Identity-trajectory as a Theoretical Framework in Engineering Education Research

Lauren D. Thomas, University of North Carolina at Chapel Hill

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Introduction

Identity theories have been recently used in engineering education research[1,2] as a means to understand student belonging[3] and development ,[4-6] with the goal of introducing strategies to improve education and retention in engineering[7]. The theory of identity-trajectory was introduced by McAlpine[8] to explain the professional identity development through time of graduate students and emerging academics through intellectual, institutional, and network strands. The three strands work independently, and at times, weave together to explain identity development for those early in their academic career. Identity-trajectory provides a means to understand these early influences impact on one's professional trajectory as they progress professionally.

The intellectual strand focuses on learning within and the contributions of an individual to their field. Past experiences, agency, individual ability, and personal responsibilities are also a part of the intellectual strand. The institutional strand focuses on identity based on affiliation and role within the university and field. There are also institutional structures, resources, and responsibilities that have an important influence on the identity of an early academic. The network strand includes professional relationships, organizations, and collaborations that contribute to professional identity. The three strands allow for a rich analysis of the complex nature of identity and how it evolves through time.

This framework was used in an engineering education doctoral dissertation[9] to explore the experience of graduate students in optics and photonics. The findings of the study demonstrated the importance of research experiences for the preparation of eventual graduate students. At the pre-graduate level, themes related to network access and the role of the institution in facilitating intellectual experiences were important for the study participants. At the graduate level, identity-trajectory reiterated the need for careful design of the research laboratory, and the importance of networks for graduate student success.

Overview of literature

Identity-trajectory, introduced by McAlpine [8,10] is a theoretical framework used to understand the professional development of graduate students and early career academics through three strands[11]: *network*, *intellectual* and *institution*. *Network* focuses on the relationships and responsibilities that can enable an individual to meet their current obligations and responsibilities. Networks also allow for broad exposure to the individual's academic discipline. The *intellectual* strand is rooted in learning in the classroom and disciplinary space and the contributions made as a result of that learning[10]. Within the intellectual strand is agency, which accounts for personal desire and actions to achieve goals or objectives[12]. The *institutional* strand specifically looks at the responsibilities dictated by a role and the resources available where one is physically located[12]. In this, and other identity-trajectory studies, the institution is the department, program or college that a student or faculty member is formally a part of.

The theory is undergird by four concepts that many in the engineering education research community are more familiar with: Discourse-identity[4], activity-theory[13], storytelling and identity[14], and agency[12]. Identity-trajectory is useful because it simultaneously accounts for these concepts and the dynamic influence that they can have on professional development and identity construction. Identity-trajectory also, examines the three strands through time, as some strands may become more prevalent than others at certain stages in time. Identity-trajectory as a theoretical approach provides attention to the individual, their actions, personal life, prior experiences, future goals, and their role within the institution.[8]

Network strand

The network strand focuses on the relationships that allow and enable a person to complete the tasks required of them.[8] These relationships take form with departmental colleagues, students and faculty, members of the academic field, and those working in the profession. In all disciplines, networks are of three main types: collaborations, work experiences, and professional membership.[6] Some studies, like Gardner's impress the importance of relationships formed and the socialization process in graduate education.[21] The knowledge and strategies gained through these relationships influence the student development process within the graduate program. Gardner, also notes that in distinctly different fields, chemistry and history, the socialization process still has similar themes around the culture of graduate education and the strategic benefits of networks. McAlpine and Lucas examine, in detail, the experience of eight sociology graduate students.[17] They found that establishing networks within the department can influence the other strands in notable ways. Some students were extremely proactive in establishing networks beyond their departments, but this was primarily based on awareness of the value of external networks, or the need to establish a professional community to better meet their academic interests.

Intellectual strand

The intellectual strand is (p. 139) "the contribution an individual has made and is making to a chosen intellectual field through scholarship".[10] The intellectual strand results in artifacts such as journal articles and presentations, but is often reasonably limited for the graduate student. For graduate students, these artifacts can be research findings, course projects, and milestone examinations such as qualifying exams. Before entering graduate school, however, students are primarily interacting with the intellectual strands of others. McAlpine and Lucas say that the less recognized artifacts are "course, curriculum, and program designs"[10] (139) which do have an influence on future intellectual pathways. Students at all levels interact with these intellectual products of others on a regular basis.

The intellectual strand has two particular themes of interest in this study: horizons for action, and agency. Horizons for action are defined by McAlpine as "the option for action seen as personally viable at any particular point."[11] These horizons for action appear in different ways, but can include the opportunity to study at a particular institution, or desire to work in a specific industry. Agency is defined as "a capacity to identify the goals at which one is directing one's action".[11]

Agency can be identified in statements of action and the steps taken to achieve goals or improve a situation for one's benefit. While individual action is central to agency, the sociocultural context is important to consider. One's role within their context can facilitate or limit their ability to act on their own. For a graduate student or new faculty member, their role within the department puts some limitations on their ability to change their context. Their individual actions to reach their goals with contextual bounds in mind, shape their academic identity in important ways. Mathieson[22] examines agency of new faculty members in the midst of a curriculum change within their department. The change required addressing individual teaching philosophy and research engagement. The study explains the different experiences of these faculty members in responding to the change. Their responses were different, but reflected their individual values and identities within the academic context.

Institutional strand

The institutional strand of identity-trajectory "represents each person's relationships, responsibilities and resources wherever they are physically located[10]" (p. 143). McAlpine explains that the institution "can support or constrain" the other strands in identity-trajectory. Ashforth[23] explains that "identification matters because it is the process by which people come to define themselves, communicate that definition to others, and use that definition to navigate their lives, work-wise or other" and is influenced by the organization that one is a part of[23] (p. 334). The institution molds and sometimes directs the identification process for graduate students. One of the four ways identity can be viewed in higher education is through discourse, according to Gee[4]. He argues that "we are what we are primarily because of the positions we occupy in society[4]" (p. 101). The "society" that is graduate school influences who students are professionally and who they become when they leave.

There are multiple levels of the university that are a part of the institutional strand, but certain levels have more influence. The department, advisor, and lab have a greater proximal influence on students, because these entities shape their experience. Other studies have found that the laboratory group is the best unit of analysis of the graduate experience because of its level of influence on learning[24].

Identity-trajectory in an engineering education study

In the larger study, the aim was to explore the graduate development experience in a reflective fashion. Twenty-five participants, enrolled or recently enrolled in optics and photonics graduate programs were recruited to participate in a semi-structured interview. The interview protocol aimed to elicit a narrative of their academic development experience. In addition to the interview, participants were asked to submit curriculum vitas as an artifact of their academic and professional development. The central question in the study was: "How do photonics graduate students construct their professional identity?" Three sub-questions were developed in relation to the three strands of identity-trajectory:

- What networks and relationships are most important to influence identity-trajectory of photonics graduate students?

- How do past intellectual experiences contribute to the identity-trajectory of photonics graduate students?
- How do institutional factors support or constrain photonics graduate students professional identity-trajectory?

The narrative tradition is rooted in the humanities and social sciences and "begins with the experiences as expressed in lived and told stories of individuals[26]" (pg. 54). Czarniwska describes this research further "as a spoken or written text giving an account of an event/ action or series of events/actions, chronologically connected[27]" (pg. 17). The approach is very similar to all of McAlpine's aforementioned studies and adopts the "narratives as identities" approach of Sfard and Prusack[14]. By telling one's own experience there is an opportunity for reflection and attention to notable experiences without being constrained by the researcher or their question.

To analyze these narratives individual transcripts were re-read and a thematic analysis of the participant's experiences was done. After the thematic analysis, the codebook for this study was applied. The initial codes were directly withdrawn from the identity-trajectory theory's three strands. Additional and sub codes were identified based on the engineering and physical science context of this study. Several codes apply to more than one strand, but the detailed definitions and the narrative context provide the appropriate rationale. The intellectual strand included six codes: contributions, past experience, agency, horizons for action, individual ability, and personal. The institutional strand included four codes: opportunity structure, advisor, department or program, and the lab. Network includes four codes: opportunity structure, advisor, intellectual access, and the lab.

In the institutional strand, the role of advisors is limited to their functional role including research oversight, advising, coursework, and in some cases funding. Within the network strand, the advisor code is focused on the relationship between the student and advisor. This was often described as support, encouragement, and access to colleagues in the field. The lab within the institutional strand is the physical space, equipment, and resources available. In the network strand, the lab refers to the members of the group, often other graduate students, postdoctoral fellows, and research associates. Intellectual access within the network strand refers to relationships sought or created to make contributions to the field or research collaborations.

In this dissertation there were interesting findings for each of the three research questions. Those findings were separated into two chapters, one on pre-graduate training and the other graduate training. This paper will focus attention to the graduate development process. This study was contributes to the development of the framework as this study was the first use of identity-trajectory in an engineering and physical science context.

Methodology and Participants

In this study a qualitative approach was used to analyze the narrative experience of graduate students in optics and photonics graduate programs. In addition to the interview, participants were asked to submit their curriculum vitae in advance of the interview. This allowed the researcher to identify milestones and artifacts of their academic and

professional development. Once interviews were conducted, both open and axial coding methods, as described by Creswell[25] were used to analyze the transcripts and vitae. The method of "restorying" was used to retell the participants' experience.

Purposeful sampling was used to identify 25 participants for this study.[28] The 25 participants were graduate students or recent graduates of 11 optics and photonics graduate programs in the United States. There were 7 women, and 18 men who participated in the study and the group consisted of 6 different nationalities or ethnicities.

Networks influencing identity-trajectory

There were two primary networks that influenced identity-trajectory for participants. First, the academic advisor provided the first step of network access by accepting a graduate student to their research lab. By becoming a part of the lab group, the graduate student has a means to intellectual development, and the opportunity to contribute to the field. Participants discussed their relationships with other lab members as instrumental for research progress. Those who did not develop relationships within their lab groups had more challenges making progress. These lab-based relationships were important for students to progress within photonics, and likely their retention in the program.

There are two interesting examples to share about the influence of networks in graduate training: Brooke and Kimberly. Brooke selected her advisor because of a positive relationship that she formed with him before she decided to enroll. She specifically noted "When it got down to where I wanted to go after I was accepted to a few places [I focused on] where I actually wanted to spend five years of my life and with people I wanted to spend five years of my life with." She went on to discuss that personality was important in her decision, followed by research focus. Her wisdom in selecting a program and advisor paid off, as she had a relatively smooth graduate experience and was able to navigate using the relationships she formed in her laboratory. During her graduate program, Brooke's network codes were based on her advisor and lab group, as those relationships were critical to her overall success.

Kimberly, selected her graduate institution based on the chance to work with a certain faculty member. Unfortunately, soon after her arrival, the faculty member left, so she had to find another advisor. She found a new advisor, group and research project, early enough to avoid any notable barriers. Two things, however, went wrong when her project started to fail: her advisor seemed disconnected and within her small research group she did not have the relationships (or the group did not have the resources) to help her through those challenges. This resulted in her changing advisors mid-way through her program. Identifying the second advisor was based on relationships she formed outside of her research group. Kimberly's graduate progress was delayed due to weaker connections within her lab group.

These two examples show how the networks within a graduate program can facilitate or may hinder research progress. These findings were similar for other participants in the study. Alex, for example, had a positive relationship with his advisor and an engaged research group that shared several projects. He frequently mentioned that when challenges arose, he would work through them independently for a while, but had others to use as

resources to determine his next steps. Students who had strong relationships with their advisors and research groups easily made progress on their research. This is a small departure from the role of networks in McAlpine's prior work. For social scientists and humanists, network was mostly related to publishing either one's own work or reading the work of others, and emphasis on personal rather than academic networks.[15] In this study, participants rarely discussed the influence of their personal networks. Their primary focus in discussing relationships were limited to their advisor, lab group, and professional network for job-seeking. The main similarity within the network strand between disciplines was the importance of the advisor-student relationship.[15] In both disciplinary contexts the involvement of the supervising faculty was critical in the student's progress. This is likely explained by differences in the nature of work between social scientists and engineers.

Intellectual influence on identity-trajectory

At the graduate level, the intellectual strand was most frequently identified by the agency code. Students' demonstration of agency rose at the mid-points of their graduate program and linked to research work within the lab. The agency code combines both capacity and actions to achieve a particular goal. This "evocation of identity"[16] represents personal commitment to becoming an academic and adopting the disciplinary prescribed identity markers (e.g. completing the degree, research work, publications). In this study, students' agency was very independent in nature, different than prior findings of collective agency of graduate students.[19] The students who took part in this study typically described their research work as very independent, regardless of the stage of their graduate career and laboratory size. The majority of them described spending hours in the lab, doing as much as they could on their own, and preparing reports or discussion points for lab meetings during which meaningful feedback could occur. Lab meetings were not just an arbitrary formality, but a means to disseminate a small artifact of their intellectual contributions. These markers of agency were for individual benefit and tied to personal gains (e.g. graduation, job seeking).

One particular participant, Will, was a solid example of agency within an optics and photonics graduate program. As an International student, Will did not identify any outside influences on his decision to apply to graduate programs in the United States. His GRE, TOEFL, and application preparation were completely independent. After moving to the US and being enrolled in his department for two years, his advisor left the university for a new opportunity that prevented Will from following. At this juncture, Will found and accepted a visiting research role at a competing optics and photonics department, followed by working for a start-up solar energy firm. He eventually returned to his university to complete his doctoral program. At every step of Will's academic journey, he relied on his own intellectual ability and agency to respond to the challenges he faced. In the interview he describes his own agency this way:

> Yeah, you know, I just have enough broadening and university enrollment and I'm also, I'm more interested in simulation but I'm working in experiments and already have a grasp of how to connect the theory and the real experimental side of stuff -that may help me in the long run. So yeah that's just, uh, yeah I'm still here and this is how I work through all my experience and stuff.

The individual nature of agency deviates from McAlpine's prior work. She found collective agency more frequently. Collective agency hinged on feelings of belongingness and contribution to a larger group, such as the department and field and resulted in individual acts of agency.[19] In this study, senior graduate students rarely articulated how their projects were part of the local laboratory strategy or contributions to the field. By not connecting their work to a larger body, the concept of collective agency may be limited or absent in this context. This finding also raises questions about how the cooperative ideal of the research laboratory is enacted in graduate training in engineering.

Institutional influence on identity-trajectory

In this study, the institution's most important feature was the research laboratory. Labs provide access and a disciplinary introduction for both undergraduate and graduate students to optics and photonics. Research labs are central to the development of graduate students in this discipline, yet lab structures are understudied as vehicles for student learning and identity development.[24] The research lab was found to enable intellectual development and provide the necessary network to facilitate research to complete the graduate program as well as identify future trajectory possibilities. The important consistent finding is that the culture of the laboratory and size are important to identity development. Every participant discussed the resources, graduate students, research staff, and in some ways the culture of their lab and its influence on their individual work. Through time, research groups also impact the students' career goals, attitudes about research work, and the value of the academy. Students in collaborative labs consisting of interdependent projects had greater productivity and satisfaction overall. Students who experienced isolation in the lab, either by the nature of their projects or socially, experienced greater frustrations and delays in progress. This reiterates the importance of laboratory structure and environment for student success.[24]

Discussion

Identity-trajectory offers a three strand approach to explain identity development in the graduate education context. Considering the network strand, relationships within the lab and with the primary advisor were important to graduate student success. Students with a solid network within the lab experienced fewer disruptions and were able to overcome research challenges with greater ease. Individual agency was most important in the intellectual strand, but often was exhibited later in the graduate career. In order to foster individual agency, lab directors may consider increasing emphasis on collaborative and interdependent research projects. The institutional influence is most prevalent in the research laboratory. The structure, resources, environment, and relationships of the research laboratory have a notable influence on graduate student success.

Overall, identity-trajectory provides an interesting way to understand professional development in the context of academia, especially for those early in their career. The prior work in social science disciplines provided a basis to explain graduate education and identity development. The dissertation explained in this paper extends and informs the theory in an engineering context. Like many theoretical frameworks used in engineering education research, a revised theoretical understanding is gained through the research process. This framework does need additional exploration within engineering and the

physical sciences. Additional findings will contribute to engineering education's current discourse on graduate education and identity.

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