their multiple identities as they engage with the multifaceted challenges of AI engineering research. In line with existing research on engineering undergraduate and graduate identity formation, Oyserman's IBM theory shows how students' identities are not fixed but are continuously shaped by various tasks and interactions in their environments. To explore these topics further, we detail the study's methodological approach before discussing the structure of the GRG, the scope, and the emerging subthemes from the study.

Project Approach

To investigate how participation in AI engineering research influences graduate students' identity development and motivation, a qualitative study using thematic analysis of narratives within the context of the GRG was developed. Following a recruitment survey, data were collected through semi-structured interviews tailored to each participant group's (the returning group and the new group) experiences—reflective for the returning students and exploratory for the new ones. Using an inductive coding approach, subthemes related to the components of IBM: Action Readiness, Dynamic Construction, and Interpretation of Difficulty were identified. Thematic analysis of narratives was then used to "restory" the transcripts, constructing narratives that chronologically organized the returning students' experiences within each subtheme. This

integrated approach enabled us to highlight shared subthemes across participants and unique individual stories, providing insights into how involvement in AI engineering research within the GRG shapes graduate students' identities and motivations.

The university's Institutional Review Board (IRB) approved the study, ensuring compliance with ethical guidelines for research involving human subjects. Participants provided informed consent and were assured of their anonymity and the confidentiality of their responses. The students were assigned or chose pseudonyms to protect their identities, and any potentially identifying information was omitted or generalized [19].

As researchers, we acknowledge that our perspectives, experiences, and decisions influenced various stages of this project, from developing interview questions to collecting and analyzing the student participants' responses. We served as instruments of data collection and interpretation, with our analyses being shaped by our interactions within the GRG's context and with participants. Aware of our roles, we aimed to present participants' voices and experiences as authentically and accurately as possible. The researchers consist of an X woman, a white man, and a white woman. The first two authors are postdoctoral scholars in an engineering education research group embedded in the department. They regularly attended the GRG meetings and were not part of the main research thrusts. The third author is a faculty member who is engaged in workforce development efforts in the GRG.

Participants

The present study relies on a small sample (n=6) of doctoral students interviewed over a relatively short timeframe. Consequently, we regard these findings as exploratory, in line with Pawley [20], which allows us to share rich qualitative insights within the interdisciplinary context of the GRG but does not assert broad generalizability to other graduate research environments. The participants consisted of two returning doctoral engineering students, referred to by the pseudonyms Leonard and Grace, who had been part of the GRG for more than one year since Fall 2023, and four new doctoral students—Nellie, John, Ryan, and Tom—who had recently joined the research group before Fall 2024. The returning students were allowed to examine the evolution of their IBM over time. The new students provided additional perspectives to explore how their IBMs were forming. The participants in this study represent 60% of the graduate students in the entire GRG. Table 1 summarizes the pseudonyms of the participants and their status as new or returning students.

Table 1. Summary of Participants

Pseudonym of Participant	Status at GRG
Leonard	Returning
Grace	Returning
Nellie	New
John	New
Ryan	New
Tom	New

Recruitment Process

Participants, both returning and new, were recruited through a multi-step process. Initially, short recruitment surveys [21] were distributed to potential participants to confirm their interest in the study. Email addresses were obtained through their research advisors, and the survey included questions about their availability and preferred interview times. Upon completing the survey, participants received emails inviting them to be interviewed.

Data Collection

After the recruitment survey, qualitative data were collected with the returning students in Fall 2023 through semi-structured interviews [22] to establish a comfortable environment that felt more like a guided conversation. After the returning participants were first interviewed, another interview protocol was developed for them to be interviewed a year later, in Fall 2024. These interviews focused on reflecting upon their experiences over the past year, exploring evolutions in their identities, motivations, and interpretations of difficulties in research. Moreover, the interview script was designed to explore how their participation in the GRG influenced their professional and personal development.

The new students were recruited using the same recruitment survey, and the same initial interview protocol from Fall 2023 was used again in Fall 2024. These semi-structured interviews aimed to capture their forming experiences and expectations as they began their work in the GRG and were designed to establish a baseline understanding of their identities and motivations.

All interviews lasted approximately 60 minutes and were conducted via the institution’s Zoom platform to accommodate participants' schedules and ensure confidentiality. The interviews were audio-recorded and auto-transcribed. The authors then verified the responses to ensure that gaps in the dialogue were removed and the responses accurately reflected what the participants meant to say, in line with Kvale and Brinkmann [23].

Data Analysis

Initially, an inductive coding approach was used to generate initial codes [24] for statements and experiences related to the components of IBM—Action Readiness, Dynamic Construction, and Interpretation of Difficulty. A thematic analysis of narratives was used after the initial coding process to add to our understanding and preserve the authenticity of participants' voices [25]. Thematic narrative analysis was chosen because it revealed common patterns and subthemes related to the three components of IBM within the context of AI engineering research, offering insights into the group's collective experience. Additionally, by constructing “restoried” narratives, narratives for returning participants could be organized based on their experiences into chronological and meaningful sequences. This narrative reconstruction provided deeper insight into how each student's identity and motivation evolved within the context of the GRG. Using a thematic analysis of narratives, the shared subthemes across participants and the unique, individual stories of their identity development could be discussed. The returning students' narratives reflected an evolution of their identities and motivations, influenced by their extended

engagement with AI engineering research. In contrast, the new students' narratives captured their initial engagement and the ongoing formation of their researcher identities.

GRG Workforce Development Context

Within the GRG, IBM theory underpins the workforce development plan and is a normal part of how all outreach and professional development activities for graduate students are structured. The concept of Action Readiness within IBM theory highlights how students in the GRG are encouraged to engage in interdisciplinary research that helps develop their personal and career goals. Dynamic Construction is also highlighted, as students are encouraged to take the lead on projects, transitioning from participants to leaders in their research. Additionally, they are guided on projects through mentor feedback and peer collaboration through weekly meetings, fostering a supportive environment. Lastly, Interpretation of Difficulty is also apparent in the GRG's workforce development plan, as students are encouraged to approach challenges by viewing them as learning opportunities.

Recognizing that students' identities are shaped by their experiences and learning environments, the GRG aims to cultivate an inclusive community of cyber manufacturing researchers and professionals. By intentionally providing students with interdisciplinary skills across manufacturing, engineering, and AI, and promoting mentorship, professional development, and collaborative learning, leading them to take on various roles and identities, the GRG aligns with IBM theory's principles to positively affect graduate students' motivation and persistence in AI engineering. Furthermore, due to the weekly meetings with graduate students and advisors from both universities, where they shared research progress and future directions, we were able to view the GRG as a unified research environment instead of separately positioning it within each university where the participants are enrolled.

Scope and Emerging Subthemes

As described in the Project Approach section, the scope of the study focuses on two returning graduate engineering students who have been part of the GRG for a year after their first interviews and includes perspectives from four new students beginning their work in the lab. The research captures the evolution of the returning students' IBM by analyzing responses from semi-structured interviews conducted at two time points—initially in Fall 2023 and subsequently in Fall 2024. It also provides a comparative perspective with new students who have joined the group by conducting semi-structured interviews with them for the first time in Fall 2024 to highlight how components of IBM are in the process of developing. Emerging subthemes related to the three elements of IBM have been identified among returning students, and these subthemes offer insights into how engagement in AI engineering research influences their identities and motivations. By exploring the emerging subthemes related to IBM, the study provides valuable perspectives on how academic institutions can better support students in developing the skills, identities, and motivations necessary to thrive in AI engineering.

Emerging Findings

An analysis of interviews with two returning students, Leonard and Grace, revealed subthemes that align closely with each component of IBM theory as they conduct AI engineering. Under the element of Action Readiness, subthemes such as a sense of purpose as a driver for engaging in graduate research and developing an interdisciplinary approach emerged as the students described what drove them to take various actions within the interdisciplinary positioning of the GRG. Regarding Dynamic Construction, the subthemes of transitioning from participants to leaders or contributors and a strengthened sense of belonging illustrated how their identities have dynamically shaped how they viewed themselves as part of the group and how they grew to feel more comfortable to continue taking action in their research. Similarly, for Interpretation of Difficulty, subthemes of determination towards challenges and viewing challenges as opportunities for growth highlighted how Leonard and Grace's determination to take on challenges developed their confidence and reinforced their identities to take on more significant challenges. While Leonard and Grace demonstrated how experiences within the GRG have shaped these subthemes over time, the new students—Nellie, John, Ryan, and Tom—highlighted how these experiences are beginning to shape these subthemes.

Moreover, the interviews revealed, in addition to the subthemes, that the three components of IBM theory are interconnected and mutually reinforcing one another. This interplay among the components suggests that, as students engage more deeply with their research and the GRG's environment, each aspect of IBM theory affects the others, collectively contributing to their identities and motivations.

Action Readiness

A *Sense of Purpose as a Driver*

Leonard initially shared a goal for his research to create societal impact, expressing in 2023 his desire to return to his home country to increase scientific awareness, "I want to go back to [home country] with the knowledge and experience that I've gained and try to spread it in our society as well because awareness regarding science is very low in our society now." While his exposure to industry a year later shifted his purpose towards pursuing industrial roles, his underlying goal of making a societal impact remained unchanged, "Initially, I thought I would go into the academic line, but now, with this more industry involvement, my interest might have changed, but the motivation remains the same."

In 2024, Leonard also highlighted how completing a major project and publishing a paper bolstered his confidence, allowing him to take more action to work effectively, saying, "We have finally finished one part of the work, and we are publishing a paper…The boost really helped me go on more efficiently in my work." Weekly discussions and peer feedback also helped him work towards his goals. He said, "The group has been very supportive. Weekly discussions help us formulate and plan our actions, and the feedback has helped me improve upon my ideas."

Grace also initially shared her sense of purpose to reach her goals, driven by her interest in polymer science and in academia, sharing, "I want to keep working in academics and research…

I really want to keep working in polymers... science, it never ends. There's always more and more to learn and more to explore." Initially, she also expressed how she wanted to develop her presentation skills, stating, "I still did not get to present in conferences because it's just still my first year. But next year, hopefully, I'll be presenting what I'm working on in conferences and in seminars." Over the course of a year, she remained committed to her goals, actively engaging with her research and collaborating: "I've been working with professors and other graduate students... having weekly meetings and working on research... this aligns with my career goals because this is where I see myself in the next five years."

Positive feedback from her research group further encouraged her to take action. By 2024, after successfully presenting her research at a workshop, she credited practice sessions with her lab mates with improving her confidence in her presentation skills. She shared, "I did a practice talk with my lab mates... they thought I explained the project in a very good and clear way." Additionally, she tied her growing confidence to learning more from her advisors, allowing her to utilize her sense of purpose toward progressing in her research. "My confidence is increasing with the experiments I'm working on... [I'm] learning how to analyze the data the same way [as the advisors], like in a more advanced way compared to the first year."

The new students—Nellie, John, Ryan, and Tom—shared how their emerging senses of purpose are progressing towards their action readiness. They shared various purposes, like Leonard and Grace initially did, highlighting how they set the stage to further take action to solidify these goals. Nellie shared that her readiness to act was conditional on her Ph.D. outcomes, illustrating how her sense of purpose is encouraging her to take action to decide which field she would succeed in saying, "If the research I [conduct during] my Ph.D. process [goes] well... I will keep doing research in the future... If it's not going well... maybe I will choose to go to a company to be an engineer." John described how his advisor's positive feedback on his work so far has given him the confidence to continue to take action towards his research goals: "When I presented my figures for my review article, [advisor] was very happy with it. That gives me promise, like as a graduate student, I want to know that I'm doing better." His action readiness was also reflected in his initial pursuit of AI engineering to solve chemical engineering problems. John said, "What I'm doing right now is combining chemical engineering and machine learning, which is one of my interests." Ryan emphasized how challenging problems and intrinsic motivators allowed him to take action towards his goals: "When I was dealing with challenging problems in the process, I always told myself, if I solve this problem, I would get a great sense of achievement. That would be great." Tom's early work received external recognition, which he viewed as a driver for him to progress further. He said, "They all think that this work is very successful, and I hope it's a very good baseline for this task. In the future, we'll continue to improve it." Additionally, his readiness to act stemmed from an intrinsic interest in AI, which he began exploring in high school and is now utilizing as he conducts AI engineering research.

Leonard, Grace, and the new students—Nellie, John, Ryan, and Tom—highlighted how their inherent sense of purpose drove them as they took action in their graduate research. Their purpose, along with the reinforcement of positive feedback and recognition, illustrated how their experiences at GRG shaped their confidence and allowed them to take meaningful actions toward their goals. Their purpose-driven actions (Action Readiness) reinforced their evolving

identities as researchers, academics, or industry professionals (Dynamic Construction), which in turn influenced how they perceived challenges in their work (Interpretation of Difficulty).

Developing an Interdisciplinary Approach

Leonard's initial interview highlighted how the interdisciplinary approach of the GRG improved his ability to take action in his research beyond his chemical engineering background. In 2023, he began exploring AI engineering by working with machine learning, a topic he had long-term interest in but now had the chance to work with:

> In this project, we are using machine learning. I didn't have much knowledge about it before—just some basic programming. But this new, innovative area of machine learning, I used to hear a lot about from my colleagues and my parents. They would say machine learning is picking up pace in the current world, but I didn't have a chance to pursue it before. Now I do.

This re-engagement allowed Leonard to expand his research focus and apply machine learning techniques to solve engineering problems. He said, "There was a time when I got detached from programming and computer-based technologies. Seeing that I can come back and learn more in an area I was once passionate about, I feel I can use this knowledge to improve my work." By 2024, Leonard's approach to AI engineering methods had become central to the actions he took for his research, allowing him to explore more disciplines:

> With the different fields of expertise that this [GRG] project brings, I have found myself trying to adapt to different areas of research. I have been involved in synthesis, manufacturing, and machine learning-based automation, and I have been talking to different collaborators and trying to learn those aspects for myself as well.

In addition to her experience in chemical engineering, Grace initially shared how she wanted to take advantage of opportunities to collaborate across disciplines, citing that as a main motivator for her joining the GRG, "I'll gain knowledge not just from chemical engineering but from other departments as well. That's why I joined this group." Though she did not immerse herself in the AI engineering side of the project, over the course of a year, she developed the confidence to take action to experiment with unfamiliar techniques and equipment:

> Before, it was really scary. But now that I understand the project, I feel more confident using certain equipment and learning the techniques we need. I used to feel nervous about trying something new, but now I'm more confident and open to learning new techniques for my project.

Grace also emphasized how interdisciplinary collaboration helped her present and share results saying, "Understanding different points of view, learning to communicate results and data, and presenting findings—these have all been very helpful."

The new students also recognized GRG's interdisciplinary positioning as an enabler for their readiness to take action in their graduate research within the group. Their initial impressions reflected diverse motivations and approaches towards engaging with the collaborative nature of AI engineering research. Nellie saw the group's interdisciplinary positioning as an opportunity to learn more about academia and industry, highlighting her readiness to explore both domains, "Joining this project gave me a broader understanding of both academic and industrial

perspectives." John's early engagement with GRG and his actions taken to pursue AI engineering were shaped by his long-held interest in machine learning as well as chemical engineering, similar to Leonard:

> I've always been a person who sits on the desk and works on any kind of coding project or something like that. So, in that sense, I feel like I've done some justice by choosing machine learning as one of my interests to pursue, along with chemical engineering.

Ryan further shared how the research group's interdisciplinary nature allows him to take action to use knowledge from different disciplines, keeping things interesting, "It's physics, materials, chemistry and computer science. You have to use different knowledge from different places… I'm interested in that, obviously." Tom viewed the AI engineering environment as a place for reciprocal learning, where collaboration led him to take action to share his expertise saying, "We have good collaboration. But also, for the people from science, they need to learn some AI knowledge from me."

The interdisciplinary nature of the GRG allowed the participants to take action to conduct research across multiple fields, expanding their knowledge and enabling them to approach challenges outside their primary disciplines. All students demonstrated how engaging with AI engineering research provided the skills necessary to contribute to the GRG's research projects in different ways. By embracing interdisciplinary opportunities (Action Readiness), students reshaped their identities as AI engineering researchers (Dynamic Construction), developing their confidence in overcoming complex problems (Interpretation of Difficulty).

Dynamic Construction

Transitioning from Learners to Contributors or Leaders

Leonard began his role as a learner, focusing on foundational tasks essential for progressing the group's work. He described his early work as laying the groundwork for others: "Since it's the first stage of the process… the main role now is to basically create a large enough data set for people to then build upon it." At this stage, Leonard viewed himself as contributing to a larger system rather than leading it, and he saw his efforts as part of a broader framework, saying, "If I can set up a large enough data set for training and testing, this would provide the basis for people to build upon." Initially, he also faced moments of uncertainty when his research efforts did not provide the results he wanted: "I tried a variety of different ways… but the results were not satisfying." Over a year, Leonard's experiences within GRG reshaped his identity as he transitioned into a leadership role. By 2024, tied to his accomplishments of completing a project and progressing towards publishing a paper, as mentioned earlier, Leonard identified more as a leader, actively guiding projects and sharing new ideas: "So, after finishing that project… I've been leading projects from the front, bringing ideas to the table."

Similarly, Grace began her Ph.D. as a learner, focusing on learning and exploring her interests in chemical engineering topics: "I really wanted to find a project that focuses on liquid crystals and polymers since they were really interesting to me." Early on, she engaged with projects to build her further build her expertise and contribute saying, "I'm working on other things as well, but

they're related to the [GRG] project… experimenting with different theories." As her understanding expanded, Grace also shared that she had begun taking on more responsibilities, preparing samples and conducting experimental work, building her identity as a contributor, "I feel like I'm preparing more samples and doing more experimental work, which is helping me understand the project better." By 2024, Grace's contributions extended to motivating others and leading her part of the project. Weekly meetings became a source of encouragement and focus for her: "At the start of the meetings, we go over what we achieved, and it makes me feel more encouraged and excited to accomplish more tasks." Furthermore, her collaboration with Leonard and completing tasks demonstrated her shift toward leadership: "Seeing completed tasks and what needs to be done next has made me more excited to work on the project, especially with [Leonard]."

Like Leonard and Grace's earlier interviews, the new students—Nellie, John, Ryan, and Tom—also illustrated how they have begun to develop their identities, each reflecting different stages of this process as they progressed within their journeys in the GRG. Nellie highlighted how she is actively engaged in her identity as a learner, working toward a deeper understanding: "I am still a student who needs to learn more about the project and the field, because, especially about the liquid crystal, I still have a lot of questions about this material, and this will also influence my research." In contrast, John described the collaborative environment as an opportunity to contribute, tied to his recognition of the group's interdisciplinary positioning as explored earlier saying, "We work on microscopic images. That's exactly what chemical engineering is…a part of it. So, I am applying machine learning to that, which is exactly my interest."
Ryan also elaborated on his role and how his perception of seeing himself as a contributor aligns with his interests in wanting to approach challenging projects, "So I think it's very challenging, but that's, that's why I like to do challenging work." Similarly, Tom emphasized his identity as an AI engineer, highlighting how he sees himself as a contributor and further emphasizing the GRG's interdisciplinary positioning:

> I think for me, I am more like an AI engineer because the science people need to collect data and analyze data. For me, I need to find out the questions or issues in their product and use AI to help them, give some AI solution, and help them to get better results.

The students shared how they were dynamically constructing their identities when they described how they have transitioned from learners to contributors or leaders. All participants actively construct or are shown to construct multiple identities based on experiences within the group's collaborative and interdisciplinary environment. As their identities evolved (Dynamic Construction), they took on more responsibilities (Action Readiness), empowering them to face challenges more effectively (Interpretation of Difficulty).

Strengthened Sense of Belonging

Leonard described himself as a "scientist-in-the-making" in this first interview, illustrating how he recognized he was beginning to feel a sense of belonging in the wider academic and research community:

> I might say that I'm a scientist-in-the-making. But, yeah, I feel like I still have a long way to go. I need input from my advisor and other friends as well, but I'm confident that the pathway I'm on right now will soon allow me to critically or independently come up with projects and work without any input from others. I feel like if you can generate ideas and accomplish them on your own, you are basically an engineer, scientist, or researcher.

Though he shared he had a long way to go, emphasizing that independent work would solidify his sense of his identity as an AI engineering researcher, he expanded on his appreciation for the more localized sense of belonging he felt within the GRG:

> I always have felt it to be very inclusive. Whenever we have discussions, everyone is listening to what others have to offer. We build upon the ideas that everyone presents, and it has never been that your idea is totally disregarded—it's more about how it can be improved to achieve what we're trying to do.

A year later, Leonard maintained this sentiment about feeling a part of his research lab. He also added how hearing industry perspectives had deepened his sense of belonging in the wider community:

> What the [GRG] has done is bring in not just academic experiences but also industrial ones. I've come to understand more of what the industry wants. We've had panel sessions with industry members, which really help guide our research and make something fruitful out of what we're doing here.

Grace initially struggled with feeling like she belonged in the academic community in the U.S., having moved far from home for her Ph.D. sharing, "I was really scared to leave my family, especially because I don't have anyone in the United States—no relatives, no friends, no one. So it was really hard at the beginning." Her father's support, however, helped her adjust to developing her sense of belonging:

> I feel like I'm really happy this happened. I'm really grateful that my dad supported me because he made me stronger and braver and live in the U.S. and do my graduate studies. Now I really think, yes, this is where I belong. I'm really happy that I'm in the U.S. doing my graduate studies.

Over the next year, Grace began to feel more at home, allowing her to develop her identity as a leader in the project as it developed, "Now I feel more at home, especially because I know how things are going, what my part is, and how I should look at my project. I've become more efficient." By 2024, she also considered the GRG like family, sharing:

> It's like family now—my professors, my lab, and the project are all part of my life. I love being in the lab, doing experiments, joining [GRG] meetings, and talking to other group members. Compared to last year, I feel like I belong more to this project and this environment.

Grace also highlighted the role of her advisors in fostering this sense of belonging:

> The professors and students taught us how to become more driven and included in the project. They supported us throughout the two years of the project. That increased my confidence and involvement. They encouraged me and helped me feel more included.

The new students in GRG demonstrated varied senses of initial belonging, reflecting the interplay of personal motivations, academic alignment, and community dynamics within the lab. Nellie's initial sense of belonging was rooted in her connection to the broader ethos of the university's engineering college rather than GRG specifically, "I feel like I belong to the engineering college, actually, especially the thoughts I have about how to do the research and what good research projects are. Somehow, I think some of my thoughts match with [name of university] Engineering." John, on the other hand, expressed, that though his sense of belonging was still developing, there is an alignment of his academic and professional aspirations with GRG's interdisciplinary focus, "Since I just started working in the [GRG] project, I'm not sure how I should define belonging, but so far, I've been enjoying whatever I've been doing because it exactly aligns with what I want to pursue." Ryan described a strong sense of belonging tied to collaboration and shared accountability, sharing how his sense of belonging also enables him to take action and contribute:

> We have weekly meetings, and we have detailed discussions for every progress... For me, I feel strong belonging to this project. I even feel self-motivation to do progress every week for this project. I have to contribute something to our team because everybody's hard-working and has progress every week. If I don't have anything, I feel ashamed.

Tom also found his sense of belonging through participating and being collaborative in the weekly meetings and sharing his AI engineering research progress, "I have the sense of that [belonging]. For the weekly meetings, I will join the discussion, but I will also present my progress, AI methods, and something similar, like diffusion models. [Advisor] will also discuss about AI and about the science. Yeah, it's very great."

Overall, the students shared responses that reflected their evolving sense of belonging. This process highlights how individual identity development is intertwined with the social, academic, and collaborative contexts of the group. Both returning students and new members have experienced differing pathways to belonging, affecting their IBMs. A stronger sense of belonging (Dynamic Construction) allowed them to increase their engagement in the group (Action Readiness), which positively influenced their approach to difficulties in collaborative ways (Interpretation of Difficulty).

Interpretation of Difficulty

Determination towards Challenges and Opportunities for Growth

The students' experiences with challenges during their research highlighted their determination and evolving problem-solving strategies. Both returning students—Leonard and Grace—and new members—Nellie, John, Ryan, and Tom—demonstrated how persistence, adaptability, and collaboration contributed to overcoming difficulties in academic research and interpersonal issues. Their approach to challenges (Interpretation of Difficulty) was influenced by their commitment to their goals (Action Readiness) and reinforced their developing identities as AI engineering researchers (Dynamic Construction).

As highlighted briefly earlier, Leonard initially faced moments of self-doubt in 2023 when he was not getting the results he wanted in his project:

> I tried a variety of different ways to achieve what I was trying to do, but in the end, the results were not satisfying. At that point, I felt like I was not getting results, and I thought, maybe I need to rethink my way out of it… or [thought] am I good enough.

Despite these setbacks, his determination led to a breakthrough, "Trying, trying, trying, doing various trials, thinking about it in lots of different ways, I finally was able to get a very unique result that is now basically my main work in my Ph.D.." A conversation with his advisor shifted his approach to problem-solving. His shared that his advisor asked, "Are you sure that this can't be done? Rather than if this can be done." This question encouraged Leonard to exhaust all possibilities before concluding that he could not solve the problem. After a year, he had further embraced this mindset: "The difficulties still remain. The challenges still remain. But now I'm not devastated by those challenges. I know how to solve them, and even if I don't, I try to figure out a way." Leonard also stated, in 2024, how he now values thinking creatively and collaborating in group discussions to overcome challenges, "We think of different ideas, read a lot of literature, and discuss as a group how to overcome challenges."

Similarly, Grace experienced stress early in her Ph.D. when experiments did not go as planned. She said, "I felt like maybe this problem won't get solved at all or I'll get stuck here... I was really scared that it wouldn't work, and it took so much time actually." Her determination, however, encouraged her continue engaging in her research. "I don't like when something does not work. I have to fix it, or I have to figure out what the problem is." Over the next year, Grace became more confident in her approach to challenges:

> I became more calm. I don't stress about challenges; I approach them more confidently. This helps because I know that at the end of the day, we will overcome the challenges, and everything will get solved.

Collaborating with other graduate students, namely Leonard, in line with the interdisciplinary approach of the GRG, and becoming more familiar with the project and equipment further supported her determination, "After reading more, doing more experiments, and working with [Leonard] at the [GRG], I understand my role better and feel more comfortable."

The new students also exemplified emerging determination in addressing their research and interpersonal relationship challenges. Nellie showcased adaptability and understanding when resolving interpersonal conflicts and navigating research challenges. Reflecting on a conflict she had, she shared, "I was angry at that time... but they apologized, so it's okay. Sometimes it happens." She also shared how she became more determined to understand questions advisors had about her research because of critiques she received about her work, "I know where the problem is now... and I gradually understood why the professors asked those questions." John's determination was rooted in his sense of purpose and long-term goals when he explained how contributing to a research paper drove him through complex tasks. "The only reason I persisted was because it was ending up in a research paper." Reflecting on a challenging problem during his master's studies, he also noted, "My basics got stronger, and it taught me how to be resilient." Ryan emphasized a systematic approach to problem-solving, contributing to his determination: "Divide a large problem into smaller parts and solve them one by one. It's easier that way."

This method allowed him to address a research problem effectively and fostered a sense of accomplishment. Tom highlighted his determination when faced with AI engineering challenges like limited data. He reframed the challenge as an opportunity to plan and learn more, saying, “The biggest challenge is the limited data... but I used that time to plan and learn.” Collaboration, in line with Leonard and Grace, also allowed him to stay determined through initial research problems: “It was hard at first, but after trying different methods and discussing with others, we found a solution.”

The students' ability to reframe research challenges as opportunities for learning further highlighted how they approached difficulties. Both returning students and new students demonstrated how transforming challenges into positive experiences and collaborative opportunities improved their AI engineering strategies and contributed to their growth in graduate research. Seeing challenges as growth opportunities (Interpretation of Difficulty) allowed them to find solutions (Action Readiness) and further shaped their sense of belonging through collaboration (Dynamic Construction).

Discussion

The experiences of graduate students in the Graduate Research Group (GRG) illustrated how identities and motivations develop within AI engineering research, as understood through Identity-Based Motivation (IBM) theory. The findings highlight the interplay of the subthemes and components in shaping graduate students' identities and motivations.

Action Readiness, as outlined by IBM theory, refers to individuals' preparedness to act in alignment with their identities, driven by their goals and values. In this study, both returning and new graduate students demonstrated how their sense of purpose, along with the interdisciplinary environment of the GRG, influenced their readiness to engage in AI engineering research.

Leonard’s journey at the GRG evolved from conducting chemical engineering research to integrating AI engineering techniques, aligning with his purpose of creating societal impact by increasing scientific awareness in his home country. By 2024, he had expanded his research focus by applying interdisciplinary methods and collaboration. His purpose as a researcher, supported by interdisciplinary approaches that led to a sense of belonging, motivated him to take further action and view challenges as opportunities for growth. Similarly, Grace's long-held sense of purpose in being a part of academia initially motivated her to take action in pursuing graduate AI engineering research. By 2024, she embraced opportunities for interdisciplinary collaboration and, supported by mentorship and a growing sense of belonging within the GRG, was motivated to take on greater responsibilities as a purpose-driven graduate researcher. As a result, she began to view challenges, such as passing her exam, as opportunities for growth.

The new students—Nellie, John, Ryan, and Tom—also exhibited emerging purposes which drove their action readiness. The GRG's interdisciplinary nature provided them with opportunities to explore diverse fields and align their personal interests with their research activities. Furthermore, they highlighted other purposes within the interdisciplinary context of the GRG, such as applying AI engineering to various fields, exploring academic and industrial

perspectives, and engaging in collaborative learning to share and gain knowledge across disciplines.

These students' readiness to act and engage in graduate AI engineering research (Action Readiness) was affected by their evolving identities (Dynamic Construction). As Figure 1 illustrates, as students pursued their goals driven by purpose and the interdisciplinary setting of the GRG, their positive experiences reinforced their self-conceptions as capable researchers. This reinforcement motivated them to take further action and influenced how they perceived challenges (Interpretation of Difficulty), viewing challenges as opportunities to grow.

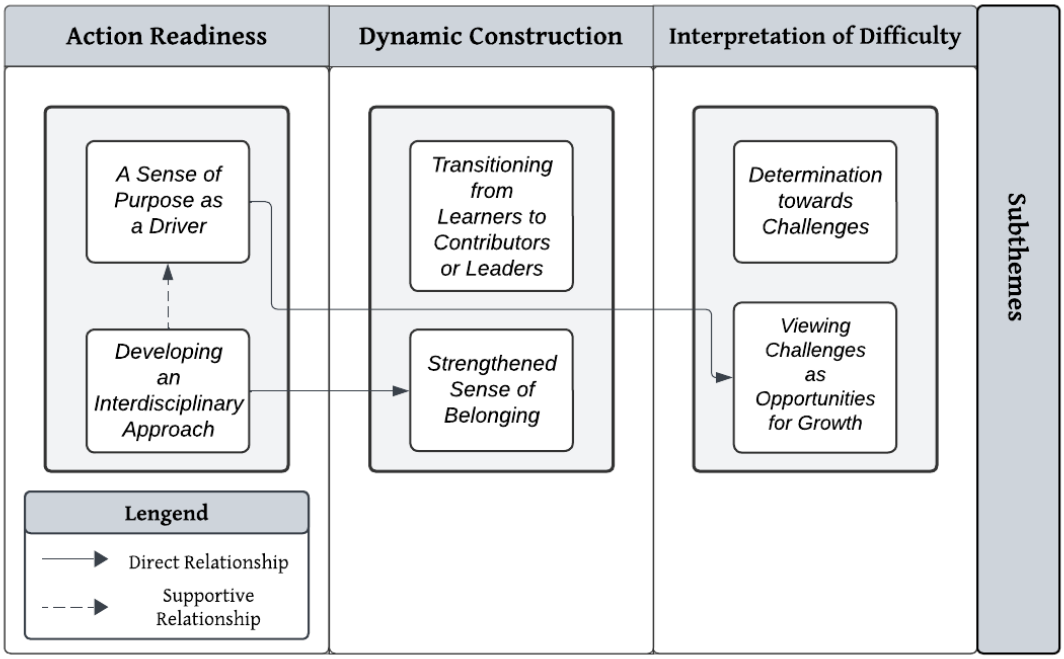

Figure 1. Action Readiness, driven by purpose and the interdisciplinary environment of the GRG, influences students' evolving identities (Dynamic Construction) and positive interpretation of challenges (Interpretation of Difficulty).

Dynamic Construction refers to how identities are continuously shaped by contexts and interactions. The students' narratives revealed how their identities evolved through transitioning from learners to contributors or leaders as their roles changed and how they developed a sense of belonging within the GRG over time. A strengthened sense of belonging emerged as contributing to the participants' identity development as well.

In 2023, although he faced moments of uncertainty, Leonard initially identified himself as a "scientist-in-the-making," acknowledging he still needed a lot of input from advisors and peers while conducting AI engineer research while feeling a sense of belonging within the broader academic community and within the research group. Over a year, achievements like being on the way to publishing a paper and leading projects reshaped his identity as a leader, increasing his purpose and driving him to take on more research challenges. His appreciation for GRG's

inclusive and collaborative environment further deepened his sense of belonging. Moreover, his sense of belonging also extended to the industrial community, empowering him to be more determined towards these research challenges. Initially, in 2023, Grace focused on learning more about the project and struggled with feeling isolated due to being far from home. However, by 2024, Grace described the GRG as family, crediting her advisors and peers for fostering a supportive environment that allowed her to be more purpose-driven in her work. As such, her role transformed her into a leader. She took on tasks like motivating others, contributing to team discussions, and collaborating with Leonard, reinforcing her determination to take on more research challenges.

The new students also displayed varying degrees of belonging, influenced by personal motivations and group dynamics—reflecting how they are still developing their roles alongside their sense of belonging. For example, Nellie's growing sense of belonging within the broader ethos of the engineering college allowed her to share about her current role as a learner, while John's sense of purpose and the group's interdisciplinary goals led him to begin to contribute in interdisciplinary ways. Ryan and Tom, by actively engaging in weekly meetings, described how collaboration and shared accountability solidified both their sense of belonging and their evolving identities as early contributors within the group.

As they felt more integrated and valued within the group (Dynamic Construction), their confidence grew, making them more driven to engage in their research (Action Readiness). Moreover, as Figure 2 highlights, their strengthened identities influenced their determination to approach interdisciplinary challenges (Interpretation of Difficulty).

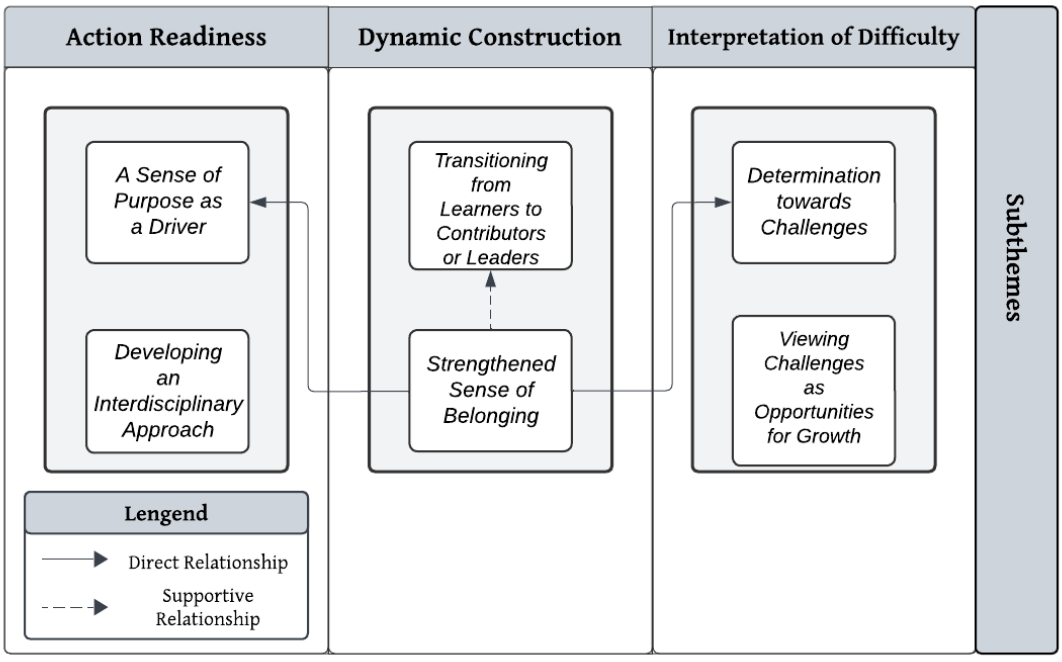

Figure 2. Students' evolving identities were shaped by their roles and sense of belonging within the GRG. The diagram highlights how a strengthened sense of belonging allowed them to feel

more driven in research (Action Readiness) and influenced their determination towards interdisciplinary challenges (Interpretation of Difficulty).

Interpretation of Difficulty refers to how individuals perceive challenges in relation to their identities. The participants in this study shared how their determination towards challenges allowed them to view challenges more positively. This shift also allowed them to feel more of a sense of belonging as they often had to collaborate with others to overcome research challenges. Moreover, their determination allowed them to feel more of a purpose to take action towards more challenges.

Over a year, Leonard began to see setbacks as valuable experiences, feeling supported by others, transforming his initial self-doubt into determination. Furthermore, Leonard's determination at the GRG allowed him to reframe challenges as opportunities for growth, reinforcing his evolving identity and sense of belonging. Initially frustrated by unproductive research results in 2023, he continued to adopt a determined approach to research problem-solving in 2024 with the support of his advisor and peers, ultimately achieving his desired results. This shift in perspective not only deepened his understanding but also motivated him to collaborate more effectively, which developed his sense of belonging and influenced his sense of purpose to take more action toward his goals. Similarly, Grace evolved to approach challenges confidently, seeing them as confidence-building, and her determination allowed her to keep trying to overcome these challenges. In 2023, she described how she felt stressed when experiments did not go as planned, but her determination allowed her to become more stay engaged in her approaches. Over a year, with a strengthened sense of belonging from her advisor and peers and a deeper understanding of her project, Grace viewed challenges as opportunities to grow and learn, motivating her to take more action towards achieving her goals, such as passing her exam, as a purpose-driven researcher.

The new students were also seen to initially have similar perspectives by turning critiques into opportunities to be more determined to understand how to improve their research approaches within the GRG's supportive environment. Their determination enabled them to start developing new solutions by utilizing collective expertise and interdisciplinary collaboration, further supporting their progress in overcoming AI engineering research challenges. This approach helped them view initial challenges as opportunities for growth, recognizing such challenges as an inherent part of research where innovative solutions and ideas are developed.

The students' determination led them to interpret challenges positively (Interpretation of Difficulty), which reinforced their evolving identities and senses of belonging through advisor support and collaborative approaches (Dynamic Construction), as Figure 3 illustrates. This determination, in turn, encouraged their readiness to take more action (Action Readiness), as they felt more motivated to pursue their goals.

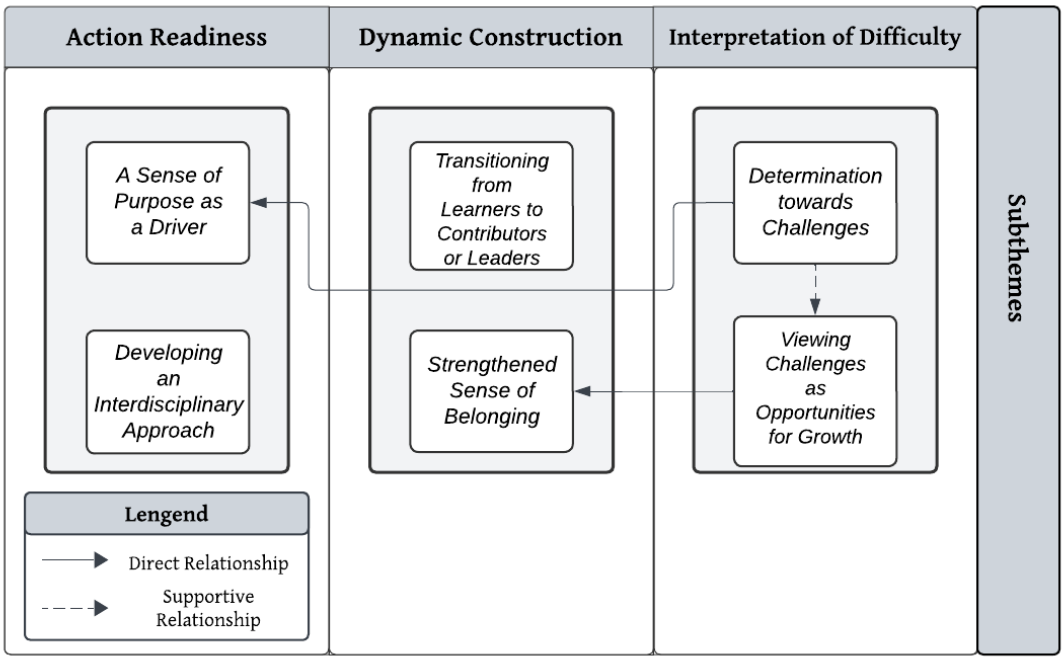

Figure 3. Students' determination, which led to viewing challenges as opportunities for growth, reinforced students' evolving identities and sense of belonging (Dynamic Construction). This, in turn, gave them more purpose to take various actions in graduate AI engineering research (Action Readiness).

The emerging findings from the study highlight, in addition to an interplay between the subthemes, interactions among the broader IBM components—Action Readiness, Dynamic Construction, and Interpretation of Difficulty—that collectively shape students' identities, motivations, and approaches to AI engineering research. The interaction among the subthemes led to interactions between the three IBM components, creating a reinforcing cycle.

Action readiness allowed students to engage with their AI engineering research, leading to experiences that dynamically constructed their identities. As their identities evolved, their interpretations of difficulty shifted, enabling them to view challenges more positively. This reframing improved their determination and motivation, further affecting their readiness to act and take on different roles in the GRG as they continued with AI engineering research. By aligning personal values and goals with collaborative opportunities, students can transition from learners to contributors or leaders while developing a sense of belonging. This cycle, in turn, improves their determination to navigate the complexities of interdisciplinary research. This cycle is visualized in Figure 4, along with all connections between subthemes made in the previous three figures. Ultimately, the study highlights how exploring graduate students' experiences of AI engineering research through the lens of IBM led to interconnected subthemes emerging, which eventually allowed for the components of IBM to be interconnected.

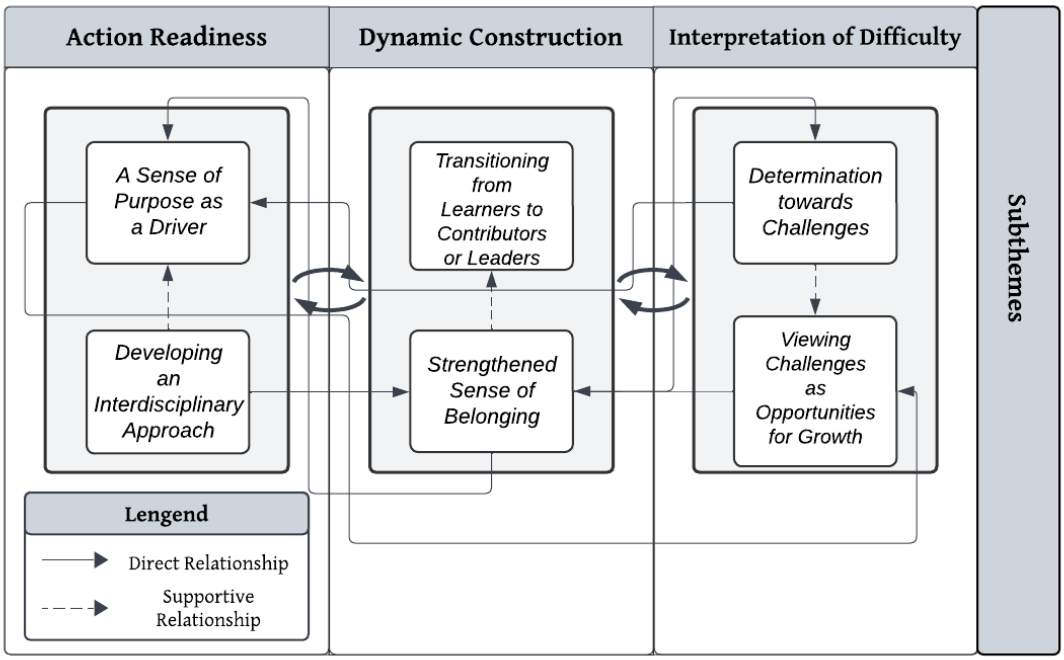

Figure 4. This figure visualizes the interaction among the three IBM components, forming a reinforcing cycle that collectively shapes students' identities and motivations. This figure also includes the interconnectedness of the subthemes from the previous three figures.

Conclusion and Future Research

In conclusion, this study explored how the interplay of subthemes related to the three IBM components—Action Readiness, Dynamic Construction, and Interpretation of Difficulty—fosters the development of graduate students' identities and motivations within the context of interdisciplinary AI engineering research. Using Identity-Based Motivation (IBM) theory [17, 18] as a framework, the research demonstrated how purpose-driven actions influenced identity development, which in turn shaped how students perceived and addressed challenges. The initial findings emphasize the importance of supportive environments, such as the interdisciplinary setting of the GRG, in facilitating this reinforcing cycle. Within this environment, supported by the GRG's IBM-based workforce development plan, students' sense of purpose drove them to take action, interdisciplinary collaboration dynamically shaped their identities, and their interpretation of challenges as opportunities for growth strengthened their determination to pursue challenges.

These initial insights highlight the role of interdisciplinary graduate research in an AI engineering environment in fostering graduate students' identities and motivation. We plan to expand on these findings through longitudinal studies within the GRG, examining how the components of IBM continue to evolve over time and uncover new subthemes or verify the ones shared in this study. Following more students as they transition from learners to experienced

graduate researchers would provide deeper insights into how their IBM's further influence long-term success and professional growth in interdisciplinary AI engineering research.

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