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First-Generation ESL Calculus Students' Beliefs about Mathematical Problem-Solving

Kevin Palencia
Northern Illinois University, United States
https://orcid.org/0000-0001-7292-5537

Breille Duncan
University of Montana, United States

Ricela Feliciano-Semidei
Northern Illinois University, United States
https://orcid.org/0000-0002-2620-0612

Alcibiades Bustillo-Zarate
University of Puerto Rico-Mayagüez, United States
https://orcid.org/0000-0003-2407-287X

Ke Wu
University of Montana, United States
https://orcid.org/0000-0001-7645-9051

ABSTRACT

This study investigates the mathematical problem-solving beliefs of first-generation calculus students using the Indiana Mathematics Belief Scale, with a particular focus on English as a Second Language (ESL) speakers. Two-tailed independent samples t-tests revealed that ESL students were less convinced of the practical usefulness of mathematics than their non-ESL first-generation peers, respectively. By identifying beliefs that support learning alongside those that may pose barriers, our findings provide a nuanced perspective on the calculus experiences of ESL first-generation students in STEM.

Keywords: beliefs, calculus education, English as a second language, first-generation college students

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INTRODUCTION

Research on retention in STEM fields has examined both the factors that lead students to leave these majors and the strategies that support persistence (Bullock et al., 2017; Brewer et al., 2021; Chen & Soldner, 2013; Rasmussen & Ellis, 2013; Sithole et al., 2017). These studies suggest that success in calculus is closely associated with persistence in STEM majors (Bullock et al., 2017; Kopparla, 2019; Sanabria & Penner, 2017). The retention issues in calculus classes and STEM programs are particularly pronounced for first-generation college students (FGS) (Katrevich & Araguete, 2017; Brewer et al., 2021). For example, they have lower retention rates (Katrevich & Araguete, 2017; Wibrowski et al., 2017) and are more likely to leave their education track (Bettencourt et al., 2020; RTI International, 2023) compared to their continuing-generation peers. At the same time, FGS brings unique strengths such as persistence, adaptability, and strong motivation to succeed that can serve as powerful resources in STEM. Importantly, FGS are not a homogeneous group, and their experiences in STEM may differ depending on other identities. For example, FGS with multiple marginalized identities face compounded challenges and strengths in STEM education (Jehangir et al., 2024; Pagliarulo McCarron, 2022). These challenges include navigating systemic barriers and experiencing a lack of representation, which can negatively affect students' retention and success in STEM fields. Recognizing both barriers and assets that FGS contributes is essential for supporting them.

Although research has examined retention, confidence, belonging, and identity among FGS in STEM, less attention has been given to how mathematics-specific beliefs, particularly in calculus, may differ for FGS whose identities intersect with being ESL speakers. Understanding these beliefs is critical, given the central role of calculus in STEM persistence and the increasing emphasis on problem-solving and active learning in undergraduate mathematics instruction.

The purpose of this study is to explore the problem-solving beliefs of calculus FGS whose identities intersect as ESL students. This study sheds light on understanding FGS's beliefs, highlighting their strengths and addressing possible obstacles that may impact the retention of these students. We used the Indiana Mathematics Belief Scale (IMBS) (Kloosterman & Stage, 1992; Fennema & Sherman, 1976), an instrument to measure mathematical problem-solving beliefs that has been validated for calculus students (Ayebo & Mrutu, 2019; Berkaliev & Kloosterman, 2009). The IMBS was distributed to calculus students to measure six dimensions of problem-solving beliefs. To better understand factors related to the academic success and retention of FGS, we explored the research question: *What are the mathematical problem-solving beliefs of ESL first-generation calculus students, and to what extent do these beliefs differ from those of their non-ESL first-generation peers?*

LITERATURE REVIEW

The following sections provide a brief overview of the college experiences of FGS in STEM and examine research on FGS in STEM who are ESL speakers.

First-Generation College Students in STEM

The population of FGS enrolled in colleges and universities in the U.S. represents one-third of the total enrollment, yet the literature on studying the experiences of college FGS in STEM is limited (Bettencourt et al., 2020; Dabiri, 2026; Dika & D'Amico, 2015). Research on FGS in STEM has focused on examining their persistence and academic achievement in college. Specifically, researchers have examined their transition from high school education to college, as well as non-academic factors, such as social capital and confidence in their mathematical abilities. Several studies highlight the critical relationship between pre-college educational experiences and retention outcomes (Bettencourt et al., 2020; Coffman, 2011; Dika & D'Amico, 2016; Katrevich & Araguete, 2017; Shaw & Barbuti, 2010; Weisen et al., 2024). For instance, FGS are affected by barriers that begin in high school, where they are less likely to take rigorous courses to develop the skills necessary to succeed in college (Coffman, 2011), including, but not limited to, calculus courses. Moreover, when FGS enter university, they are more likely to take developmental mathematics classes (Katrevich & Araguete, 2017). For instance, Bettencourt et al. (2020) analyzed national U.S. data to examine high school students who enrolled in postsecondary education within two years of graduation. Their findings revealed that FGS had significantly less exposure to advanced science and mathematics courses in high school compared to continuing-generation college students (CGS). This disparity was strongly associated with lower STEM degree completion rates.

Beyond academic preparation, research has identified social capital, the role of identity, and belonging as key factors for FGS success in college (Chaffee et al., 2025; Glass, 2023; Jehangir et al., 2024; Martin et al., 2020; Museus et al., 2021). For example, Martin et al. (2020) conducted a qualitative study to examine how 47 undergraduate engineering students at one public university in the U.S. described social capital within their networks, finding that FGS perceived social capital primarily as encouragement and emotional support (Martin et al., 2020). In another study, Museus et al. (2021) investigated the relationship between campus environment and sense of belonging among FGS in a large public research university in the U.S., identifying factors that positively impact belonging, such as opportunities to connect with people sharing common backgrounds, access to relevant learning activities, and exposure to collectivist orientations within the campus culture. Another angle in studying the college experiences of FGS concerns their confidence while working on mathematics problems. Specifically, research has found that FGS tend to have lower confidence in their mathematical abilities than their continuing-generation peers, a factor linked to lower mathematical achievement (DeFreitas & Rinn, 2013). Yet confidence is strongly associated with mathematical problem-solving skills (Pajares & Miller, 1994) and persistence in calculus (Ellis et al., 2016). Thus, investigating the problem-solving beliefs of FGS offers critical insight into the barriers they face in calculus and the support needed to improve STEM retention.

Building on this connection between confidence, problem-solving, and persistence, the literature further highlights the broader role of beliefs in shaping student success in STEM. Although studies have examined the beliefs of FGS in general, relatively little research has focused on mathematics—particularly in calculus, a recognized gateway course for STEM retention. The limited work that does exist suggests that FGS often draw upon cultural and experiential resources that influence their beliefs about academic performance (Aspelmeier et al., 2012; Snodgrass et al., 2020; Verdín et al., 2020), yet the role of mathematics-specific beliefs is underexplored (Urbieta, 2022; DiGregorio, 2018). Urbieta (2022) investigated the differences in sense of belonging to calculus among various subgroups of 55 FGS calculus students. In this study, Urbieta found no statistically significant difference between racial, gender, or generational subgroups regarding their sense of belonging to calculus. In another study, DiGregorio (2018) interviewed eight FGS in precalculus or calculus and examined their students' self-belief in mathematics. DiGregorio found that students expressed a strong appreciation for how taking mathematics courses in college helped shape their learning experience. For example, this included transforming their attitude toward valuing practice, devoting time and effort, gaining mastery of mathematical concepts, working with other students outside of class, and valuing help requests when needed. While these studies shed light on the experiences of FGS students in calculus, it is crucial to recognize that FGS possess intersecting identities and that they are not a homogeneous group (Nguyen & Nguyen, 2018).

ESL First-Generation College Students in STEM

Intersectionality, coined by Crenshaw (2013) in her work on critical race theory, provides a lens through which to consider the experiences of those who hold more than one marginalized identity. This framework acknowledges that identity-based harm is often heightened for these communities and can be unique to their intersectional identities. Some researchers have focused on examining the intersectionalities of FGS in STEM with other identities they hold (Marco-Bujosa et al., 2023), and some have highlighted the intersectionality with being a woman (Google et al., 2023; Jehangir et al., 2024) or an immigrant (Jehangir et al., 2024). At the moment we reviewed the literature, we did not find studies specific to FGS in STEM who are also ESL speakers.

First-generation ESL speakers in STEM face unique challenges in learning and applying specialized vocabulary, even when they are proficient in everyday English (Antwi, 2026; Collier et al., 2016). This language barrier can limit their ability to grasp concepts, engage in discussions, and demonstrate knowledge, ultimately influencing persistence. Research has shown that language proficiency shapes ESL students' perceptions of their problem-solving abilities (Mallika, 2024), yet most college-level studies focus on instructional tools (Collier et al., 2016) or sense of belonging (Stebleton et al., 2014; Yao, 2016), with relatively little attention to mathematics-specific beliefs (LaCosse et al., 2020). Because effective problem-solving strategies are fundamental to calculus success, investigating the problem-solving beliefs of ESL students is essential to understanding how language and problem-solving interact in this gateway course, which strongly influences STEM retention.

By focusing on the beliefs of calculus FGS who self-identified as ESL, this study directly addresses an underexplored intersection of these identities in STEM education. Moreover, beliefs are a powerful predictor of persistence and performance in mathematics (Muis, 2004), and understanding students' beliefs about problem-solving in the context of calculus, the course most frequently associated with STEM attrition, is particularly timely, as calculus instruction increasingly emphasizes student-centered strategies that rely on student engagement, collaboration, and problem-solving skills.

RESEARCH METHOD

For this study, we conducted a quantitative cross-sectional survey of college calculus students. This research approach was appropriate to provide a snapshot of the state of variables of interest among FGS, allowing for the analysis of patterns and relationships at this point (Johnson & Christensen, 2019). Students included in this analysis are FGS, which means that they reported that none of their parents earned a bachelor's degree. Guiding our analysis by the views of intersectionalities, we investigated possible differences in FGS beliefs about mathematical problem-solving concerning the variable of primary language spoken at home.

Participants & Data Collection

The participants of this study were calculus students from a U.S. midwestern doctoral public university. All students who were enrolled in Spring 2023 calculus courses were invited to participate in the study. There were 16 total sections from Calculus I, II, and III, in which 362 students were enrolled. These classes met four times a week, with approximately 20-30 students in each class. Calculus instruction was based on active learning strategies such as small-group work, in which students collaborated on weekly worksheets aligned with course topics. These worksheets also incorporated applied problems designed to connect calculus concepts to real-world contexts. Students who agreed to participate completed the IMBS survey and a demographics questionnaire at the beginning of the semester. Students who completed the surveys received three points for each survey completed, which were added to their scores in Exam 1 and Exam 2, respectively.

We collected demographic information, including generational status and language spoken at home, from 225 calculus students. Students were enrolled in Calculus I (39.6%, n = 89), Calculus II (28.9%, n = 65), and Calculus III (31.6%, n = 71) classes. From the demographic survey, we used the following indicators to filter our populations of interest. Students who responded that neither parent had received a bachelor's degree on the survey are considered *FGS*, and those who reported that at least one parent had received a bachelor's degree are considered *CGS*. For this study, students who reported that English was not the primary language spoken at their household are considered *ESL* students, and those who reported that English was the primary language spoken at home are considered to be non-ESL students.

Research Instrument

The IMBS (Fennema & Sherman, 1976; Kloosterman & Stage, 1992) comprises 36 Likert-type scale questions that measure six beliefs about mathematical problem-solving, each including six questions that either positively or negatively reflect it. For each question, a student could answer *strongly disagree, disagree, uncertain, agree,* or *strongly agree* to indicate how much they relate to the statement.

The six beliefs measured by the IMBS are as follows, and the questions to measure each belief are in Appendix A.

- Belief 1 (Difficult Problems): I can solve time-consuming mathematics problems.
- Belief 2 (Steps): There are word problems that cannot be solved with simple, step-by-step procedures.
- Belief 3 (Understanding): Understanding concepts is important in mathematics.
- Belief 4 (Word Problems): Word problems are important in mathematics.
- Belief 5 (Effort): Effort can increase mathematical ability.
- Belief 6 (Usefulness): Mathematics is useful in daily life (Kloosterman & Stage, 1992; Fennema & Sherman, 1976).

Data Analysis

To analyze the data, we assigned numeric values from one to five to students' responses to the IMBS. For questions that positively reflect the belief, the responses are scored as 1=strongly disagree, 2=disagree, 3=uncertain, 4=agree, and 5=strongly agree. Questions that negatively reflect a belief are scored in reverse order, with 1=strongly agree and 5=strongly disagree. These values allowed quantitative measurement. A score greater than three indicates that the student agreed with the belief, a score less than three indicates that the student disagreed with the belief, and a score of three indicates that the student was neutral about this belief. A mean belief score close to one or five indicates a strong level of disagreement or agreement, while a mean belief score close to three indicates a neutral position.

We used Cronbach's alpha to measure the internal consistency of each belief and then analyzed the beliefs with internal consistency. The analysis included a computation of the mean, standard deviation, and 95% confidence interval for FGS who speak English as their primary language and who are ESL speakers. Then, we used an independent t-test to identify mean differences between these subgroups. The p-values helped determine the strength of the evidence of a significant difference (Ganesh & Cave, 2017). The two-tailed t-test was chosen to determine if the belief scores were statistically significant.

RESULTS

The IMBS survey and demographic questionnaire were distributed to 362 students, and 225 responses were received, with a 62.2% response rate. Two students (0.89%) responded to the IMBS survey but did not complete the demographic questionnaire, so their responses were removed from the dataset, resulting in 223 remaining responses. The analysis includes 94 FGS (42.15% of the 223 responses). In Table 1, we compare the Cronbach's alpha values for each belief calculated in this study with those from the original article introducing the

IMBS (Kloosterman & Stage, 1992) and another study using the IMBS by Kloosterman (Mason, 2003).

Table 1

Cronbach's α Internal Validity Test Results by Belief

Beliefs	Cronbach's α for Current Study	Cronbach's α for Kloosterman & Stage 1992	Cronbach's α for Mason 2003
Difficult Problems	0.76	0.77	0.76
Steps	0.61	0.67	0.59
Understanding	0.79	0.76	0.72
Word Problems	0.38	0.54	0.27
Effort	0.88	0.84	0.94
Usefulness	0.84	0.86*	0.82

When testing the internal validity of the beliefs measured by the IMBS using Cronbach's alpha, all but the *Word Problems* scale had α>0.50, suggesting moderate to strong reliability (Mason, 2003). Therefore, the *Word Problems* scale will not be included in the results. In Table 2, we include the values of the sample mean and the 95% confidence interval for the population mean of non-ESL FGS's (n=51) and ESL FGS's (n=43) beliefs. We also include the results of the unpaired two-tailed t-test.

Both first-generation ESL and non-ESL agreed with the *Difficult Problems, Understanding, Effort*, and *Usefulness* scales, and disagreed with the *Steps* scale. The mean score on the *Steps* scale was less than three, meaning that ESL and non-ESL FGS disagree that there are word problems that do not have straightforward solutions. In other words, they believed that word problems can always be solved with simple procedures.

Effort and *Usefulness* scales received the highest mean scores, showing that within FGS, both ESL and non-ESL had a higher agreement that effort can increase mathematical ability and that mathematics is useful in daily life, compared to other beliefs. There is moderate evidence of a difference in the level of agreement with the *Usefulness* scale, showing that ESL FGS are less convinced of the usefulness of mathematics than their non-ESL peers.

Table 2

Belief Score Comparison between First-Generation non-ESL and ESL Students

	Mean	95% Confidence Interval	Unpaired t-test (df=92)
Difficult Problems			
non-ESL	3.502	3.340-3.664	t=0.565
ESL	3.426	3.215-3.638	p=0.573
Steps			
non-ESL	2.542	2.377-2.708	t=0.454
ESL	2.597	2.433-2.761	p=0.651
Understanding			
non-ESL	3.820	3.606-4.035	t=-0.337
ESL	3.868	3.704-4.033	p=0.737
Effort			
non-ESL	4.471	4.283-4.658	t=-1.346
ESL	4.291	4.113-4.469	p=0.182
Usefulness			
non-ESL	4.228	4.067-4.389	t=-2.609
ESL	3.891	3.693-4.090	p=0.011*

*Significant at p<0.05 (moderate evidence)

DISCUSSION & CONCLUSIONS

In this study, we investigated and analyzed the problem-solving beliefs of FGS using the IMBS. We adopted an intersectionality approach to account for the variation within the FGS population and studied the beliefs of ESL FGS students compared to non-ESL FGS.

Calculus FGS's Beliefs About Mathematical Problem-Solving

The research question that guided our study is: *What are the mathematical problem-solving beliefs of ESL first-generation calculus students, and to what extent do these beliefs differ from those of their non-ESL first-generation peers?*

We measured the FGS's beliefs about mathematical problem-solving by surveying participants' level of agreement with six beliefs. Only five beliefs were considered in the analysis, as the *Word Problems* scale showed internal validation challenges in our dataset. We found a statistically significant difference for Belief 6 between ESL FGS compared to non-ESL FGS. There was no statistically significant difference in the other beliefs. In this discussion, we link the other beliefs with the literature and the results of this study, calling for their practical implications.

The *Difficult Problems* scale brings students' perspectives about the type of problems that should be solved in mathematics courses, such as calculus. The newer calls for focusing on conceptual understanding and the development of flexible problem-solving skills (e.g., Kramer et al., 2023) suggest the need to solve conceptual calculus problems, which may be time-consuming. Therefore, students agreeing that they have the ability to solve time-consuming mathematical problems signifies higher overall math confidence and may encourage students to continue their STEM path. In our study, we found that ESL students tend to agree with this statement. This finding is a significant strength of our population, as this belief may provide a lens that could enhance their success in mathematics and future STEM courses. Our finding aligns with DiGregorio's (2018) research, which also found that FGS students appreciate devoting time and effort to their college mathematics courses.

The *Steps* scale sheds light on the fact that word problems can be complex. This was the belief with the lowest average ESL students, and was one of the beliefs that students disagreed with. This may indicate that FGS tend to believe that most, if not all, word problems can be solved quickly and through simple procedures. Other studies using IBMS to understand mathematics college students' beliefs about mathematics problem-solving have also found students disagree more with this belief (e.g., Araña Sangcap, 2010; Berkaliev & Kloosterman, 2009). To make sense of this finding, we may consider the instructional choices that shape students' experiences with word problems, such as the selection of the in-class examples and assessments. Building on Schoenfeld's (1989) insight that highachieving students question straightforward solutions, we can reflect on how to engage learners in deeper, more analytical problem-solving. Persisting in solving relevant word problems can improve problem-solving skills, which are associated with STEM retention (Sithole et al., 2017).

The *Understanding* scale highlights the importance of conceptual understanding in calculus, which supports deep comprehension, problem-solving, and critical thinking—skills essential for success in STEM studies and future careers (e.g., Habre & Abboud, 2006; Kramer et al., 2023). In our study, students agreed that conceptual understanding is important, consistent with Berkaliev and Kloosterman's (2009) findings across various student groups. Although we did not find differences in this belief between ESL and non-ESL first-generation students, prior research has shown variation by population and gender (Berkaliev & Kloosterman, 2009; Araña Sangcap, 2010). Our results suggest that first-generation students may hold a relatively uniform belief about the value of conceptual understanding. While this belief indicates that students value grasping mathematical concepts, it does not reveal how they view procedural knowledge—an important considerations such as technological advances, including artificial intelligence, increasingly demand conceptual rather than purely procedural skills.

The *Effort* scale reflects the growth mindset belief that ability improves through practice, contrasting with a fixed mindset that views intelligence as static (Dweck, 2010). Higher effort scores are encouraging, as research links growth mindsets with greater academic achievement (Bostwick et al., 2017). In this study, the Effort scale yielded one of the highest mean scores, suggesting that FGS are confident that effort enhances mathematical ability. This finding aligns with results from Filipino college students (Araña Sangcap, 2010) but contrasts with those from engineering, elementary mathematics methods, and remedial mathematics students (Berkaliev & Kloosterman, 2009). FGS's strong belief in the value of effort is a valuable asset that can be purposefully leveraged to support calculus learning.

The *Usefulness* scale measures students' beliefs about the value of mathematics in daily life and future careers, an important factor for STEM retention and enrollment. Research indicates that STEM courses often prioritize conceptual mastery over career applications, making these programs less appealing to students (Sithole et al., 2017). In this study, students generally agreed that mathematics is useful, though ESL first-generation students (FGS) expressed lower agreement than their non-ESL peers. This difference may reflect the compounded challenges faced by students with intersecting identities (Jehangir et al., 2024). ESL FGS may not see their experiences represented in examples or applications, which can weaken their sense of relevance and connection between mathematics and future careers. Limited representation in STEM fields and differing educational access may further contribute to their lower belief in mathematics' usefulness.

Is the context we are using more relevant to the majority of the students, but not as relevant to ESL speakers FGS? Teaching mathematics in a context that is relevant to minority students could make these connections clearer for them and foster a more equitable experience in the learning of mathematics (e.g., Gutierrez, 2012; Steele et al., 2005). This should be extended to the calculus classes and be specific to ESL speakers who are also FGS.

Since beliefs about mathematics and mathematics problem-solving may positively correlate with mathematics achievement and persistence in mathematics (Fernandez et al., 2022; Mason, 2003; Pilgrim, 2010), we recommend reinforcing them through explicit teaching. For example, Wibrowski et al. (2017) and Steele et al. (2005) used humanized mathematics by contextualizing problems to connect with students' experiences. Targeted support for FGS (e.g., Wibrowski et al., 2017, Carver et al., 2017) should consider the intersection of language, as well as alignment with mathematics learning support skills. Additionally, the curriculum should reflect these beliefs to enhance the performance of this student group.

Limitations

The dataset used in this study offers focused insights, drawing from survey responses collected at one university. Since the social climate and school-based interventions can influence students' beliefs, similar studies would benefit from using data from multiple institutions, especially ones with different levels of diversity and support for marginalized identities, to accurately represent the beliefs of calculus FGS.

The study's findings are shaped by the specific design and scope of the IMBS survey. This may show some limitations; for example, the *Word Problems* scale was not validated in this study. A related limitation is the use of the term word problems, which could have many interpretations depending on the mathematical experience of the respondent. Moving forward, there are avenues for continuing this research using both quantitative and qualitative data. A possible research topic is comparing FGS and CGS ESL students. Research could also be done using a mixed-methods approach to compare students' survey answers to their perceptions of their beliefs based on interviews. A qualitative study using interviews could also be used to determine what drives these beliefs and how they manifest.

Final Remarks

This study highlights that while most beliefs about mathematical problem-solving did not differ significantly among FGS students' subgroups — ESL vs. non-ESL—, notable differences emerged in the belief that mathematics is useful. Specifically, first-generation ESL FGS reported lower levels of agreement compared to their non-ESL FGS peers. These findings underscore the importance of recognizing how intersecting identities within the first-generation student population shape perceptions of mathematics. By documenting measurable gaps in beliefs, this study contributes to the growing literature on first-generation students and offers evidence to guide curricular and pedagogical decisions in calculus. In particular, these results point to the value of intentionally designing learning experiences, such as the use of meaningful, real-world word problems that affirm the relevance of mathematics for diverse student populations. Ultimately, strengthening such connections may play a critical role in supporting persistence in calculus and, by extension, in STEM pathways for first-generation students.

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Bio

KEVIN PALENCIA, PhD, is an Assistant Professor and Calculus Coordinator at the Department of Mathematical Sciences at Northern Illinois University. His research interests include the teaching and learning of calculus, community-based pedagogies, and equity in STEM education. Email: palencia@niu.edu

BREILLE DUNCAN, MA, works for an insurance agency in Allentown, PA. Their research interests are in undergraduate mathematics education with a focus on community college education, foundational math classes, and first-generation students. Email: breille.duncan@umconnect.umt.edu

RICELA FELICIANO-SEMIDEI, PhD, is an associate professor of the Department of Mathematical Sciences, Northern Illinois University. Her research focuses on the use of students' experiences as assets for teaching mathematics. Email: ricela@niu.edu

ALCIBIADES BUSTILLO-ZARATE, PhD, is an Associate Professor in the Department of Mathematical Sciences at the University of Puerto Rico at Mayagüez. His research focuses on digital watermarking, cryptography, and mathematics education. Email: alcibiades.bustillo@upr.edu

KE WU, PhD, is a Professor in the Department of Mathematical Sciences and Dean of Graduate School at the University of Montana. Her research interests include mathematics education, STEM integration, and mentoring and mentorship. Email: ke.wu@mso.umt.edu