Designing Developmental Experiences for Graduate Teaching Assistants Using a Holistic Model for Motivation and Identity*

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The first step to strategically improve developmental programs for Graduate Teaching Assistants (GTAs) is to understand GTAs' motivations for teaching and their identities as teachers. The objective of our work was to propose and evaluate the Longitudinal Model of Motivation and Identity (LMMI) for examining the teaching motivation and teacher identity of GTAs, specifically in engineering. The proposed model is based on Self-Determination Theory and Possible Selves Theory; both theories are used to holistically understand a GTA's teaching experience. The LMMI was evaluated through a set of online journal entry surveys administered to 65 GTAs teaching in first-year engineering programs. Thirty GTAs provided survey responses, and the results of our research provide a baseline understanding of GTAs with regard to motivation and identity, confirming that the LMMI is appropriate for this context. Specifically, we describe potential implications for GTA development with regard to knowledge of content, sense of responsibility, connectedness to other GTAs, and future faculty identity. We conclude that these four items related to motivation and identity are essential in creating appropriate developmental programs for GTAs to ultimately improve teaching within engineering.

Keywords: Longitudinal Model of Motivation and Identity, graduate teaching assistants, developmental programs

1. Introduction

Although there has been a strong focus on transforming engineering education [e.g., 1], little effort has been extended to understand or promote Graduate Teaching Assistants (GTAs) as an important resource to enable change. While faculty have been viewed as critically important in transformation [2–3], GTAs have not been similarly considered despite being commonly employed in engineering [e.g., 4–6] and spending significant time with undergraduates in engineering. Moreover, GTAs represent the next generation of faculty and are already in a learning mode since GTAs are students themselves; this makes GTAs an opportune group for developmental activities. To maximize the potential of this opportunity, we need GTA development programs that are theoretically grounded and widely transferable. Currently, few programs exists, and we have insufficient knowledge about GTA development needs in engineering to create such programs.

While there are a great many resources to promote faculty development, similar resources do not exist for graduate students. Faculty resources include discipline specific programs such as the American Society for Engineering Education Summer School for Chemical Engineering Faculty (http://www.chesummerschool.org/) and more general programs such as the National Effective Teaching Institute [7]. While graduate students are typically not prohibited from attending such programs, the developmental needs of GTAs specifically, which differ from those of faculty, are not a central focus. Moreover, current literature about GTAs in engineering tends to focus on GTA evaluation/assessment tools, faculty and/or student perspectives of GTAs, and/or program/institution-specific needs [e.g., 8–10]. The literature that does exist about GTA development programs in engineering tends to concentrate on describing specific programs developed for single departmental or organizational needs [e.g., 4, 11–13] as opposed to those designed to be widely transferable and solidly based in research and theory.

Towards creating GTA development programs that meet these needs, the objective of our work was to propose and evaluate the Longitudinal Model of Motivation and Identity (LMMI) for examining the teaching motivation and teacher identity of GTAs, specifically in engineering. In doing so we offer data-inspired suggestions for designing GTA development programs. The LMMI combines Self-Determination Theory and Possible Selves Theory to provide a more complete understanding of the

factors affecting GTAs' identity development as teachers and motivation to teach. We argue that the first step in creating GTA development programs is to understand GTA motivation for teaching and identity development as teachers. Though motivation to teach and teacher identity development have long been studied, this is often done separately and not with regard to GTAs. If we understand the motivation and identity of GTAs, we can identify GTA knowledge and experience gaps to develop approaches that will best align with their needs. Our approach in proposing and evaluating a model is similar to that taken by Panchal, Adesope, and Malak [14] in a past issue of the *International Journal of Engineering Education* where the authors presented theory then demonstrated associated practice. Our data comes from a sampling of GTAs in first-year engineering programs. We chose first-year engineering programs as our context because these programs typically employ a significant number of GTAs [6], allowing us to capture individual diversity in identity and motivation across multiple schools while keeping the content area similar.
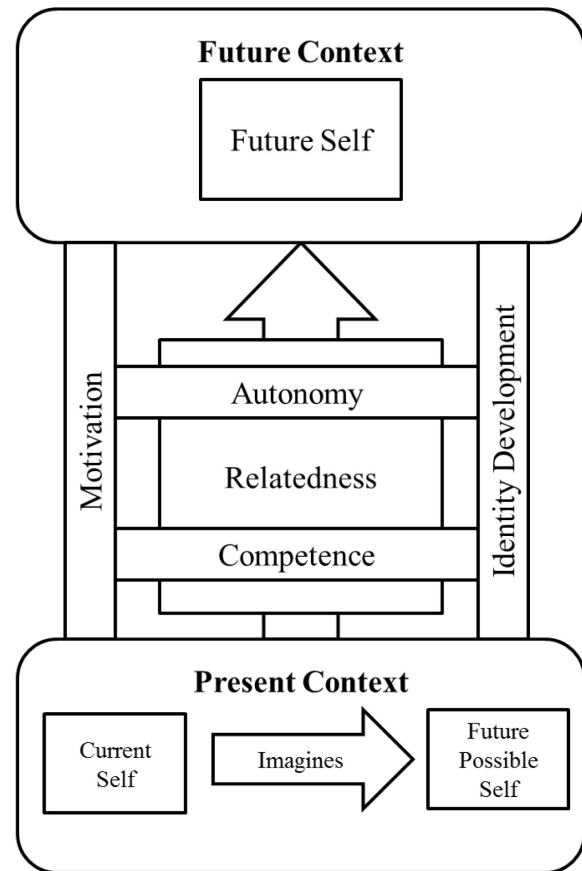
2. The Longitudinal Model of Motivation and Identity (LMMI)

The general concept of connecting motivation and identity is not new; however, the specific approach we propose in the LMMI is novel. For precedence, we call particular attention to a special issue of *Educational Psychologist* from 2009 titled *Motivation and Identity* that exclusively concentrated on the intersection of identity and motivation and brought light to this emerging and interconnected domain [15]. The articles in this special issue all focused on the educational setting and were theoretical pieces or position papers designed to elicit considerations for the connections between motivation and identity [e.g., 16–19]. Our proposed model is consistent with the trends captured in the special issue, but we have gone a step further in our work by explicitly connecting two different theories (one traditionally from the identity domain and one traditionally from the motivation domain), which enables us to concretely examine the areas simultaneously.

The LMMI is built on Possible Selves Theory as a theory of identity and Self-Determination Theory as a theory of motivation. It should be noted that others have theorized the role of identity in Self-Determination Theory. For example, LaGuardia [17] argued that the strong similarities and connection between Self-Determination Theory and traditional identity theories and concluded that in primary and secondary education more support

for identity exploration and development is needed. She discusses how autonomy, competence, and relatedness not only lead to motivation but also serve as essential elements necessary for identity formation and development. Nonetheless, the challenge remains to operationalize identity within these frameworks such that it can be measured and studied in context. We argue that combining Possible Selves Theory and Self-Determination Theory (forming the LMMI) allows us to operationalize motivation and identity in ways that are consistent with and connected to the separate bodies of literature surrounding motivation and identity. Additionally, this approach facilitates the detailed examination of constructs that are essential for understanding potential differences of GTAs. Fig. 1, which is represented through the analogy of a ladder, depicts the relationship between the two theories that we propose in this work.

In Fig. 1, the bottom items represent the key elements of Possible Selves Theory as conceived by the individual in his or her current situation (i.e., the present context). The two sides of the ladder represent the main focus areas for this work, motivation and identity development. At

Fig. 1. Longitudinal Model of Motivation and Identity (LMMI)—A Combined Theoretical Model Based on Self-Determination Theory and Possible Selves Theory.

the center, the rungs of the ladder represent the key components of Self-Determination Theory, which were used to connect motivation and identity development: competence and autonomy are main foundational components, and relatedness is an interacting element in the experience. Including the Self-Determination Theory constructs as rungs in the ladder was done to indicate that they help mediate the vision of the future self. Finally, the top items relate to the future context, while the vertical arrow symbolizes a GTA's movement through the process. Based on Fig. 1, if both of the rungs are present (i.e., autonomy and competence) and the interaction of relatedness is included, a GTA will have motivation and identity development, enabling him or her to become the positive version of his or her future possible teacher-self after graduation. Although the depiction of the model is linear, we propose that the process is iterative. That is to say, once a person reaches his or her future self, the future self becomes the current self, and the process begins again: the notion of motivation and identity development is a never-ending conception. Motivation will continue to change along with identity continuing to develop. These two constructs must be persistently updated and evaluated because they are fluid and ever changing. For this research, we focus on GTAs' (1) current experiences teaching in first-year engineering programs and (2) present context views of their future possible selves after graduation. We did not conduct a longitudinal study to verify future outcomes since this is the initial exploration of the theory and is part of a larger mixed methods study. However, a longitudinal study would be important future work to fully validate the LMMI.

In the following sub-sections, we separately discuss the two theories in detail, justifying the necessity of using them together in the proposed LMMI. Since the literature specifically on GTAs is minimal, we draw on both teacher and student literature throughout these sections as GTAs are both teachers and students in their role.

2.1 Motivation: self-determination theory

Self-Determination Theory has been broadly applied in educational contexts [e.g., 20–23] and in studies focusing on individuals in teaching roles [e.g., 24–26]. Self-Determination Theory incorporates the foundational idea that people act in ways that lead to satisfaction based on basic psychological needs [27]. Three psychological needs have emerged as particularly salient for Self-Determination Theory including *competence* [28–29], *autonomy* [30–31], and *relatedness* [32–33]. Each of these components is needed for optimal functioning and intrinsically driven motivation, which is highly
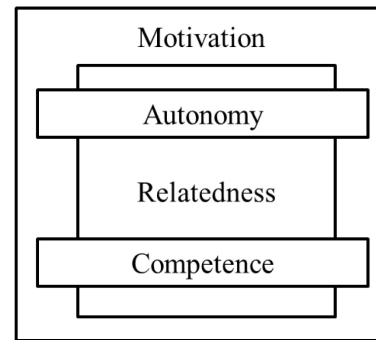
Fig. 2. Self-Determination Theory Representation—A Traditionally Motivation Based Model.

desirable and at the core of Self-Determination Theory. These three needs comprise the Basic Needs Theory, which is a significant and fundamental part of the larger Self-Determination Theory [34].

In Fig. 2, we show how Self-Determination Theory is represented in the LMMI. We suggest that autonomy and competence are viewed independently while connecting directly through relatedness. There is an implied understanding that competence must be achieved before autonomy but, despite the hierarchy, each is equally needed for optimal self-regulated motivation.

2.1.1 Competence

Current literature supports the idea that competence is at the heart of motivation and personal development. Suggesting it may be needed first, Elliot and Dweck [35] state, "Competence would seem to represent not only an ideal cornerstone on which to rest the achievement motivation literature but also a foundational building block for any theory of personality, development, and well-being" [35, p. 8]. The need for competence has been defined as "an attempt to master [your world] and to feel the sense of effectance when [you]" are successful [36, p. 25]. Self-Determination Theory suggests that people act in ways that satisfy competence needs. Therefore, to study teaching, it is important to understand which elements of teaching must be mastered to feel competent. Based on research on teaching, not necessarily with GTAs, competence refers to mastery of content knowledge and knowledge of teaching [37–38]. Consistent with our proposed model, research shows that interventions can be successful in improving competence [e.g., 39]. However, research also shows that assessments of competence should be context specific to ensure they are accurate (i.e., teaching assessments should be tailored to the teaching environment) [40]. In combination, this means that competence development is possible, but it must be relevant to the

context. Accordingly, our evaluation of the LMMI includes GTAs in the context of first-year engineering programs.

2.1.2 Autonomy

In our model, autonomy follows competence on top of relatedness; this signifies their foundational nature in the theory compared to relatedness, which is often discussed in a secondary manner compared to the other two constructs [e.g., 21, 27]. According to Self-Determination Theory, an individual needs autonomy to be motivated. Deci and Vansteenkiste [36] stated, "the need for autonomy concerns people's universal urge to be causal agents, to experience volition, to act in accord with their integrated sense of self (i.e., with their interests and values), and to endorse their actions at the highest level of reflection capacity" [36, p. 25]. Essentially, people need to feel self-regulated in their choices.

Researchers have demonstrated that a sense of autonomy is critical to student success [e.g., 41] and, therefore, autonomy is most often studied in educational settings with regard to teachers supporting the autonomy of their students [42]. For example, research has shown that students' motivation can be increased through autonomous yet supportive environments [22, 41] and that increased autonomy leads to increased productivity with tasks and increased learning of concepts [21, 43–45].

Other studies, though relatively few, have investigated the autonomy of teachers. Such studies generally show that more autonomous teaching positions lead to increased motivation [46], decreased on-the-job stress [47], and an increased sense of personal accomplishment [48]. They also show that autonomous teachers tend to have autonomous students, which increases learning in the classroom [48–49]. Research also shows that autonomy support from administrators and education systems increases a teacher's motivation [50]. Though studies specifically on GTAs' autonomy are rare, Winters and Matusovich [23] used qualitative techniques to examine GTAs' experiences of autonomy with regard to teaching in engineering. They found that GTAs often have varying degrees of autonomy based on course structures and those who lack autonomy find it difficult to adjust to classroom challenges in the moment. In combination, these studies support autonomy as critically important within the LMMI.

It should be noted that all of the studies discussed above took a Western approach to autonomy, where independence is generally valued. Considering the international diversity of GTAs in engineering, some may argue that autonomy may not be motivating to those who hold a more Eastern perspective. However, although limited, research investigating Western and Eastern perspectives found that autonomy was important in Eastern cultures as well [e.g., 51-52]. Consequently, we believe autonomy would be important to consider for GTAs from Eastern and Western cultures though it may manifest itself in different ways.

2.1.3 Relatedness

Of the three basic needs highlighted in Self-Determination Theory, relatedness is the least directly researched construct in Self-Determination Theory. According to Deci and Vansteenkiste [36], who paraphrased Baumeister and Leary [32], "The need for relatedness concerns the universal propensity to interact with, be connected to, and experience caring for other people" [36, p. 25]. Within Self-Determination Theory literature, researchers have examined relatedness between teachers and students as well as relatedness between teacher colleagues; both have been shown to positively impact teacher motivation [53]. The common approach is to investigate the teacher-student relationship, and researchers often report that students who feel connected to their teachers tend to perform better [e.g., 54–55]. Investigating the teacher-teacher relationship is less common.

Though not grounded in Self-Determination Theory, research on GTAs in particular shows that connections to peers (i.e., other GTAs) are particularly important. Specifically, the notion of a community of practice, which is specifically operationalized to include a joint enterprise (shared mission), shared repertoire (common knowledge), and mutual engagement (person-to-person interaction) [56], was found to be useful when examining GTAs' teaching. For example, one study formally established communities for graduate students through student organizations and activities with the intention of increasing retention and improving experiences [57]. The results of their work were preliminary but suggested their implementations had a positive effect. A study by Crede and Borrego [5], which focused on GTAs in engineering, found that graduate students who teach want peer interaction and a sense of community with their colleagues. These studies support that a strong sense of community can strengthen motivation and foster positive experiences. From this research, GTAs would benefit from a sense of community or relatedness, which is included in the LMMI. Interacting with others is one way that people build a sense of competence and autonomy and therefore relatedness intersects the two in our model [58].

2.2 Identity: possible selves theory

Like motivation, identity can be defined and examined in many ways. For this study, identity is defined
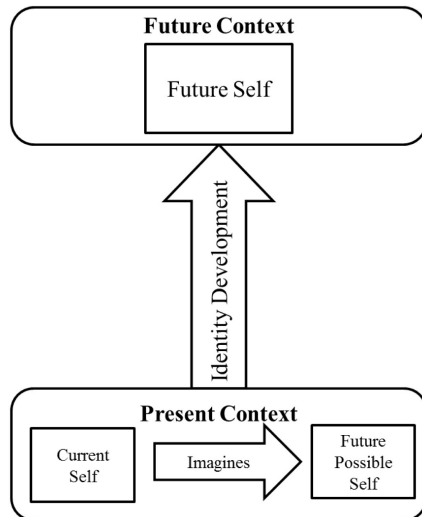
Fig. 3. Possible Selves Theory Representation—A Traditionally Identity Based Model.

as the answer to the question "Who are you?" [59], and it refers to the individual's answer to this question regardless of what others may believe about a person [60]. This perspective recognizes that while external influences inform the personal perspective, it is still an individual response. For this study, Possible Selves Theory [61] was used to operationalize identity because it targets an individual's thinking towards his or her future roles, which is defined as a future role as a teacher for this study.

Fig. 3 represents Possible Selves Theory as conceived in this work. The connection between the present and future self is depicted by the vertical *Identity Development* arrow, which captures a GTA's growth and movement towards the future context. The general concept of Possible Selves Theory is captured in the bottom block: Possible Selves Theory is an identity theory in which individuals think about and envision who they would like (and not like) to become [61]. In addition to thinking about a future self, Possible Selves Theory also requires that the view of the future self be connected with a current identity, be congruent with other aspects and goals of the current self, and be possible to attain [62]. Since Possible Selves Theory considers individuals' personal views of their selves in future positions, it is an appropriate framework for this study that examines GTAs' views of becoming teachers after they graduate.

Possible Selves Theory has been used as a theoretical framework (or lens) in a variety of studies related to education, including student and teacher perspectives—again, both of which are needed when you are interested in the experiences of GTAs. Possible Selves Theory has often been applied to high school settings, examining high

school student experiences and aspirations and fears for the future [e.g., 63–66]. Additionally, Possible Selves Theory has been used to study teachers in the academic setting. A study by Hong and Greene [67] used Possible Selves Theory to understand pre-service science teachers' views of their future teacher selves; the results of this study indicated that past experiences in teaching and learning played a great role in teachers' views of their future selves compared to their actual education program. Possible Selves Theory has also been used in teacher and education literature to examine graduate students' identification with becoming a researcher and future faculty [68].

Overall, these studies demonstrate the utility of Possible Selves Theory in examining both student and teacher success in academic settings, which is important in this context because GTAs are both students and teachers. The use of Possible Selves Theory with graduate students is particularly relevant because—though they are still students in the formal sense—graduate students are developing as individuals in the professional domain and may be still deciding on a career path as they balance their roles as teachers, researchers, and students [69].

2.3 Theory combination

The approach we propose in the LMMI is novel; however, it builds on past work that highlights the complementary nature of Self-Determination Theory and Possible Selves Theory. As mentioned above, a special issue of *Educational Psychologist* from 2009 titled *Motivation and Identity* explicitly draws attention to the possibility of and need to combine motivation and identity approaches [15]. The LMMI is consistent with the special issue but provides a concrete way of connecting two theories in traditionally different domains.

3. Evaluating the model as a foundation for development programs

To evaluate the LMMI, we undertook a small exploratory study, collecting data from GTAs in first-year engineering programs at multiple universities. We chose to focus on first-year engineering programs because they often employ many GTAs and allowed us to collect a diversity of experiences within a similar course context. This study was not intended to fully validate the model through longitudinal examination and confirmation of constructs and connections through statistical analysis; rather, it was intended to evaluate the utility of the model and demonstrate its applicability to GTAs and usefulness in shaping GTA development programs.

Table 1. Basic University and First-Year Engineering Program Information

Basic University Information	University	U1	U2	U3	U4
	Public/Private	Public	Public	Public	Private
	Student Population	55000	30000	20000	10000
Basic First-Year Engineering Program Information	Program Structure	2 Courses, Honors Available	2 Courses, Honors Available	2 Courses	2 Courses, Honors Available
	Student Program Enrollment 2011–2012	1600	600	700	460
	Teaching Assistant Use	Both	GTAs	GTAs	Both

3.1 Participating universities

Table 1 provides basic demographic information about the universities and the first-year engineering programs that participated in the research. The general university information was gathered from the Carnegie Foundation classification of schools and universities (http://classifications.carnegie-foundation.org/), and the program information was gathered in the first-year engineering program Directors Study [6], which was previously conducted by the two lead authors of this work. In the Directors Study, 15 different first-year engineering program directors and supervisors responded to an online survey designed to collect information related to the size of their first-year engineering program, the program structure, and the responsibilities of both GTAs and undergraduate teaching assistants. This information was used to gain a basic understanding of first-year engineering programs in the U.S. and the roles and responsibilities of teaching assistants within those programs. Based on the 15 universities who participated in the Directors Survey, the sample used in this research (a sub-set of four institutions) is representative of the content-based first-year engineering programs in the U.S., where most first-year engineering programs were established at large public research institutions. This type of program is representative of a "Pre-major with FYE Structure" engineering programs based on Chen et al. [70] taxonomy of matriculation practices in engineering. While there were similarities across the universities there was also uniqueness, which provides a more transferable picture of first-year engineering programs and makes this research applicable across different programs. In terms of differences, the size of the first-year engineering programs ranged greatly from 460 students to 1600 students; two of the first-year engineering programs employed just GTAs while two employed both graduate and undergraduate teaching assistants; and three of the four first-year engineering programs offered honor track courses. It should be noted that GTAs were sampled from both standard and honors track courses when applicable.

3.2 Data collection

To evaluate the model, we collected at least one of three journal entries from a total of 30 GTAs out of a potential pool of 65 GTAs from four different first-year engineering programs (41 from U1, 7 from U2, 13 from U3, and 4 from U4) over the course of the Spring 2013 academic term. Of the 30 GTAs who participated (23 from U1, 3 from U2, 3 from U3, and 1 from U4), 15 responded to all three surveys (i.e., submitted all three journal entries). Each survey invitation was initially distributed to the potential participants via email along with one follow-up reminder email. To increase the response rate, an incentive was given in the form of a gift card.

Each journal entry consisted of basic demographic questions, a set of common scaled response questions, and three open-ended questions that varied by journal entry (i.e., Survey 1 and Survey 3 did not have the same questions). Multiple journal entries were used so data points across the semester could be obtained for comparison in a short-term longitudinal manner. Table 2 lists the open-ended questions for each journal entry along with the topic each question was designed to explore. The questions were intentionally related to broad topics to allow the GTAs to respond in whatever manner they saw fit without biasing the questions towards the model.

In total, 65 GTAs from the four institutions were asked to participate and 30 GTAs submitted at least one journal entry: Survey 1 had an overall response rate of 37% (24 participants); Survey 2 had a response rate of 32% (21 participants); and Survey 3 had a response rate of 31% (20 participants). Twenty-three percent of the potential participants (15 participants) responded to all three of the surveys. The GTAs who participated were a mix of PhD and Master's level students representing a variety of engineering disciplines. While the sample was relatively small and favored U1, it was adequate for the purposes of evaluating the model. Again, due to the exploratory and baseline nature of this work, no demographic information was collected or analyzed.

Table 2 Journal Entry Survey Open-Ended Questions

Survey	Questions	Topic
1	What motivated you to become a GTA?	Motivation
	What is the most rewarding part about being a GTA?	Motivation
	What is the most challenging part about being a GTA?	Motivation
2	What motivates you to teach each week?	Motivation
	As of today, do you think you will be a GTA next year? Why or why not?	Future Teaching
	As of today, can you envision yourself in a future job with a teaching role? Please describe what that job would be and how teaching would be involved.	Future Possible Self
3	Looking back on the term, what is one thing you would change about your teaching experience?	Teaching Experience
	Over the course of the semester, did your motivation to teach change? Why or why not, and how?	Motivation
	Overall, do you consider yourself a teacher? Why or why not?	Identity

Table 3. Journal Entry Survey Major Codes

Survey	Questions	Major Codes
1	1	Competence, Autonomy, Relatedness, Other
	2	Competence, Autonomy, Relatedness, Other
	3	Competence, Autonomy, Relatedness, Other
2	1	Competence, Autonomy, Relatedness, Other
	2	Will be a GTA, Will NOT be a GTA
	3	Teaching Future, Unsure, No Teaching Future
3	1	Competence, Autonomy, Relatedness, Other
	2	Increased, Stayed the Same, Decreased
	3	Teacher, NOT a Teacher

3.3 Analysis

The analysis of the open-ended questions first involved an open-coding approach following the recommendations of Rossman and Rallis [71]. Rossman and Rallis state that coding is an iterative process starting with general large codes that are broken down into smaller sub-codes, where sub-codes are collapsed as needed to allow the salient trends to emerge from the data. For our approach, we used the major codes shown in Table 3 during our initial review and then developed sub-codes.

For our analysis, we initially coded Survey 1 (Q1–3), Survey 2 (Q1), and Survey 3 (Q1) using the motivation related constructs from the LMMI (competence, autonomy, and relatedness) along with a major code of "other" that was applied to segments of text that seemed related to GTAs' experiences but were out of the scope of this project. Table 4 captures the operationalized definitions of the Self-Determination Theory (i.e., motivation) related codes. Additionally, we coded Survey 2 (Q3) to determine possible future teacher selves. After the initial coding, we reviewed the individual code segments within the major codes to create sub-codes that captured key trends in the response; this process was iterative, where we started creating sub-codes in Survey 1, moved to Survey 2 then Survey 3, and then revisited each survey to ensure no sub-codes were missed. An example of a sub-code that emerged from the first question on Survey 1 was "gaining experience," which was a sub-code for the major code of "competence." The sub-code "gaining experience" is exemplified by the following GTA journal entry quote:

> "I had no previous teaching experience and thought, through a GTA, I might achieve this experience." [Participant 1]

The sub-code of "gaining experience" was related to "competence" because "gaining experience" was viewed as acquiring knowledge which directly

Table 4. Self-Determination Theory Operationalized Codes

Self-Determination Theory Codes	Operationalized Code
Competence	self-recognized knowledge of content, pedagogy, and instructional/program structure; this would not include simple statements of what they did—it would include a discussion of what they learned or knew or a deep discussion of what they did that showcases knowledge of a topic (a characterization of what they did)
Autonomy	having control or decisions making power over your classroom or course in terms of content, activities, and policies; this also includes a lack of control or decision making power
Relatedness	feelings of connection or belonging to your teaching colleagues or students; this also includes connections to the department or university, this does not include a simple discussion of position within a structure—they must mention their feelings in that environment or describe the relationship

relates to ones' views of competence and Self-Determination Theory in general. See Appendix A for a complete list of the sub-codes, brief definitions, corresponding major codes, and sample quotes. Additional questions were included and analyzed in the three surveys as shown in Table 2, but they are beyond the scope of this manuscript.

4. Results and implications for development programs

Through analyzing the data, we were able to operationalize each of the relevant constructs in the LMMI. The sub-codes in this work help to illuminate impactful items for TAs and GTAs' future teacher-selves. Our complete findings for the constructs are shown in Fig. 4. We interpret select items from our findings in the context of designing a GTA training program in the following sections.

Below we list one sub-code from each construct and provide possible implications that may be of interest to GTA faculty coordinators and administrators. While there are potentially other implications, we believe the items below have the most potential for impact based on our work and previous research.

4.1 Knowing the content (competence)

Knowing the content is operationalized to mean 'GTAs need to know the material they must teach,' and approximately a third of the GTAs discussed something related to this code. Self-efficacy directly relates to knowledge and the idea of knowing, and has been found to be lower in women and minorities when compared to men in science, technology, engineering, and math [e.g., 72]. Therefore, when designing development programs for a range of GTAs related to content, resources should be developed to account for these potential differences, ensuring that *all* GTAs not only know the content but also feel confident in their abilities. To accomplish this goal, we recommend weekly training, which is typical of many first-year engineering programs [73], that includes both technical content and pedagogical content. The technical content will ensure that GTAs are equipped to teach the material. The pedagogical content will assist them in delivering the content and should support their confidence in their teaching abilities. Additionally, we suggest that GTAs are encouraged to use information from their past experiences—both as a teacher (if they have them) and as a student—as
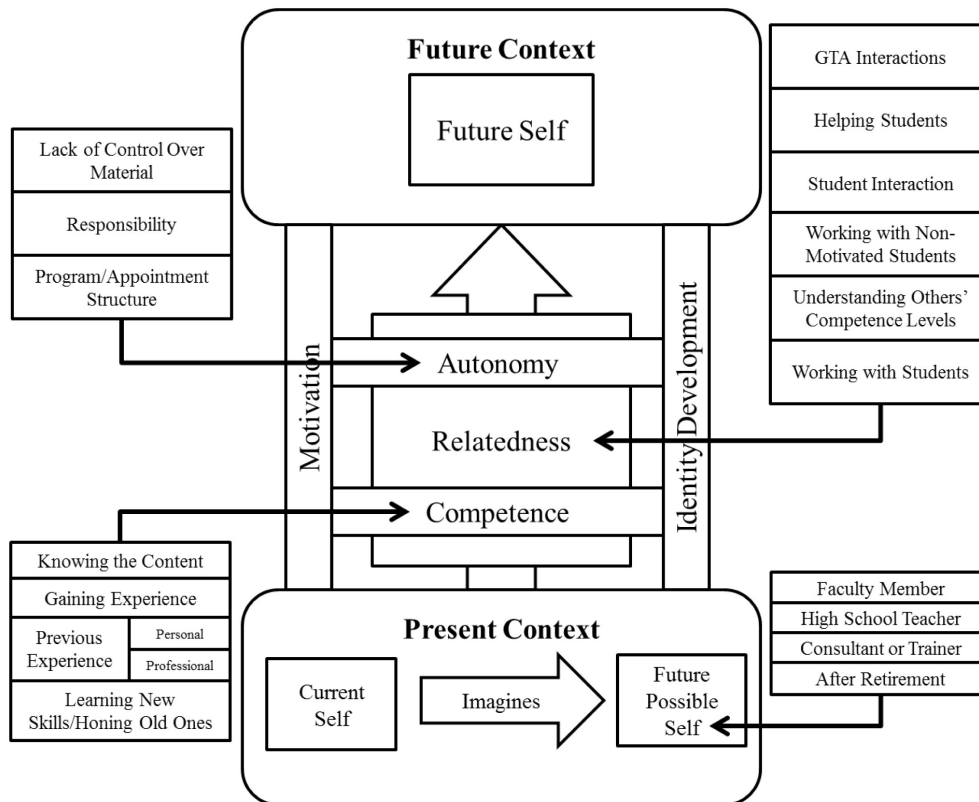

Fig. 4. Survey Codes Mapped Back to the Longitudinal Model of Motivation and Identity (LMMI).

these experiences can be a great source of information about content as well as pedagogy.

4.2 Responsibility (autonomy)

Responsibility was cited as a key item related to autonomy and was operationalized to 'being a GTA means you are responsible for the classroom or course'. Only 4 GTAs provided specific responses that were coded as *responsibility*; however, their comments seemed significant to their experience. First-year engineering programs tend to be large in size, often requiring an army of instructors, GTAs, and graders. In this course structure, GTAs may be given a wide range of responsibilities. For example, we suggest that GTAs be given outlets for their autonomy through different responsibilities; this could include permission to alter slides, freedom to develop study guide materials or review sessions, or invitations to contribute to curriculum development. It is important for autonomous experiences to be given to GTAs early in their teaching experience to help in the development of their teaching motivation and identity. Early experiences with a range of responsibilities will also allow GTAs to gain a range of knowledge related to their position that may be useful if they become faculty in the future.

4.3 Student Interaction (relatedness)

Student interaction was when a GTA expressed liking interactions with students. This appeared in almost all of GTA responses. To promote interactions between students and GTAs, we suggest that a community of practice [56] be established within the classroom and that GTAs are taught the skills to create that community. Crede et al. [11] used a community of practice approach to study a teaching community of GTAs in engineering from a variety of engineering disciplines and found the community to be beneficial in professional development. By establishing a community of practice in the classroom, GTAs and their students can have a joint enterprise related to the content the students are learning, they can have a shared repertoire by all being students even though they are at different levels, and they can achieve mutual engagement, something GTAs discussed as being central to their teaching.

4.4 Faculty Member (identity)

Faculty member was a possible future teacher role for a third of the GTAs in the sample. GTAs need role models, which in many cases are faculty. For these role models to be effective in supporting GTA developmental programs, faculty need to interact with GTAs and serve as examples of faculty who identify with teaching and are motivated to excel in their teaching. Interacting with these types of roles

models has the potential to positively impact GTAs. We recommend that faculty take an active part in creating and participating in GTA development programs (i.e., these programs should not be developed by only staff). By doing so, GTAs have role models of how teaching can be embraced in the faculty role. This is especially important in fields where research can dominate faculty responsibilities and teaching can be seen as an afterthought.

4.5 Using the model to create a development program

There are a variety of implications for GTA development programs based on the findings. These implications begin to bridge the research to practice divide that is often present in educational research. Jamieson and Lohmann [74] argue that for engineering education to progress and succeed as a discipline, research to practice and practice to research must be achieved. The recommendations above serve as a starting point and are initial suggestions for those wishing to create a GTA development program based on a theory and research that is transferable. We suggest program developers use each sub-code as a starting point for inspiration on learning objectives or program activities. From there, a program can be crafted that supports the unique needs of GTAs regarding their motivation to teach and identity development as a teacher.

Additionally, program developers should consider that GTAs are not only students but also teachers. Since GTAs are serving as teachers, it is important to ensure that they are adequately prepared and supported in their instruction. However, because they are students, they need to be guided through their development. Based on our review of the literature and the evaluation of the LMMI, we believe that the proposed model provides a strong foundation on which to build GTA development programs that provide such support.

5. Limitations and future work

We believe there are two main limitations to our research. First, a limitation to this study is that we only explored the GTA perspective. While this perspective is essential to understanding GTA motivation and identity, additional perspectives would provide a more holistic understanding of the GTA experience. To address this limitation and further validate the LMMI, future work will link the student experience to the GTAs' perspective of motivation and identity. Additionally, we will gather data from GTA supervisors to better understand what supports are currently in place for GTAs. Finally, our work is limited to the first-year engineering program context. While we strategi-

cally chose this context due to the number of GTAs and fundamental nature of the content, we recognize that GTAs may have different experiences in other disciplines as well as in more advanced courses. To address this limitation in scope, future work will examine GTAs in additional contexts and contribute to our better understanding of the similarities and differences across engineering and other areas of science, technology, engineering, and math.

6. Conclusions

We proposed and evaluated the LMMI. The LMMI is a model of motivation and identity development based in Self-Determination and Possible Selves Theories. This model is a new contribution to engineering education and teacher education with potential to inform instructor education. We specifically evaluated the LMMI in the first-year engineering program context by examining GTA motivation and identity. Based on our work, we believe the model is a viable option for better understanding GTA motivation and identity and can be used by GTA faculty coordinators and administrators to create developmental programs that specifically support GTAs.

In the long term, we believe improved teacher preparation programs focused on motivation and identity development will lead to overall improvements in the quality of teaching in engineering. Such programs could be particularly helpful for GTAs as GTAs are future faculty and are the key to long-lasting change. We proposed and evaluated a model in the context of first-year engineering programs but believe that future research will confirm the applicability of the LMMI beyond GTAs in first-year engineering programs and to GTAs more broadly in engineering and related fields.

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APPENDIX A: Phase 1 Codebook and Sample Quotes

Survey 1

1. What motivated you to become a GTA?
    a. Competence
        i. Gaining Experience
            1. *(becoming a GTA to have the opportunity to teach)*
            2. "I had not previous teaching experience and thought through a GTA I might achieve this experience." [1]
        ii. Previous Experiences
            1. Personal Experiences
                a. *(past personal experiences that GTAs could look to for information about how to be a GTA)*
                b. "I had a bad GTA my first semester and a great one my second semester in two sequential classes. I saw the differences and saw how well having a good GTA can help you in a class." [4]
            2. Professional Experiences
                a. *(past professional experiences such as being an undergraduate teaching assistant that GTAs could look to for information about how to be a GTA)*
                b. "I was a UTA for 3 years." [2]
    b. Autonomy—No items could be found that fit autonomy.
    c. Relatedness
        i. Student Interaction
            1. *(GTAs liked interaction with students)*
            2. "I really enjoy interacting with the students and wanted to continue supporting the [. . .] program." [2]
    d. Other
        i. Funding
            1. *(a reason for being a GTA was to pay for their graduate studies)*
            2. "Opportunity to pay for my studies..." [20]
        ii. Enjoyment or Interest
            1. *(GTAs expressed an interest, joy, or happiness when teaching)*
            2. "I really enjoy teaching." [15]
2. What is the most rewarding part about being a GTA?
    a. Competence
        i. Learning New Skills or Honing Old Ones
            1. *(being a GTA allowed them to learn something new or practice something they learned elsewhere)*
            2. "The most rewarding part of being a GTA is acquiring new and honing old social skills and one's discretion when it comes to evaluating work; to know what work deserves what grade. . ." [17]
    b. Autonomy
        i. Responsibility
            1. *(being a GTA means you a responsible for the classroom or course)*
            2. "Also, it [teaching] comes with responsibilities as well..." [1]
    c. Relatedness
        i. Working with Students
            1. *(as a GTA you get to directly assist students)*
            2. "The most rewarding part about being a GTA is working with a student trying to solve a problem. It is a great feeling watching the student figure out the answer to their own question by just guiding them to the right answer and not giving them all of the answers." [2]

    ii. Helping Students
        1. *(as a GTA you get to help students learn)*
        2. "Helping students understand a concept that they previously didn't understand." [8]
  d. Other
    i. The Ah Ha Moment
        1. *(a motivating factor for being a GTA is better to see students understand and grasp a concept)*
        2. "When a student understands a difficult problem and that 'lightbulb' goes off over their head!" [19]

3. What is the most challenging part about being a GTA?
  a. Competence
    i. Understanding Other's Competence Levels
        1. *(GTAs need to understand the knowledge level of their students)*
        2. "Being patient and not taking knowledge for granted. I've been solving these problems for years whereas these students are just learning the skills." [4]
    ii. Knowing the Content
        1. *(GTAs need to know the material they must teach)*
        2. "In addition, sometimes I don't feel that I've been prepared well enough for some of the content prior to the quarter beginning, and I don't like to feel unprepared!" [23]
  b. Autonomy
    i. Lack of Control Over Material
        1. *(GTAs comment on not developing any of the course materials)*
        2. "For me it has been the teaching as well. I have no problem talking to an audience or delivering a message, yet having material that you did not created is hard to go over it and impart it. You have doubts whether something is important or not really important." [1]
  c. Relatedness
    i. Working with Non-Motivated Students
        1. *(GTA specifically comment on helping or understanding students who do not show an interest in the class)*
        2. "The most challenging part is working with students who don't care or don't want to be there. There aren't that many of them, but when you come across them it is difficult to deal with. " [15]
  d. Other
    i. Life Balance
        1. *(talking about various roles that GTAs have beside being a teacher)*
        2. "Having to teach AND do research AND take classes is murder" [14]

Survey 2
3. As of today, can you envision yourself in a future job with a teaching role?
  a. Yes
    i. Faculty Member
        1. "Yes, I certainly see myself in some sort of teaching role in the future. Teaching is something that has always fascinated me. I have observed teachers consciously and sub consciously throughout my academic career all the time thinking how I would do things differently. In the future, I see myself working in academia, hopefully as a professor doing my research on the side." [12]
    ii. High School
        1. "Possibly, in the distant future, I can see myself teaching full time. If I were to teach, I would most likely teach high schoolers." [2]
    iii. Consulting or Training
        1. "Though I do not plan to be in academia in the future I would like to take up small teaching roles [. . .] like consulting and training." [7]
    iv. After Retirement
        1. "Currently, I do not see myself teaching. I think this will change over a couple of years. I think I might come back and teach when I'm close to retirement. I could see myself teaching in a college or high school setting." [13]
  b. No
    i. Industry
        1. "No. As great as this was, I am ready for job in a civil engineering field." [25]
  c. Not Sure
    i. "Perhaps—haven't quite decided yet." [19]

Survey 3

1. Looking back on the term, what is one thing you would change about your teaching experience?
   a. Competence—No new items could be found that fit competence.
   b. Autonomy—No new items could be found that fit autonomy.
   c. Relatedness
      i. GTA Interactions
         1. *(expressed interest in working with other GTAs)*
         2. "More preparation with engagement with the class would be desired—in addition to interaction with other GTAs." [3]
   d. Other
      i. Program/Appointment Structure
         1. *(comments related to their appointment or responsibilities in the class that are concrete items such as giving lectures, grading, office hours, etc.)*
         2. "I would try to give more lectures." [8]

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