2023 Annual Conference & Exposition
Baltimore Convention Center, MD | June 25 - 28, 2023

The Harbor of Engineering
Education for 130 Years

ASEE

Paper ID #37074

Investigating Graduate Students' Perspectives of Influences on Interdisciplinary Scholar Identity Development: An Ecological Systems Theory Approach

Margaret E.B. Webb, Virginia Polytechnic Institute and State University

Margaret (Maggie) Webb is a master's and Ph.D. student in sustainable land development (civil engineering) and engineering education, respectively, at Virginia Tech. She graduated with her mechanical engineering degree from Rice University and worked for ExxonMobil as a subsea engineer and as a high school STEM teacher in a Houston charter school before starting grad school. Her research interests include supporting the needs of displaced engineering students, understanding the supports and barriers to educational continuity for engineers in a disaster context, and preparing engineering students interdisciplinarity to address disasters in their work. She works as a graduate research assistant for the Virginia Tech Disaster Resilience and Risk Management interdisciplinary graduate program, as well as for the VT Center for Refugee, Migrant, and Displacement Studies.

Dr. Marie C. Paretti, Virginia Polytechnic Institute and State University

Marie C. Paretti is a Professor of Engineering Education at Virginia Tech, where she directs the Virginia Tech Engineering Communications Center (VTECC). Her research focuses on communication, collaboration, and identity in engineering.

Investigating Graduate Students' Perspectives of Influences on Interdisciplinary Scholar Identity Development: An Ecological Systems Theory Approach

Abstract

Spanning hundreds of higher education institutions, the surge in interdisciplinary graduate programs designed to prepare the future STEM professoriate for the grand challenges, big ideas, and demands for convergence is difficult to ignore. These interdisciplinary graduate programs pose great opportunities for expanding the professional skills and knowledge base of STEM graduate students, but they exist within academic structures such as departmental siloing and conflicts in policies, procedures, and budget models across disciplines that often impinge upon interdisciplinary student development [1][2][3].

Previous findings based on faculty perspectives on facilitating interdisciplinary programs reveal the ways in which multiple differentiated layers of the academic environment impact graduate student development, but students' perspectives have often been left out, leaving an incomplete picture. Additionally, existing literature tends to focus on levels of the academic environment that students interact with directly, with less attention to external influences at or beyond the institutional level that are also relevant to the interdisciplinary graduate student experience.

To extend understandings of interdisciplinary scholar development beyond students' immediate surroundings and to incorporate graduate students' perspectives into this research space, this study takes a qualitative approach grounded in Ecological Systems Theory [4][5]. The data consist of 48 semi-structured interviews with students in an interdisciplinary graduate program, spanning four program cohorts and three years. The study investigates how the broader academic social environment in which interdisciplinary graduate students operate influences students' abilities to see themselves as interdisciplinary scholars and align their studies with convergent research career goals.

Ultimately this longitudinal qualitative case study suggests that the cultural and historical background of universities as sites of disciplinary and department-driven initiatives challenges interdisciplinary graduate students who are seeking answers to convergent questions and building identities as interdisciplinary scholars. Because of disciplinary-based cultures, norms, and incentives in academia, interdisciplinary students' professional identity development is often in conflict with their institution's corresponding organizational structures (i.e., departmentally based thesis/dissertation committees and promotion practices), and even when these structures and norms are unwritten or designed for faculty only, they have cascading and compounding impacts on interdisciplinary graduate scholar development. This study shows that supporting the future professoriate's interdisciplinary identity development begins with addressing siloed education at the undergraduate level and involves increasing institutional capacity for advising interdisciplinary students, institutionalizing development plans for interdisciplinary researchers, and aligning university incentives for scholars with convergent research aims.

Background

The research site for this study is an interdisciplinary graduate program centered on resilience (referred to in this paper as the IR program), currently funded through a National Science Foundation (NSF) Research Traineeship (NRT) grant, located at a large land-grant university. IR is designed to spur collaboration and develop convergent research skills related to resilience for both graduate students and faculty in STEM, business, policy, governance, natural resources, and humanities. The coursework and other IR workshops and events work to provide opportunities to develop innovative transdisciplinary problem-solving approaches for resilience.

Though IR grants an interdisciplinary graduate certificate, most researchers involved are still housed within disciplinary departments, possess disciplinary degrees, and respond primarily to disciplinary institutions and supervision. This structure means that the interdisciplinary nature of the IR program is still embedded within disciplinary norms across colleges, making it an ideal site to study the tensions that arise for emerging interdisciplinary scholars because of conflicting academic structures. As a result, we pose the following research questions:

1. How do individual, microsystem, and mesosystem-level influences in a students' academic environment affect graduate students' abilities to develop a strong sense of interdisciplinary scholar identity, critical to self-efficacy and professional development, as they become professors in interdisciplinary spaces?
2. What are graduate students' perceptions of the interrelationship between various layers of their academic environment (i.e., academic backgrounds and previous learning, microsystems, and mesosystems) and their interdisciplinary scholar professional identity development?
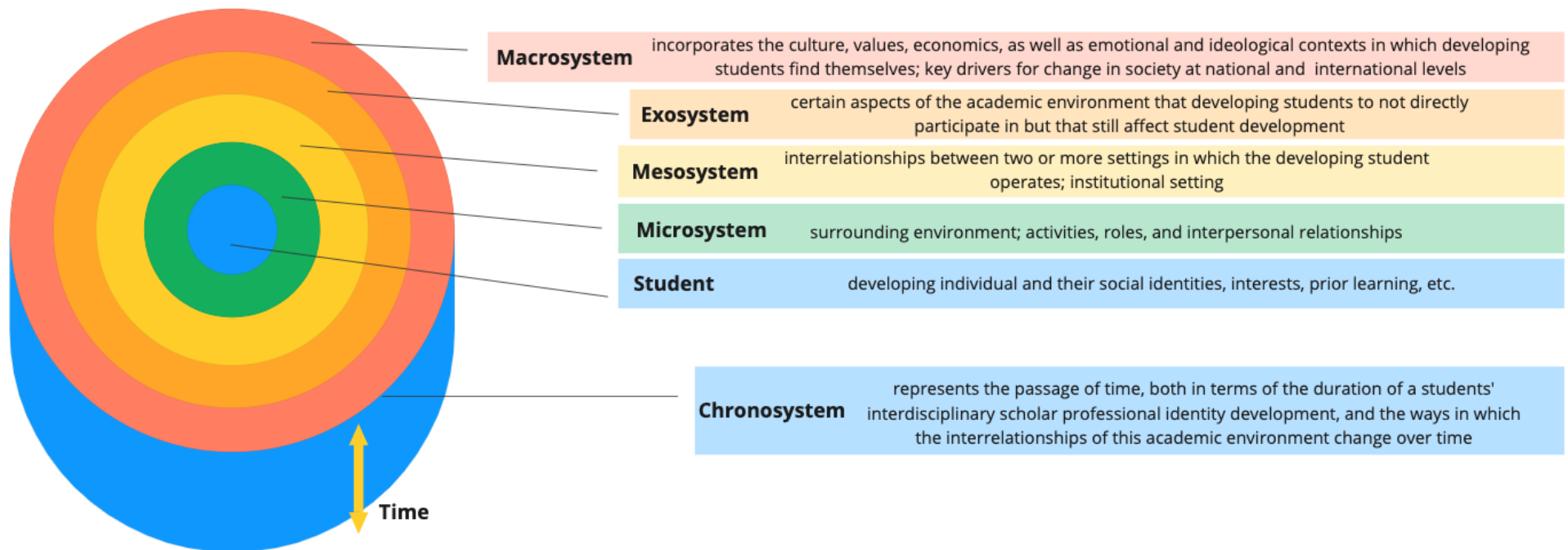
Theoretical Framework

Previous studies of interdisciplinary education have highlighted critical differences between multidisciplinary, interdisciplinary, transdisciplinary, and even convergent collaboration that motivate the framing of interdisciplinarity in this study [6][7][8][9]. In the context of the IR program, interdisciplinary graduate education is characterized by learning that integrates traditional academic disciplines and stakeholders' knowledge, values, and approaches to answer research challenges not satisfactorily addressed by a single discipline alone; it is also driven by authentic, compelling problems that arise from deep scientific questions and pressing societal needs.

Consistent with a situated view of learning [10], most interdisciplinary graduate programs seek to not only provide students with the skills that support interdisciplinary collaboration, but also those that help students develop professional identities that incorporate interdisciplinary work. As students engage with others in an interdisciplinary research education community, they learn and negotiate professional norms, idealized images of professions, and the professional recognition of significant others [11][12][13] that impact their abilities to see themselves as interdisciplinary scholars. These negotiations can help their sense of belonging within an interdisciplinary professional community [14][15]. That said, because of the disciplinary nature of universities, interdisciplinary students are likely to have a clearer picture of how to develop a

disciplinary professional identity as compared to an interdisciplinary one; more examples of disciplinary scholars exist, and scholars such as Welch-Devine et al. [3] suggest that structural barriers of academic environments such as this siloing, the presence of conflicting departmental policies and procedures, as well as funding issues, impinge upon graduate students' abilities to develop their identities as interdisciplinary scholars.

In an effort to expand this study beyond the analysis of direct environmental barriers to interdisciplinary scholar identity development identified by previous research, this study uses Ecological Systems Theory (EST) and a cognitive-constructivist approach to understand the interrelationships between more expanded and indirect, structural layers of siloed academic environments (i.e., microsystem, mesosystem, etc., [4][5]) and the professional identity development of the future interdisciplinary professoriate.

Bronfenbrenner described 5 layers of an individual learner's environment, emanating from the individual to the microsystem, the mesosystem, the exosystem, the macrosystem, and the chronosystem [4][5][16] to provide a model for understanding the relationship between a student and the layers of their academic environment, and the ways in which these relationships affect student identity development. Bronfenbrenner's original work focused on child development, but more recent scholars have shown CST's saliency in the graduate student environment [17][18], though not specifically to interdisciplinary graduate programs. Figure 1 below provides a visual overview of the EST model. For this study, the theory serves as a lens for unpacking the influences on interdisciplinary scholar identity development as well as the ways in which various layers of a students' environment interact with and either support or impinge upon positive professional identity development.

Macrosystem — incorporates the culture, values, economics, as well as emotional and ideological contexts in which developing students find themselves; key drivers for change in society at national and international levels

Exosystem — certain aspects of the academic environment that developing students to not directly participate in but that still affect student development

Mesosystem — interrelationships between two or more settings in which the developing student operates; institutional setting

Microsystem — surrounding environment; activities, roles, and interpersonal relationships

Student — developing individual and their social identities, interests, prior learning, etc.

Chronosystem — represents the passage of time, both in terms of the duration of a students' interdisciplinary scholar professional identity development, and the ways in which the interrelationships of this academic environment change over time

Time

Figure 1: Model of Ecological Systems Theory

At the core of the EST model for graduate student development is the masters or doctoral student themselves, along with their individual attributes, interests, and previous experiences; like other cognitive-constructivist understandings of identity development, the theory emphasizes that students are not blank-slates when they enter a learning environment. Rather, they are agents with an entire life history within an environment that affects their development [17].

Surrounding the graduate student most immediately is the microsystem, where developing persons experience learning-related activities, roles, and interpersonal relationships that make up a students' surrounding social and learning life [18][19][20]. This level includes interactions with near-peers, instructors, and personal friends, all of whom have a critical impact on a students' development. In more recent years, the microsystem has also expanded in definition to include smartphones, personal computers, and other ways of accessing the internet—with the advent of technology, these interactions are inextricably linked to the learning environment [21].

Next is the mesosystem, which includes the interrelationships between two or more of developing students' direct settings. For graduate students, this layer is their institutional setting more broadly and how its structures interact with graduate students' sometimes conflicting priorities stemming from and impacted by microsystems in their lives [17][19].

The other three layers of Bronfenbrenner's academic environment model are the exosystem, macrosystem, and chronosystem. These layers provide a lens for unpacking indirect influences on interdisciplinary graduate student development that exist beyond the mesosystem and institutional setting, changing through time. While students only passively interact with these layers, they are still affected by these features of their environment that include research funding structures, hiring institutions, and social trends in knowledge-making [20][22].

Though the larger study associated with this conference paper investigates all the layers of Bronfenbrenner's model for interdisciplinary graduate students in resilience, this conference paper focuses only on the center of the model, the individual student level, microsystem, and mesosystem. Future work will elaborate on how change at the broadest levels of interdisciplinary graduate students' environment, the exosystem, macrosystem, and chronosystem, can have a profound effect on the identity development and learning experiences of an individual learner.

Methods

To gain a qualitative understanding of graduate students' perspectives on their interdisciplinary scholar identity development over time, 48 semi-structured interviews were conducted for 3 cohorts of students in the IR program across 3 years. Participants were interviewed annually, which yields up to 3 interviews per participant. See Table 1 below for a breakdown of the number of students who consented for their interviews to be used over these three years.

Table 1: IR Program Student Interview Numbers

Cohort	N for Year 1	N for Year 2	N for Year 3
Cohort 1	8	9	9
Cohort 2	NA	6	6
Cohort 3	NA	NA	10

The participants for this study are masters and doctoral STEM students in the IR program. Students in Cohort 3 have completed only one year in the program, while those in Cohort 3 are near completion, providing a diverse set of perspectives. The IR program has funded 37 doctoral students overall and graduated 7 as of the Fall of 2022. To date, 68 interviews have been collected for program assessment and 59 include consent for research; those who consented for this specific study have had their perspectives on influences on their development as interdisciplinary scholars tracked over time (48 interviews from Table 1).
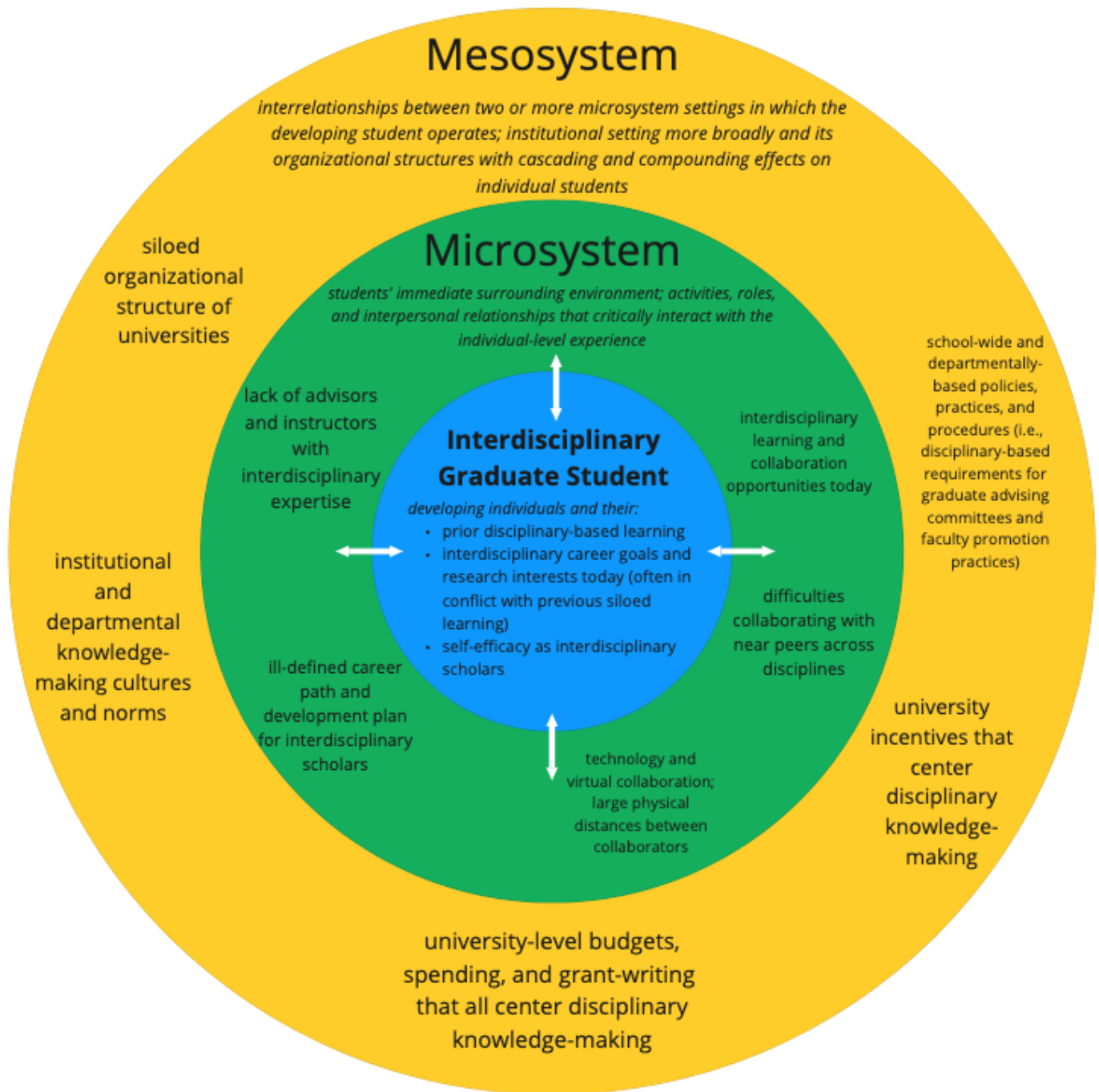
As is typical of inductive qualitative research, the semi-structured interviews called for open-ended questions to encourage students to retell stories about experiences in the interdisciplinary graduate program as opposed to providing a precise definition. Questions focused on student experiences in their interdisciplinary program and what students found to be most helpful or challenging about their academic environment and development as interdisciplinary scholars. Note that the interviews were not designed around the theoretical framework; the protocol was developed to broadly explore participants' experiences in the program and their development as interdisciplinary scholars; iterative review of the transcripts, our own previous analyses [1][15], and readings of the existing literature led to the identification of Bronfenbrenner's framework as a lens for this analysis.

These interviews were transcribed and analyzed in a two-phase coding cycle [23]. First, transcripts were coded inductively for discrete units of influences on interdisciplinary graduate student identity development through content analysis, isolating the data relevant to this study's research questions. This technique condensed the transcripts into salient units of analysis. The second phase categorized or themed these influences according to an a priori coding framework based on EST. Aligned with the research questions associated with this study, the goal with data analysis was to achieve an initial categorization of the influences on interdisciplinary scholar identity development through the eyes of students, and then to provide an in-depth interpretation of the meanings of these various influences and ways in which they align with Ecological Systems Theory's model for student development.

Findings

Our findings include influences to interdisciplinary scholar identity development for graduate students at the individual, microsystem, and mesosystem levels of their academic environment, as well as the interrelationships between layers.

Overall, both students' individual backgrounds and their institutional contexts more broadly have significant impacts on their identity development. They also suggest that interdisciplinary graduate students experiences are similar and related to those of interdisciplinary undergraduate students and faculty, but they are distinct and impacted by the disciplinary nature of learning prior to graduate school, difficulties finding interdisciplinary advisers, collaborators, and development plans when they are not prominent, and broader institutional cultures related to disciplinary knowledge-making. Figure 1 below summarizes the findings identified for at each level; the white arrows indicate the criticality of individual/microsystem level interactions.

Mesosystem

interrelationships between two or more microsystem settings in which the developing student operates; institutional setting more broadly and its organizational structures with cascading and compounding effects on individual students

Microsystem

students' immediate surrounding environment; activities, roles, and interpersonal relationships that critically interact with the individual-level experience

siloed organizational structure of universities

institutional and departmental knowledge-making cultures and norms

lack of advisors and instructors with interdisciplinary expertise

ill-defined career path and development plan for interdisciplinary scholars

Interdisciplinary Graduate Student

developing individuals and their:
- prior disciplinary-based learning
- interdisciplinary career goals and research interests today (often in conflict with previous siloed learning)
- self-efficacy as interdisciplinary scholars

interdisciplinary learning and collaboration opportunities today

difficulties collaborating with near peers across disciplines

technology and virtual collaboration; large physical distances between collaborators

school-wide and departmentally-based policies, practices, and procedures (i.e., disciplinary-based requirements for graduate advising committees and faculty promotion practices)

university incentives that center disciplinary knowledge-making

university-level budgets, spending, and grant-writing that all center disciplinary knowledge-making

Figure 1: Influences on Interdisciplinary Scholar Identity Development: The Individual, Microsystem, and Mesosystem Levels

The following sections highlight findings at the individual, micro, and mesosystem level, as well as interactions between levels. Given the scope of the conference paper, we present those findings most prominent in the data, but note that additional emergent themes will be addressed in subsequent publications. Note that we refer to individual participants by letter; we did not ask students to self-select pseudonyms at the outset of the study, and choose not to assign them as a research team given the potential demographic identifiers and assumptions embedded in names.

RQ1: Influences at Each Level

The Individual Student Level

The individual student level of the EST model for interdisciplinary graduate student development includes individual attributes like these burgeoning scholars' research interests, career goals, social identities, and prior learning experiences. In this study, graduate students suggested that the most critical elements of their individual-level experiences were related to the fact that, despite increasing interest in convergence, they were still "brought up" in undergraduate departments siloed by discipline. In this way, though our participants are interdisciplinary now, their previous siloed career goals and learning experiences left their frames of reference, interests, and career goals today limited, which in turn impacted their access to relevant experience, necessary for increasing their capacity for interdisciplinary collaboration as well as bolstering their positive identity development as interdisciplinary scholars. Summarizing the thoughts many students expressed, Student O (2020) described,

> All of my formal like educational background is [disciplinary]. And then all of my job experience before coming here… I really didn't have any experience with [interdisciplinary resilience] before and I didn't have any really like good, uh, like interdisciplinary experience.

For example, for Student H (2019, 2020), working as an interdisciplinary graduate scholar after a disciplinary-focused undergraduate experience involved having to figure out problems for which they have "no concept, no frame of reference." Similarly, Student I (2021) explained, "if you're asking me something about [disciplines outside of my major], no, I don't know it at all. I have never even taken a test." The IR scholars also noted that rigid, lockstep course structures as well as course scheduling problems across disciplines limited the breadth of their exposure to divergent ways of thinking at the undergraduate level at the expense of disciplinary depth.

Interestingly, many students in our study noted that they were glad their undergraduate experiences were siloed to facilitate deep disciplinary thinking then, but now that they are interdisciplinary graduates, their career goals are changing, and the recognize that their previous learning makes it hard for them to negotiate diverse skill sets need to do convergent scholarship with other researchers. Students G (2019), AC (2021), W (2021), A (2021), and H (2021) all discussed this issue with comments such as, "it's really hard to become an expert on something that …[I] never cared about before."

In essence, the siloed awareness developed at the undergraduate level acted as individual-level previous learning and as a career goal- related influence on interdisciplinary graduate student

development. Being exposed to only one disciplinary-based set of perspectives, methods, and conceptual approaches prior to graduate school affected interdisciplinary graduate students' abilities to collaborate across disciplines, to see themselves as interdisciplinary scholars, and to learn outside of their home discipline after graduation. Student N (2020) expressed anxiety over their ability to become an interdisciplinary scholar at all, saying "I feel like part of me saying I don't is part of like imposter syndrome just a little bit, you know. Like feeling like I hadn't had any experiences that makes me be able to say that."

In this way, interdisciplinary graduate students' prior disciplinary based learning experiences and their interdisciplinary interests and career goals today were often in conflict, revealing the time-dependent nature of influences on interdisciplinary scholar identity development and the ways these graduate students' self-efficacy and sense of belonging in academia is tied to their abilities to see themselves as interdisciplinary researchers.

The Microsystem Level

Surrounding the interdisciplinary graduate student most nearly is the microsystem, made up of the interdisciplinary graduate student's immediate context (i.e., their interpersonal relationships, collaborations, and learning activities today). Graduate students in this study interacted with many different microsystems, including other students and peers as well as their personal friends and relatives. That said, for IR students in this study, relationships and experiences with advisors, instructors, courses, and collaborations within their interdisciplinary graduate plan of study were the most salient influences on their identity development at this level.

Specifically, IR students noted that though they are studying to be interdisciplinary scholars, have interdisciplinary goals, and might operate outside of a single silo themselves, their closest mentors and most critical learning activities overall still exist within disciplinary structures and, like their undergraduate experiences, are often siloed (or separated) in nature. As a result, influences on a student's development at this level included the lack of advisors and instructors with interdisciplinary expertise, ill-defined career paths / development plans for interdisciplinary researchers, and geographical or physical distances between disciplinary hubs on campus and the prevalence of virtual interdisciplinary collaboration.

For example, Student G explained that it was hard to find interdisciplinary advisors who support their work as interdisciplinary researchers-- they saw everyone (especially faculty) "sticking to their own discipline." Student D (2020) noted that the faculty in their interdisciplinary program seem interested in the program but "maybe not specific to individuals," perhaps partially related to the fact that "some of them are not able to uh attend meetings regularly…we have some uh *separation* to faculty." Student I specifically said that for IR faculty not on their committee, "I wouldn't expect any big help from him" and Student B added, "there's a lot of frustration around being the pioneers of DRRM" because being first to do something involved "[building] an entire program" that did not exist before.

In considering the scarcity of few academics with interdisciplinary expertise at their university, IR students noted that the burgeoning nature of convergent research means that their interests are novel within their institution's portfolio, making it difficult to find many courses or faculty in the

area. Students suggested that without examples of interdisciplinary scholars or the opportunity to be advised formally by more than one person, they lacked a clear career path or guidance to follow in pursuing interdisciplinary careers after graduation. Student B (2021) said that they are "not completely clear on that path…I don't know what to ask for help about because I don't know what I don't know." Student G (2021) echoed this with, "I mean what do we do when we graduate as a DRRM fellow?" In other words, while the structures that define typical career paths for disciplinary scholars were well-established and robust, scholars in this program felt their development plan was largely undefined. Despite increasing interest in convergent research, students felt universities still need to bolster and build capacity for educating interdisciplinary graduate students, advising on cross-disciplinary research, and creating development plans for these types of scholars.

As for the microsystem-level impacts of geography and physical distance between collaborators on campus, graduate students in this study commonly discussed the dearth of campus interdisciplinary spaces and the dominance of departmentally-based, geographically distributed buildings as barriers to their abilities to collaborate and develop a sense of belonging as an interdisciplinary scholar. In 2021, Student D said,

> Interdisciplinary researchers or scholars [are] people who know how to work together with people from different disciplines…but it's not always possible to find these people – they-they're not in your building, like they aren't in department.

Students noted that the advent of digital technology in academia has allowed for convergent research collaborations unbounded by geography as well as broader access to interdisciplinary courses and mentorship, but they also highlighted these technologies designed to combat the limitations of physical distance between scholars also means that they missed out on "how to be social and how to interact with people outside of a screen" and on those spontaneous conversations considered essential to idea generation (Students X and W, 2021). Student F (2021) described the dynamic as a need for informal student spaces to talk, collaborate, and get to know each other. Student AA (2021) agreed and said these spaces need to be "not online…[because] the social component is a more, is more important in that interdisciplinary kind of work than it is in just your own field."

Students found social interactions critical to developing trust, a strong working relationship in teams, and idea generation in research, and they suggested that physical space is a particularly important support to these ends. Meeting online had its uses, but students mentioned that dedicated spaces for interdisciplinary students to come together to work, collaborate, and get to know each other are pivotal for their abilities to see themselves and have others see them as interdisciplinary scholars. In this way, academic structures that pose barriers to interdisciplinary identity development in graduate students are not just organizational in nature; they are also physical or geographical.

In sum, microsystem level influences that challenge IR student identity development primarily related to the idea that interdisciplinary graduate students were pioneers of their types of plans of study surrounded by disciplinary forebearers– the courses and faculty around them were not always designed or readily equipped to facilitate the collaborative and transdisciplinary

experience these graduate students saw as necessary to their identity development. In other words, interdisciplinary scholars in this study navigated multiple intersecting and sometimes conflicting microsystems in their plans of study; some are more disciplinary in nature and others more interdisciplinary, and the porosity of these microsystems' support structures differ.

The Mesosystem Level

The mesosystem includes both the institutional setting and interactions among microsystems. We discuss the institutional setting here, and the interactions in the next section.

At the mesosystem level, IR students discussed the siloing and influence of their institutional setting more broadly, as well as the impacts of departmentally-based organizational structures on interdisciplinary identity development. They focused specifically on incentive-based norms, policies, and procedures and the ways in which their university's practices align with disciplinary research priorities and create structural challenges for interdisciplinary scholar identity development. They discussed ways departmental structures and personnel come with their own cultures, norms, and incentives for knowledge-making that often center disciplinary approaches. The most common examples were related to institutional research decisions regarding thesis and dissertation committees; normative, disciplinary-focused ideas of the purpose graduate school; and the ways university spending and monetary incentives (de)motivate (inter)disciplinary research.

In terms of norms, policies, and procedures, interdisciplinary graduate students in this study focused on incentive-related parts of their direct academic mesosystems, from normative ideals about publishing to graduate students themselves, that impact their interdisciplinary journey and demotivate their interdisciplinary scholarship. For example, one of the main priorities graduate students discussed as in conflict to their interdisciplinary scholar identity development is the expectation to have publications in certain disciplinary-acclaimed journals and to specifically be the first author on those publications. In 2020, Student A said,

> So I was thinking about the IR program, and I think it is a little bit hard to be motivated, because PhD students need to be the first author of their dissertation. And everyone is PhD student so … their priority cannot be that interdisciplinary project. And I get also faculty have similar feeling, because they have their own disciplinary issues projects. So, I think the IR projects became um not a priority … If we want to be motivated, I think there needs some force that's pushing students to interdisciplinary research as a requirement. …if there's a requirement like that, it will be hard and it will be an extra work, but I think without those kind of forces, it will stay the same. People want to do it, but it's hard to do in this circumstance, in this system. That's the hard part.

Other scholars also noted that trying to get published in disciplinary venues often conflicts with interdisciplinary work because disciplinary models devalue collaborations and interdisciplinary publishing. For example, in some fields certain journals and publishers carry more legitimacy than others due to their long-standing reputation; participants in this study highlighted that these journals are often disciplinary in nature. For example, Student D (2021) talked about how their business discipline has "a list of…elite journals you can just publish in these in order to, eh, get

promotion, get tenure, or something." In other words, getting published in interdisciplinary journals carries less weight toward promotion and tenure, making both students and faculty less motivated to do convergent work.

IR students also cited ways institutional ideals about what a graduate student "should be" are contrary to their identity development, sense of belonging, and non-traditional pathway in academia; specifically, they shared that their advisors' constructed ideals for graduate students were often based on institutional, cultural, and historical norms of disciplinary-based knowledge-making. For example, Student C (2019) described normative conceptualizations of graduate students as disciplinary in nature; they noted that their committee members had a certain "idea about what the PhD trajectory should look like." Student U (2021) said that as an interdisciplinary scholar, they feel "kind of constrained by just the nature of the PhD," because incentive structures at their institution are created with the "normal" PhD student in mind. Notably, these doubts persisted over time, as Student C said again in 2020,

> I feel like a lot of us maybe doubt ourselves a lot [laughs], but nobody really wants anybody to know that. And I think especially in interdisciplinary work, we are prone to falling into feeling like we don't belong in academia, because of the structures that are in place…the incentive structures are not there..we have a hard time publishing interdisciplinary papers and teaching courses outside of our departments.

These norms reveal the impact that institutional cultures and their related policies and organizational structures around what it means to be an academic have on interdisciplinary graduate students' development of expertise in addition to their ability to publish and gain notoriety. Whether it is university or departmental policies that incentivize disciplinarity in tenure and promotion practices, or specifically advisors' normative ideas about knowledge generation and graduate students, IR students shared that disciplinary-based norms at a university level are often hidden, unwritten, embedded in disciplinary cultures and their associated organizational structures, and that these these ideals were in conflict with interdisciplinary identity development.

In this way, interdisciplinary graduate students' perspectives and the lens of the mesosystem reveals the ways in which larger, disciplinary-based institutional structures designed for faculty promotion and tenure have a cascading and compounding influence on the experiences of interdisciplinary graduate students, despite their being designed for someone else. When incentive structures are designed with normative ideals of disciplinary-based knowledge-making in mind, not only faculty but also their interdisciplinary graduate students struggle to publish and find enough support for their work, impacting their motivation for interdisciplinary research and development as interdisciplinary scholars. In addition, even those "unwritten norms" about research at an indirect and institutional level significantly impact student development.

RQ2: Interactions Across Levels

Interactions between the Individual and Microsystem

In terms of the interrelationships between the individual and microsystem layers of IR graduate

students' academic environments, students in this study found interactions between their previous learning experiences, career goals, and the (inter)disciplinarity of their microsystems most salient. Specifically, IR students cited collisions of or conflicts between their interdisciplinary research interests and career goals with the availability of interdisciplinary instructors, advisors, and learning activities; this combination of interdisciplinary students' previous learning experiences and lack of interdisciplinary advising in graduate school were compounding demotivators for students seeking interdisciplinary work and identity development.

As alluded to before, interdisciplinary graduate students in this study often mentioned knowledge gaps resulting from sole exposure to certain methodologies, techniques, and pedagogical styles at the undergraduate level. Through the lens of interrelationships between the individual and microsystem, IR students made it clear that their previous learning experiences interact with their microsystems and interdisciplinary career goals today in terms of the significant impact these individual-level phenomena have on students' abilities to collaborate, gain breadth in knowledge, and develop research network connections needed to become interdisciplinary scholars now that they are in graduate school. Student G (2020) summed it up well and said,

> If you don't have any background on other disciplinary education it's hard for you to become an interdisciplinary scholar. [If you] have some education in different disciplines, it's more easy for you to become an interdisciplinary scholar because you can understand that. My trouble is I cannot understand other's views in the first place. If I try to understand it, I needed to take a course; I need so much time to focus on that.

Student AB (2021) described the phenomena as, "just the language that's used [in interdisciplinary teams]…each discipline kind of has its own vocabulary," and in 2019, Student G felt they "lack the techniques to combine [disciplines], to do the interdisciplinary research." For Student I (2021), this inability to see overlaps and extract meaning resulted in their not trying "to read some paper, literature…to understand that" because they "don't think it's worth it." In this way, students' limited prior interdisciplinary learning is often in conflict with their interdisciplinary career goals in graduate school. The feat of becoming interdisciplinary felt insurmountable, and students shared that interdisciplinary collaborations are not even worth trying for them because of their siloed expertise.

This is particularly troubling because students also added that their more individual experiences of identity development and career goal building in interdisciplinarity are relatively unsupported within their university or interdisciplinary microsystem. Students commonly noted a lack of available advisors with interdisciplinary expertise and the time to take on additional students, particularly when they are spread all across campus, and shared that their abilities to seek interdisciplinary work collide with microsystem phenomena of the lack of interdisciplinary advising in graduate school and demotivate their desire to be interdisciplinary scholars. For example, in 2021 Student G shared,

> I mean so what's the point of being in a program where we don't have that support. Yes, we do have the financial support… but how does IR support us through our research, or how do they offer us more time? Because, you know, like with time I think – I don't know, I don't know how I have like, you know, developed my skills as a researcher,

because it's just been one advisor, and I didn't have any other scope. And there has been little scope of like expanding on whatever I was doing, or I don't know, maybe it was I would say a lack of mentorship, or what, I don't know.

In summary, IR graduate students' identity development was impacted quite critically by interactions at an individual-microsystem level; influences at these layers of the academic environment and the interactions between them included but were not limited to tension and conflicts associated with the interrelationships of students' previous disciplinary-focused learning experiences and their capacity for interdisciplinary collaboration today, the increasing demand for faculty doing interdisciplinary work and the need for clearer interdisciplinary career paths in the future, as well as the limitations of physical space in convergent collaborations and virtual forms of communication.

In this way, disciplinary-focused environments at the microsystem level had extended impacts on participants' decision-making and development of scholarly identity, and they interacted quite critically with participants' identity development experiences and attributes at an individual level particularly because of the important and extensive role these discipline-based advisors play in students' lives, as well as the dominance of disciplinary-based thinking and organizational structures in both education and society more broadly today.

Interactions between Microsystems and the Mesosystem

Mentioned earlier, at the mesosystem level, interdisciplinary graduate students discussed the influence that their institutional setting more broadly has on their identity development as interdisciplinary scholars; that said, this mesosystem is not just about how students interact with their institution– it also includes the interrelationships between IR students' microsystems. The most salient interactions IR students discussed at this model's microsystem-mesosystem ecological threshold are the interrelationships between interdisciplinary graduate students' different microsystems, whether it be between a disciplinary microsystem and an interdisciplinary one (i.e., the IR graduate program) or between multiple disciplinary microsystems (i.e., departmental graduate programs).

The site in which students experienced these interactions most significantly is within their interdisciplinary thesis or dissertation committee, made up of faculty across their universities, who often have divergent ideas about the priorities of research, the value of interdisciplinary work, and the nature of graduate school and specifically a disciplinary masters or PhD; in other words, students referred to the way departmental microsystems often conflict over norms, ways of researching, teaching, and funding such work, as well as the ways this impacts their identity development. Specifically, IR students described how, because their thesis/dissertation committees were chaired by their disciplinary advisor but still governed by other faculty across divergent disciplines, they were caught in an awkward place between microsystems in trying to earn their degree; students described balancing being primarily funded by their disciplinary advisor's grants which often had specific disciplinary aims tied to their capstone work with having an interdisciplinary committee and approach, negotiating multiple perspectives on the nature of a PhD and the value of interdisciplinary work.

For example, Student O (2021) described a grant they received for doing research from national foundation focused on ecology; they said, "it's not going to allow for interdisciplinary…my funding is like 'you're doing ecological research.'" Corroborating this, Student U (2021) discussed how once an academic advisor accrues this type of disciplinary funding for a certain proposal, they are expected to conduct the research as they said they would (i.e within disciplinary bounds). Often graduate students support these professors on these projects, and for interdisciplinary researchers like Student U, this meant they could not "really go beyond these limits and these expectations of projects…I don't think that for PhD students we could really go beyond what we should do because it just about funding…it's just about the project goals."

Essentially, graduate students who do not have funding of their own often work for it under their academic advisors' grants which are not always pitched to include interdisciplinary aspects that the student is more focused on. Because the money students get to do their dissertation work in the form of grants and other types of funds tends to come from disciplinary sources that expect disciplinary research results, IR students' opportunities to secure funding and to do interdisciplinary work were limited. These examples reveal how disciplinary and interdisciplinary microsystems interact and often conflict; interdisciplinary graduate students operate in and have to negotiate both disciplinary and interdisciplinary microsystems and their organizational/funding structures that create barriers to their interdisciplinary development. The next examples highlight interactions between different disciplinary microsystems.

In 2021, Student Z discussed how they balanced being disciplinary versus interdisciplinary in their PhD dissertation and committee relationships, and said "It is very challenging. Especially at the beginning…I realized I have to have the support of my primary advisor first. I cannot do the multidisciplinary collaboration without him first." They highlighted how their committee chair had the final say on their dissertation and their funding came from them, putting them in an awkward position when "during my qualifying exam…when I start to say some words from both my disciplines my other committee members say that 'oh, perhaps this is out of scope." For IR students, interdisciplinary committees meant finding approaches to dissertation work that resonated across a variety of disciplines or fields– not just one– complicating IR graduate students' interdisciplinary identity security. For Student Z this meant finding a working balance between their advisor's aims, their own, and that of their other committee members as well as finding language that resonated with everyone.

Student C (2019, 2020) echoed Student Z's sentiments and said,

> A bad thing is that in my committee meeting I got the comment that… I needed to be careful that I'm not spreading myself too thin or doing everything at once or something like that, which I think people who try to do interdisciplinary research, I think that's often a comment they get all the time, like you can't do everything. You're supposed to collaborate with people effectively, so I think I'm definitely towing that line between ... I'm not focused on anything yet. And I thought that was the point of this year, is that I was supposed to be like trying everything, but I don't know. Each person on my committee maybe has a different idea about what the PhD trajectory should look like and the primary driver of my trajectory is saying that this year I should go wild and try whatever I want, and then some of them are like well this is looking like you're doing a lot of stuff… I don't

know, it makes things hard. I feel like this is just in academia in general, being interdisciplinarians brings insecurities and conflicts. I feel like a lot of us maybe doubt ourselves a lot [laughs], but nobody really wants anybody to know that.

In summary, not only individual actors and microsystems created conflicts between disciplinary and interdisciplinary research priorities, so did the academic institutions that brought these microsystems together, as well as the interactions disciplinary and interdisciplinary microsystems had with each other in IR students' mesosystem. The interrelationships between microsystems in IR students' lives influenced their development most prominently in their thesis/dissertation committees where they were funded often through one chair's grant with their progress in the degree resting on multiple individual faculty who often conflicted and represented the divergent knowledge cultures across disciplines. In this way, the siloed organizational structures associated with dissertation and thesis committees and the ways in which disciplines conceptualizes graduate school in conflicting ways challenged interdisciplinary scholars' development and created barriers to interdisciplinary research priorities.

Discussion, Limitations, and Future work

This study extends existing knowledge about interdisciplinary graduate education because it incorporates students' perspectives on influences on interdisciplinary scholar identity development in research. While before we knew that departmental norms, practices, and incentives impacted faculty decision-making in interdisciplinary programs [3], this work now highlights additional potential weaknesses/porosity in current interdisciplinary research infrastructure and microsystems (i.e. lack of interdisciplinary faculty, formalized interdisciplinary development plans, lack of physical space for interdisciplinary collaboration or geographical limitations), the ways facilitating interdisciplinary scholarship at the graduate level depends upon a strong interdisciplinary undergraduate foundation, as well as the cascading and compounding effects of departmentally-siloed institutional cultures, decision-, and incentive-making on interdisciplinary scholarship, particularly in terms of the limitations of interdisciplinary thesis and dissertation committee structuring. The work also reveals the ways in which interdisciplinary graduate education research differs from but is still related to previous understandings of undergraduate and faculty interdisciplinary programming.

This research suggests that positive interdisciplinary scholar identity development at the graduate level is strongly influenced by aligned incentive structures and both physical and virtual spaces that motivate interdisciplinary undertakings, as well as not just exposing students to diverse perspectives, but also providing them with skill-set training in the ability to synthesize divergent perspectives across geographical and epistemological boundaries. The layered nature of students' academic environments and the interrelationships between these layers means that even indirect and unwritten policies, practices, and procedures aligned with disciplinary scholarship have cascading and compounding effects on interdisciplinary students development, and that universities as well as broader academic institutions need to explore and enact structural change in university policies and practices, to ones that incentivize interdisciplinary research, teaching, and service for both graduate students and their faculty.

While the contributions of this study are noted, there are limitations to the work, particularly in

terms of the studys' focus on only direct environmental influences on interdisciplinary scholar development (i.e., the microsystems and mesosystems) as opposed to those layers that are more indirect but still exert a meaningful influence on students' development. In addition, though longitudinal data from scholars was collected, this study does not specifically address the effects of time on interdisciplinary scholars' identity development and the influences on that process.

This research space will benefit from future work that explores the differences in the robustness and extent to which interdisciplinary microsystems are and not developed, the cascading impacts of the less-understood and broader layers of the academic environment impacting interdisciplinary scholar development– the exosystem, macrosystem, and chronosystem, and the strategies for structural change towards interdisciplinary-aligned incentive structures for academics. It is also important to better understand how unwritten rules and cultures stem from and are related to broader social trends as well as how these unwritten rules are linked to diversity, equity, and inclusion issues in graduate education.

Acknowledgments

References

[1] Deters, J., Webb, M., Paretti, M., and Menon, M. "Building a Sustainable University-Wide Interdisciplinary Graduate Program to Address Disasters." *2022 ASEE Annual Conference & Exposition,* 2022.

[2] O'Meara, K., and Culpepper, D. "Fostering collisions in interdisciplinary graduate education." *Studies in Graduate and Postdoctoral Education*, vol. 11, no. 2, pp. 163-180, 2020.

[3] Welch-Devine, M., Shaw, A., Coffield, J., and Heynen, N. "Facilitating interdisciplinary graduate education: Barriers, solutions, and needed innovations." *Change: The Magazine of Higher Learning*, vol. 50, no. 5, pp. 53-59, 2018.

[4] Bronfenbrenner, U. "The ecology of human development: Experiments by nature and design." *Harvard university press,* 1979.

[5] Bronfenbrenner, U. "Making human beings human: Bioecological perspectives on human development." *Sage,* 2005.

[6] Borrego, Maura, and Stephanie Cutler. "Constructive alignment of interdisciplinary graduate curriculum in engineering and science: An analysis of successful IGERT proposals." *Journal of Engineering Education,* vol. 99, no. 4, 355-369, pp. 2010.

[7] Borrego, Maura, and Lynita K. Newswander. "Definitions of interdisciplinary research: Toward graduate-level interdisciplinary learning outcomes." *The Review of Higher Education,* vol. 34, no. 1, pp. 61-84, 2010.

[8] Richter, David M., and Marie C. Paretti. "Identifying barriers to and outcomes of interdisciplinarity in the engineering classroom." *European Journal of Engineering Education,* vol. 34, no. 1, pp. 29-45, 2009.

[9] NSF. Learn About Convergence Research. https://beta.nsf.gov/funding/learn/research-types/learn-about-convergence-research.

[10] Lave, J., and Wenger, E. "Situated learning: Legitimate peripheral participation." *Cambridge university press,* 1991.

[11] Beddoes, K., and Borrego, M. "Facilitating formation of shared mental models in interdisciplinary graduate student teams." *International Journal of Collaborative Engineering,* vol. 1, no. 3-4, pp. 236-255, 2014.

[12] McCall, C., Shew, A., Simmons, D. R., Paretti, M. C., and McNair, L. D. "Exploring student disability and professional identity: navigating sociocultural expectations in U.S. undergraduate civil engineering programs". *Australasian Journal of Engineering Education,* vol. 25, no. 1, pp. 79–89, 2020.

[13] Wenger, E. C., and Snyder, W. M. "Communities of practice: The organizational frontier." *Harvard business review,* vol. 78, no. 1, pp. 139-146, 2000.

[14] Boden, D., Borrego, M., and Newswander, L. K. "Student socialization in interdisciplinary doctoral education." *Higher Education*, vol. 62, pp. 741-755, 2011.

[15] Deters, J. R., Menon, M., Paretti, M. C., and Webb, M. "Exploring interdisciplinary identity development using possible selves: An exploratory study." *Australasian Association for Engineering Education,* 2021.

[16] Bronfenbrenner, U., and Morris, P. A. "The ecology of developmental processes." 1998.

[17]   Mayne, D. "An ecological systems theory approach to academic acculturation of female international students from the Arab Gulf." 2019.

[18]   Naidoo, K., Yuhaniak, H., and Abel, Y. "An ecological systems approach to exploring facilitators and barriers to success for minority students enrolled in a doctor of physical therapy program." *Health Professions Education,* vol. 6, no. 3, pp. 394-405, 2020.

[19]   Onwuegbuzie, A. J., Collins, K. M., and Frels, R. K. "Foreword: Using Bronfenbrenner's ecological systems theory to frame quantitative, qualitative, and mixed research." *International journal of multiple research approaches*, vol. 7, no. 1, pp. 2-8, 2013.

[20]   Sanders, M. K. "Exploring Online Graduate Student Experiences in Doctor of Education Programs at a Private Christian Institution: An Ecological Systems Theory Approach." 2020.

[21]   Stokols, D. "Social ecology in the digital age: Solving complex problems in a globalized world." *Academic Press,* 2018.

[22]   Bond, M., and Bedenlier, S. "Facilitating student engagement through educational technology: towards a conceptual framework." *Journal of Interactive Media in Education*, 2019.

[23]   Stemler, S. "An overview of content analysis." *Practical assessment, research, and evaluation,* vol. 7, no. 1, pp. 17, 2000.