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REGULAR ARTICLE

Identifying Key Influencers of Professional Identity Development of Asian International STEM Graduate Students in the United States

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Abstract This qualitative study involves tracking the process by which Asian STEM (Science, Technology, Engineering, and Math) graduate students encounter graduate studies as they build professional identities. We derived data from interviews and observations of 27 Asian international STEM graduate students at various stages of their graduate careers at a large research university located in the United States. The following research question guided this investigation: What are key influencers of STEM students' professional identity? We conducted this study using a qualitative grounded theory approach, and we developed a central *professional identity development model* from emergent themes that related to the central phenomenon. Findings indicated Asian international STEM graduate students' previous work experiences, disciplinary skills acquisition, English proficiency, and socialization with peers and faculty advisors were significant influential factors to their professional identity development. These influencers interacted to both positively facilitate and negatively hinder the student's progress toward professional identity development. Together, this work suggests academic socialization is a crucial factor for student success and professional identity development.

Keywords Professional identity · International graduate students · Grounded theory

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Introduction

The present study explores Asian international Science, Technology, Engineering and Math (STEM) graduate students' professional identity development. There are two reasons why professional identity research contributes to the understanding of the concept of identity and its construction. First, as identity construction may be a result of enculturation processes, professional identity development can be understood in the context of individuals undergoing new professional disciplinary experiences. Second, among an individual's many identities, one's professional identity is usually a central identity because it provides socially respected position, agency, and power in a disciplinary community (Moje and Lewis 2007).

The development of professional identity is presumed to be influenced by an individual's significant need to attain agency and power. Therefore, investigating the process of professional identity acquisition in a specific disciplinary field would help to clarify the mechanisms of the professional identity development process. In addition, as Park et al. (2017) reported, sufficient interpersonal communication skills are necessary for STEM graduate students to advance academically in their research group, a need recognized by STEM graduate students themselves. Further, Ducheny et al. (1997) explained *professional identity* as a sense of empowerment and an appreciation for the multidimensional nature of growth and advancement in a

profession. In other words, the term *professional identity development* can be used to describe the process of maturing and evolving as a professional in one's field.

Literature Review

Asian International STEM Graduate Students in the United States

The Institute of International Education (2016) reported that there have been an increasing number of international STEM graduate students from Asian countries (such as China, India, and South Korea) to the U.S. research institutions in the past few decades. The report showed that approximately 50% of STEM graduate students in the U.S. are international students. In most American research labs, it is common for international STEM graduate students to participate in research projects with their advisors and other graduate students in a designated laboratory space throughout their graduate programs.

The typical stakeholders in STEM research labs are a principal investigator (usually a faculty advisor), postdoctoral fellows, doctoral and master's students, and undergraduate interns. These graduate STEM laboratories are designed to be interactive and collaborative learning environments. Litzler et al. (2005) claimed that graduate lab members should have willingness toward understanding cultural diversity because understanding diversity has become a crucial factor in the productivity of STEM labs.

In addition, Park et al. (2017) reported that international graduate students experience challenging acculturation processes while adapting to Western culture and often experience high stress and depression throughout this adaptive process. This acculturation process includes interpersonal psychological challenges such as homesickness and competency threat. Further, Kim (2006) reported that English proficiency is another big challenge that international students experience at the start of graduate programs. In sum, Asian STEM graduate students' academic and personal acculturation process may influence their professional identity and their performance in graduate school.

Professional Identity

Professional identity has been commonly defined as an individual's professional self-concept based on their attributes, beliefs, values, motives, specialized experiences, skills, and education in a chosen field. Sutherland et al. (2010) explained professional identity as one's identity related to their professional roles and status. Professional identity development entails combining one's personal identity, including personal beliefs, life experiences, racial/ethnic identities, and gender roles with more professional and discipline-specific experiences (Carter 2007; Slay and Smith 2011). When individuals find themselves in a new role, current identities often conflict with the new identity, and this dissonance is often accompanied by some emotional turmoil (Woodruff and Schallert 2008). This may occur because a person's beliefs or identity are not initially perfectly matched with the new tasks and activities, and this mismatch may affect an individual's motivation to take on new social roles and responsibilities. Individuals' perceptions of others' expectations also affect their own cognitions and behaviors and views of self.

Professional identity development can be viewed as a process of enculturation into discipline-specific practices. Berkenkotter et al. (1988) described the life of graduate students as that of becoming initiated into a research community through disciplinary reading and writing practices, through instruction in research methodology, and through interactions with faculty and peers. They described what graduate students encounter and experience throughout their graduate program as an enculturation process that affects their professional identity development. Because influences on professional identity development are complex, it is important to address the current conceptualization of identity and professional development as it pertains to graduate training and its influence on newcomers' professional identity development. Finally, the emphasis on the relationship between self-efficacy and professional identity development is also found in several studies (Moss et al. 2014; Rønnestad and Skovholt 2003). Healey and Hays (2012) reported that self-efficacy was highly associated with individuals' own perceptions, proficiency of skills, and knowledge in their own profession.

Graduate School as Site for Professional Identity Development

Ducheny et al. (1997) suggested that graduate student professional identity development typically includes three primary elements: (a) the importance of continued training and familiarity with relevant research, which is the most commonly mentioned component of professional development, (b) the influence of a supportive peer group or mentor, and (c) the organization of professional development into stages articulated by formative events and level of training. For example, most doctoral students go through a qualifying process, a dissertation stage, and a job search process. These stages can be explained as a progression of professional development through a series of stages that contain significant task completion requirements or critical, identity-relevant events. In addition, individuals' beliefs, values, areas of interest, and their professional and personal

needs are essential components of professional development as graduate students (Miller 1992).

Gazzola et al. (2011) investigated what experiences and conditions counseling psychology doctoral students perceive as contributing to their professional identities. The results showed that experiencing negative views of the profession, disappointment with institutional training, and internal conflicts, such as concern about completing their graduate program, hindered students' identity development. By contrast, positive experiences with clients during clinical training and achievements in the program crystallized their views of their professional selves. The results also showed that institutional training, such as classroom activities, research participations, and interaction with faculty members, were the most significant element in cultivating their professional identities. Interestingly, participants had moments when they needed to adjust and balance between their personal and professional lives, and typically, the professional self became a dominate priority (Moss et al. 2014). In addition, their values and beliefs were mostly consistent with those traditionally adopted by the field of psychology. Such congruence may simply be the result of students choosing to join a program with careful consideration of whether they match well with institutional philosophy. Over time, their growing expertise signaled a shift from the role of student to someone with professional knowledge and expertise.

Similarly, Pratt et al. (2006) studied the role of work and professional identity development among medical residents. They reported that professional identity construction happened when the residents were acquiring work competence with different patterns of identification constructed by their specific medical professions. The study emphasized the importance of the relationship between "doing" and "being" among professionals. In other words, when residents faced a conflict between their work and professional identities, they rectified this violation by customizing who they were to match what they did. Furthermore, Kaplan and Flum (2012) claimed that academic learning cannot be divorced from students' development of their values, goals, social roles, and worldviews when mode of knowledge construction and accessibility to different types of knowledge are rapidly increasing and diversifying.

Kaplan and Flum (2012) also highlighted how graduate students build their social roles, positions, and identities in the process of their professional training. They addressed the research question of whether a person adopting a new role in a new situation experiences constraints on his or her behavior by the expectations associated with the new role, namely, becoming a graduate student. Students' cognitive ability, such as their decision-making, showed evidence of influence by these expectations and the role enactments they elicited. Additionally, Dean and Jolly (2012) studied graduate students' identity construction and disengagement in learning situations. The study demonstrated that students sometimes rejected learning opportunities, experiencing disengagement from learning activities that challenged their identity. In other words, some learning activities can trigger elements of students' identities, forcing a cognitive dissonance confrontation. Dean and Jolly (2012) argued that students' identity engagement will increase the benefits they gain from learning experiences.

Professional Identity Development of International Graduate Students

Choi (2006) reported that international graduate students' identities are developed through social experiences and interactions. She explained that international students' level of disciplinary competence and social status in their home country are highly correlated with their professional identity. However, international students needed to prove their disciplinary competence by demonstrating knowledge confidently and achieving higher grades in the United States. She claimed that when international students perceived their faculty or peers acknowledging their disciplinary knowledge, their identity was fueled dramatically. Hsieh added that international students reconstruct and negotiate their identities when they come to America because they join a new sociocultural environment in which they have to establish themselves.

Another factor that may influence international students' professional identity is their English language proficiency. Historically, literacy researchers have emphasized the importance of language and communication as a critical factor in identity development (Baxter 2004; Gee 2001; Moje and Luke 2009; Schallert et al. 2016). Moje and Luke (2009) claimed that the texts about which one reads, writes, and talks can have a critical effect on what identities one develops. In addition, Street (2009) claimed that three characteristics of academic writing relate to identity formation by articulating a particular position that is both meaningful to the writer and recognizable to readers. In other words, writers convey themselves in texts to express their values, credibility, and relationship to ideas in order to influence others. This writing process shapes authors' identities, and the produced text influences readers' identity formation. When applied to graduate students' reading and writing of published papers, proposals, or conference papers, this experience can be seen as one of identity construction as researchers.

According to the perspective on the discourse practices and identity development, levels of language proficiency are among the factors that influence one' identity development (Bakhtin 1953). For international students, the English language is a critical medium for their pace of

learning and speed of enculturation process (Choi 2006). Chang and Kanno (2010) addressed that international engineering graduate students' sufficient verbal interaction with lab members is essential to acquire necessary hands-on knowledge, such as operating laboratory equipment. However, international students often avoid interactions with peers due to their awareness of a limitation in English. As addressed above, English writing proficiency is another significant factor that influences international students' professional identity development. Typically, graduate students are required to produce peer-reviewed scholarly publications and complete a dissertation in order to acquire their degree. In the course of developing their writing, they learn how to convey themselves in texts to express their own values, beliefs, and philosophy. Therefore, English writing proficiency to produce quality scholarly works is an important success factor for international graduate students (Ravichandran et al. 2017).

Methods

Participants and Setting

A total of 27 (22 Male and 5 Female) East Asian international STEM doctoral students from one large research institution in the U.S. participated in this study. We chose students who were from East Asian countries because we wanted to highlight their professional identity development by academic enculturation process in their graduate programs. We did this under the assumption that East Asian graduate students may stand out more from other international students who did not use English as a primary language due to the differences in Western and Eastern cultures. We chose ten students from electrical engineering, ten students from chemistry, and seven students from mechanical engineering. The nationalities included 15 Koreans, ten Chinese, and two Vietnamese.

Data Collection and Data Sources

Initial data collection began in Fall 2014 and continued until Summer 2016 when data saturation was reached. Major data sources were participant interviews and supplemental data collection from field observations during several research meetings and informal social gatherings. We conducted semistructured interviews in which we guided participants toward elaboration on their professional identity and related experiences using a set of questions borrowed and modified from Moss et al. (2014). During the initial interview, we presented open-ended general questions regarding students' lives prior to graduate matriculation and then progressed to more specific questions reflecting on their professional identity and its development: What kind of previous experiences did you have prior to joining your graduate program? What does it mean for you to be a professional in the field? What experiences to date have contributed to your professional identity and why? The interviewer then asked participants about more specific activities and practices that contributed to their professional identity development: Tell me about your professional identity development. Can you describe your professional achievement since you have joined your graduate program? Can you explain what kinds of experiences have helped you to improve your professional identity development? As a secondary data source, with permission from participants, we observed them in formal and informal activities such as research meetings, social gatherings, and professional conference participation. We used observational notes to confirm and expand upon interview data. As part of a member-checking process, we asked questions after observation. Upon completion of acquisition, we added these data to the coding process. In sum, there were several data sources: interviews (either one or two primary interviews with each participant), member-checking meetings, and observational notes.

Procedures

Data sources were interviews and observations. We conducted initial interviews for approximately 30 min and afterward audiotaped and transcribed them. Open-ended questions guided the interviews. These questions concerned individuals' acculturation trajectories in their respective graduate programs, their current and past experiences, and their future plans. We then conducted member-checking interviews, including questions that were personalized for each participant. We derived personalization from analysis of initial interviews, and we informed this personalization by emergent understanding and other participants' responses. Secondary data sources included observational notes as we shadowed participants during social gatherings and research team meetings. We anonymized all identifiable participant data.

Data Analysis

We used the constant comparative method, in which the researcher created descriptive codes and categories based on interview content and field notes, to analyze collected data (Charmaz and Mitchell 2001). First, we conducted broader level initial coding to identify categories to each unit of information, composed of events and incidents around the central phenomenon of professional identity. Data analysis involved several levels of coding processes, starting with open coding and axial coding of data that

identified specific categories and subcategories related to professional identity development. Then, we utilized axial coding to identify logical relationships among the information from open coding, to place outcomes into context, and to identify antecedents of professional identity. Lastly, we conducted selective coding to make a logical link and created a theoretical model (Fig. 1) from four categories (previous work experience, social relationship, skills and knowledge acquisition, and English proficiency) and subcategories where selective coding involved developing themes. These themes connected different categories related to a core phenomenon professional identity. As a validation process, we conducted peer debriefings to confirm coding themes and the logical structure of the themes (Creswell and Brown 1992).

Findings

The primary aim of this study was to investigate Asian international STEM doctoral students' professional identity development throughout their graduate programs. There were several factors that influenced Asian international STEM graduate students' professional identity development. These factors were previous work experience, social relationships among peers, disciplinary skills and knowledge acquisition, and English language proficiency. Factors interacted to both facilitate and challenge the student's progress toward professional identity development.

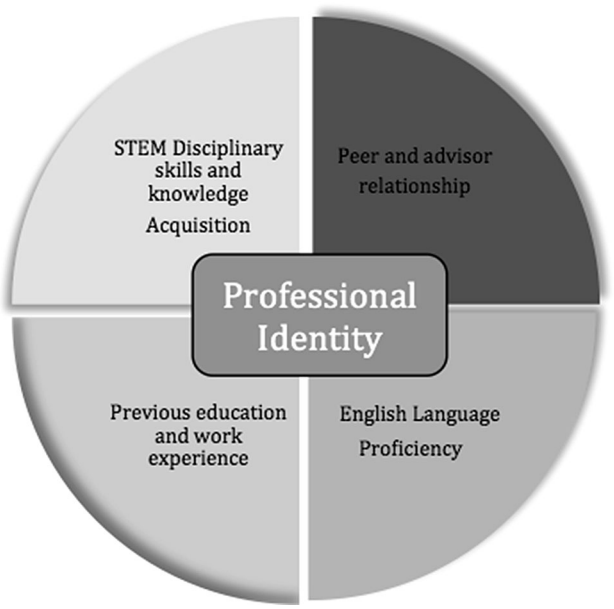

Fig. 1 Four factors that influence Asian STEM International graduate students' professional identity

Previous Work Experience

One of the significant influences on Asian international STEM doctoral students' professional identity development was if they had worked professionally prior to matriculating into graduate school. There were students who had substantial previous work experience related to their program, and also students who had no such related experiences. Students with previous work experience commonly testified that their previous experience helped them understand new knowledge and skills that they learned in their coursework and research projects. Their disciplinary identity development seemed smoother than students who did not have substantial work experience. Don stated: *I was working as an engineer for several years. I was designing electrical circuits. What I am doing at the lab is almost same as what I was doing in a company. But I had to learn how to write a report academically. Writing is a challenging part here…Yes. I think I am an engineer, and I am learning the research side of engineering.*

Kyungju, who worked in his field for ten years, mentioned that his graduate lab is not much different than his work lab in Korea. He stated: *Yes. I am a professional engineer. I am in America now, but what I do is almost similar to what I've been doing in Korea. Most of machines are exactly same as what I used in Korea as well.*

Further, students who had work experience usually had a better understanding of how to navigate the program, and they held more expectations of the program. When their expectations were not met, they tended to struggle even more than students who had no previous job experience. Jaehak mentioned: *I do not understand what is happening here. We ran out of chemicals I needed to use for the experiments. It should not happen. It never happened when I was working. This department funding is very unstable, so I had to do TA for different department. It's just waste of time. I am not sure what I am doing here. I just need to finish my dissertation and get out of here as soon as possible*.

Social Relationships

Students who had previous work experience usually could find research interests and develop their professional identities faster, but if their interests did not match their advisor's interests, most experienced difficulty and hindered professional identity development. Most participants testified that social relationships were key to success as STEM graduate students in the U.S. These included relationships with same-year peers in the program, other newer or more advanced students, students from different subprograms, advisors, other individuals in the field, and family members. Pran mentioned the following regarding

peer socialization: *When I was working for a company in India, I had to communicate with my supervisor and team members well. Getting along with other people in the lab is a crucial aspect of being an engineer in my country and here in America, too. Work is work, but you work with other people so you should get along with others well.*

Participants reported that they often socialized with other international students in the lab, not only to simply relax, but to also obtain information regarding their programs. For example, Ming, a fourth-year graduate student, stated that it was not possible to have come this far without his fellow students' support because "others always know what I don't know." Likewise, Hyung also attested to the construction of social relationships due to attending professional conferences. He stated: *I was attending technology conference every year. Last year was in Germany. I met a lot of people from the world, and I got a chance to talk to people who are interested in the same topic. I felt like I was a professional technology developer and researcher when I presented my research. Yes, I felt like I am a technology researcher when I was attending conferences.*

In addition, Ken from China mentioned this about his conference experiences: *I met a lot of people from ASEE. I built a good relationship with researchers who are from different institutions, and I still keep in touch with them. I feel like I am a researcher when I am participating in conferences. I met a lot of business people in the field because of attending conferences. I love to share my ideas with them. Yes. Definitely, I feel like I am a researcher when I present my research.*

In addition, participants commonly shared that their relationship with their advisor was a critical factor in having a successful doctoral life as a STEM student, although not all saw it as a positive or central factor. Hyun, a STEM doctoral student from Korea, said: *The most important relationship in graduate school is relationship with my advisor. He is the key man. Even if he is very mean sometimes, I can't say anything because he is the one who can let me graduate. It sucks sometimes, but what can I do? My head should be down, if I want to graduate.*

Ming from Vietnam had a great relationship with his advisor. He appreciated that his advisor had introduced him to another well-known professor, who was an editor of a major journal, and helped Ming navigate the field. He stated: *My advisor is great. We published several papers already. He sent me to a conference during the summer and got me an internship. He is a very successful scholar in the field and my mentor. I think I am lucky to have him as my advisor. I learned so much from him.*

By contrast, Jaeyoung, another graduate student from Korea, had undergone some mental and emotional distress because his research interests did not match his advisor's. Thus, he had to quit the program and get a job in the field even though he had spent several years in the program and was close to graduation. He stated: *"I am not sure what I am doing now. I've been wanting to do different research, but I just do what my advisor told me to do for the lab. I have "0" motivation about what I am researching now. I just need to do what I need to do and graduate and get a job. That is my goal. I was expecting to do something different…"*

In short, it seems when international students get along with their advisor's professional identity, development processes with learning content are smooth. Some participants saw their advisors as role models through whom they could envision the field and themselves in the field. However, if students struggled with their advisors in some way, this same relationship aspect seemed to hinder the identity development process, and students were negative about the future.

Lastly, all graduate students who had spouses or children mentioned that having a family tremendously affected their graduate student life. They reported facing many critical decisions when family responsibilities and research schedules conflicted, so that the management and balancing between two different roles resulted in significant physical and emotional challenges. For example, Lihan from China mentioned that mostly he did not have enough time to prepare for teaching assistant jobs and even do homework because of his two-year-old daughter. He mentioned: *I felt really horrible about my life! I am always afraid that I will lose my job and at the same time afraid I will be a bad father. My wife doesn't know how to drive, so I have to be there for her a lot. I am not sure when I can graduate and get a real job. I don't think I am a good student and father. I am always depressed!*

He added that he did not have any time to spend with peers in the program and sometimes felt isolated. During his second follow-up interview after one year, he also addressed that his biggest challenge had been to balance work, school, and family. He had been hospitalized twice because of overwork and stress from multiple duties. In addition, Kim from Korea mentioned: *It's very difficult to be a father and a doctoral student. I am not doing what I am supposed to do for school. A lot of times, I am not sure what I am doing now. I just have limited time and energy to handle school and family. My life is chaos now. I don't think I am growing as a researcher. It will be lucky if I will graduate and get a job somewhere.*

These participants addressed that they "never had enough time" to socialize and often struggled during collaboration on research projects with other students. Chen mentioned that once, when he did not have enough time to prepare for research meeting because his two-year-old son had been sick, he felt "horrible" and afraid that he will not

be able to finish his degree on time. According to participants who have family obligations, these obligations seem to hinder students' professional identity development.

English Language Proficiency

Participants, especially beginning stage students from non-English speaking countries such as South Korea, Vietnam, and China, shared serious concerns and stress about their English language proficiency. They shared that although they have abilities to explain complex phenomena in their mother language, translating every word of such explanations into English in research has been a significant challenge.

Although they had the disciplinary knowledge and the capabilities to produce work in their fields, they were not able to demonstrate their knowledge and acquire necessary information from others, which led them to feel isolated and experience psychosocial stress and a threat to their competence. Juhan from Korea stated: *I absolutely hated going to my lab and classes. I don't understand what other people are saying. My English is just good enough to buy a hamburger, but not good enough to understand their jokes. I feel like I became a kid again.*

English proficiency can be a wall between Asian international students and American students because socialization among lab members can be a crucial factor for collaboration among STEM graduate students. Shinje from China mentioned: *I don't talk to people in my lab. No. I just talk to them when I need to. Especially, it's hard to talk to Americans because I am afraid that I don't understand what they are saying. I just need to say "Yes" even if I don't understand. But I talk to other international students like Koreans and Indians. Their English is not that good, but we can still talk.*

Disciplinary Skills Acquisition

All participants mentioned that their collaborative research projects served as a main source for technical knowledge and skills that they needed to acquire. Seven students mentioned that knowledge of core STEM concepts gained from research experience contributed to building their identities as researchers in the discipline. For example, Chu from China reported that MATLAB programming with another student in the lab was very helpful because he did not know much about programming language. He also described how collaborative projects helped him further develop his research and writing skills. Chu stated: *Research is collaborative work. I cannot do everything by myself. And my writing is not good, so I need someone will edit for me. Graduate school is all about collaboration. It is important to know how to work with other people as a researcher.*

Third-year graduate student Daehan mentioned that he had acquired information in the field through his cohort and felt most like an engineer when talking to peers about new research ideas and projects. Most senior students reported that they acquired hands-on methodology and technical skills experience from other students in the lab. Hyung from Vietnam mentioned: *I had a great mentor when I was a beginning student here. He was a Taiwanese genius. He knew everything about solar cell and battery. He helped me to find research idea and dissertation topic. He is my savior. I did not learn much from my advisor, but my friend was my advisor. I cannot imagine my life here in graduate school without him.*

Based on the results, we created a professional identity development model (see Fig. 1). In this model, we portray the four key influencers on professional identity development, the central phenomenon of our interest, as four pieces making up a professional identity "pie." Technical Skills and Knowledge, Previous Experience, Peer and Advisor Relationship, and English Language are these four key factors that contribute to the central phenomenon that governs the development of Asian international STEM graduate students' professional identity. This pie visualizes key factors in confluence that affect the success with which participants could develop professional identities.

Discussion

Ligorio (2010) explained the relationship between identity development and learning based on the general framework of sociocultural constructivism. He explained that sociocultural constructivism recognizes identity as being closely dependent on context and as the outcome of a knowledge building process. Further, Jorgensen and Keller (2008) explained identity formation implies a trajectory that connects individuals' past, present, and future. Data showed previous professional or education experience usually enhanced students' professional identity development by providing contextual knowledge. Further results showed that sufficient progress in disciplinary knowledge acquisition from collaborative research projects also helped students further strengthen their professional identity through learning and working together. The concept of self-efficacy can explain the relationship between disciplinary competency and professional identity (Bandura 1989). In addition, Healey and Hays (2012) reported that professional identity development is highly related with self-efficacy of one's domain-specific skills and knowledge in their profession.

Further, Bakhtin (1953) introduced language as a critical medium for dialogue that allows a manifestation of individual dispositions, goals, and social locations among individuals. The results of this study provide clear evidence of the significance of language proficiency as a medium to acquire technical skills and knowledge, participate in professional socialization, and obtain disciplinary practice in developing professional identity. Therefore, English language proficiency facilitates Asian international students' professional identity development since English language fluency for nonnative speakers greatly impacts their communication and explanatory ability. Such ability is critical for collaboration and socialization with faculty and lab members. Further, Baxter (2004) explained communication as an active identity development process that functions to express the self's beliefs and attitudes to others so that the self is understood and influenced by others' actions and beliefs as well. This study showed that active communication as well as cultural understanding helped students to build relationships with colleagues and faculty members. Therefore, among four key influential factors on professional identity, the proficiency of English language as a medium for active communication is a fundamental skill to other factors such as proficiency of professional skills and professional and personal relationships with their peers and advisors.

Wenger (1998) explained identity development process as participation and active interaction among members in a domain-specific community. He explained that when individuals join a community of practice, as they try to acquire the core disciplinary skills, they develop a new identity. Once individuals enter a community of practice, their disciplinary enculturation begins and speeds up compared to remaining on the outside of the community's boundaries. In line with his hypothesis that identity formation is significantly influenced by disciplinary practices, those who had previous experience in their discipline already joined a disciplinary community and also created a professional identity. Therefore, for Asian international graduate students, when they join graduate school in the U.S., they are enhancing their professional identity in the same disciplinary community, or they have to build a new identity.

Peer–peer and student–advisor relationships had a more complex influence in our study, with some good relationships enhancing their professional identity, but some bad relationships making the trajectory to professional identity development precarious. Importantly, when students had a positive relationship with their advisor, they seemed to have a clear idea or image of the future professional community they were going to join and, thus, built up a more concrete sense of professional identity. However, data showed that these relationships are not always positive, as is the case with any other human relationships. When students experienced conflict with their peers or advisors, these conflicts seemed to affect their professional identity negatively. This phenomenon raises an interesting question about community of practice that, as Wenger claimed, the importance of the legitimate peripheral participation is sustaining and maintaining the status also crucial for their identity development. Findings presented in this study showed professional identity process to be reciprocally dependent on both the student's own resources, such as previous disciplinary training and knowledge, and the sociocultural context in which they find themselves.

Limitations and Future Study

There are several limitations that we can identify. The first limitation stems from restrictions of the sample population. Because participants in the present study were recruited only from STEM fields, results need to be generalized with caution, as international students' professional identity development may differ by processes across different disciplinary practices, such as social science fields including psychology, history, and liberal studies. Further, participants were only sampled from one U.S. institution. Due to the size and diversity of America, this greatly limits the study's ability to assess broader regional impacts. Another possible population differentiator limited in this study is different phases within graduate students' programs. Second, as main data came from interviews, participants' emotional response to certain topics at the moment of their interview may have influenced their testimony. For example, if a student was experiencing a difficult time before the interview, it may have affected his or her testimony about certain aspects of their experience in their program. However, despite these limitations, this study can contribute to a better understanding of professional identity development in general and professional identity development of international STEM graduate students in particular. Therefore, as for the future study, focus groups could be a good supplement as verification of certain factors of international students' professional identity development. In addition, the model with these four factors of professional identity development can be applied to STEM international students of other nationalities and tested with the influence of cultural aspects, so that more research on professional identity development can be completed across cultures.

Conclusion

Findings indicated Asian international STEM graduate students' previous work experiences, disciplinary skills acquisition, English proficiency, and relationships with peers and faculty advisors were significant influence to their professional identity development. These influencers interacted to both positively facilitate and negatively hinder the student's progress toward professional identity development.

Cultivating a successful scientist in the STEM field requires effort from multiple layers, and identifying the obstacles these junior scientists experience in the process could provide the government and universities invaluable information to help future generations of scientists. Since there are a large number of Asian international STEM graduate students in the U.S. graduate programs, we particularly focused on the professional identity development of Asian international STEM doctoral students in the U.S. This study contributes to the literature of international graduate student education and higher education in STEM disciplines by highlighting the importance of professional identity development and socialization among peers by participating in various projects and social groups. Considering the collaborative nature of graduate schools in the U.S., socialization among lab members is a crucial factor for student success. Our work suggests it would be beneficial to provide frequent socializing opportunities, such as happy-hours, morning tea time, and research sharing time, to graduate students so they all have opportunities to get to know each other and share insights of their field and individual expertise. In addition, at an institutional level, financially supporting students to attend professional conferences to share their research would promote professional socialization experiences.

Compliance with Ethical Standards

Conflict of interest The authors declare that they have no conflict of interest. There was no funding for the project.

Appendix A
Sample Semi-Structured Interview Questions

In line with qualitative methodology (e.g., Strauss and Corbin 1998; Creswell and Brown 1992), questions should begin with general queries, so as not to prime interviewees' responses by asking specific questions. However, the following sample questions were used as a guide to explore the different elements and phases of professional identity development of educational psychology graduate students.

General Identity Questions

How do you introduce yourself to others?

Can you tell me about who you are?

What were you doing before joining this graduate program?

What other roles do you have beside being an international graduate student?

Can you tell me about your graduate school life?

What milestones of graduate school have you completed so far?

What obstacles did you have to overcome in graduate school in America?

How do you think those obstacles influenced you?

Professional Identity

Can you tell me about your professional identity?

Can you define what professional identity is in your field?

What does it mean for you to be a professional in the field?

What experience so far has contributed to your professional identity and why?

What experiences have resonated with you as a professional in the field and why?

What kind of professional skills do you think you need to acquire?

Do you personally know any professional individuals in the field?

Future Plans and Professional Identity

What is your short term academic/career plan?

What is your long-term plan?

How do you envision yourself in your field?

What kind of career would you like to have after graduation?

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