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# Analyzing multilingual students' experiences in introductory college mathematics courses

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*The goal of this paper is to better understand the experiences of multilingual students in undergraduate math courses, particularly when active learning is used. Despite significant advances at the K-12 level, little research at the post-secondary level has examined language in mathematics education. To address this, this paper analyzes survey data from undergraduate students in introductory math courses. Using a quantitative critical lens, the analysis focuses on identifying salient features of students' identities that impacted their course experiences, particularly their comfort speaking in class, comfort being oneself in class, and recognition by others as being good at mathematics. In addition, the analysis examines the effect of different frequencies of active learning on these outcomes.*

*Keywords: curricular and institutional issues concerning the teaching of mathematics at university level, students' practices at university level, multilingual mathematics classrooms, active learning*

## INTRODUCTION

At the post-secondary level, math classrooms are becoming more reflective of the multicultural landscape that we live in. Because of political and economic global shifts, college mathematics classrooms serve increasingly more students whose home language differs from the language of instruction (Durand et al., 2016). It is becoming more common for college math classrooms to be rich, multilingual spaces where students use different cultural, linguistic, and experiential knowledge to make sense of mathematics.

At the same time, language is often over-looked in mathematics education because of the common viewpoint that math is a universal language. However, research at the K-12 level has shown that students' linguistic and cultural backgrounds significantly shape how students learn math (Planas & Civil, 2013). Furthermore, language is not neutral, as some languages – like English – are assigned higher social status over others – like Spanish. The literature on K-12 math education has documented examples of how multilingual students (whose home language differed from the language of instruction) experienced less access to classroom participation (Planas & Civil, 2013) and were less likely to be positioned as mathematically competent (Takeuchi, 2016). Despite significant advances at the K-12 level, little research at the post-secondary

level has focused on better understanding multilingual students' classroom learning experiences and best practices for supporting equity in language diverse classrooms.

### **Active learning**

Active learning is becoming more commonly implemented in post-secondary mathematics classrooms and the literature has generally considered active learning to be an equitable teaching approach. Some scholars, however, have demonstrated that not all students experience active learning in the same way (Henning et al. 2019; Voigt et al., 2022). For example, Henning et al. (2019) examined the different facets of students' identities (like race, gender, socioeconomic status, etc.) that were most significant in shaping their classroom participation, STEM self-efficacy, and sense of belonging in active learning introductory college biology courses. For instances, findings indicated that black students reported "higher pressure to conform to the views of their peers" during active learning (p. 7). In introductory college math courses, Voigt et al. (2022) found that women and Indigenous students experienced a larger decrease in their mathematics identity over the course of the semester compared to white male students.

Multilingual students may also have differential experiences with active learning. Active learning is a talk-intensive pedagogy and participating in active learning generally requires students to communicate verbally, engage in interpersonal interactions, and make sense of mathematics collectively. Given that these practices are all mediated by language, language becomes a more visible tool for learning and participating in active learning settings. More research is needed to better understand multilingual students' experiences in undergraduate mathematics courses, particularly those which utilize active learning pedagogies.

### **Research Question**

Using critical quantitative methods, this paper seeks to answer the following research question: *How does active learning and different aspects of multilingual students' identities influence their perceived experiences in undergraduate math courses?*

## **THEORETICAL FRAMEWORK**

### **Sociopolitical Theory**

This paper draws from sociopolitical theory (Gutiérrez, 2013), by foregrounding issues of identity and power in the classroom. Particularly in active learning spaces, students' identities become more visible as they negotiate social interactions (Henning et al., 2019). Furthermore, students' identities can impact classroom power and participation structures (Takeuchi, 2016). For example, given the high status that English is often afforded in the college classroom, students' language identities can shape how others perceive their mathematical abilities (Rios, 2022).

In this study, sociopolitical perspectives were used to identify significant aspects of student experiences. Instead of analyzing students' classroom experiences from a normative lens (i.e., examining access or achievement), this study focuses on

understanding them using a critical lens that centralizes issues of power and identity in the classroom (Gutiérrez, 2013). For instance, focusing on students' comfort speaking and comfort being themselves in the classroom can inform whether multilingual students' identities were affirmed by classroom practices (Henning et al, 2019). Similarly, examining whether students were positioned as being *good at mathematics* by their peers can inform how power and participation were distributed in classroom discourses (Takeuchi, 2016).

## **QuantCrit Theory**

QuantCrit is an emerging field in education research which applies the core tenets of critical race theory (CRT) to traditional quantitative methods (Garcia, López, & Vélez, 2018). QuantCrit studies often use statistical modeling to explore the impact of discrimination (e.g., racism or sexism) on outcomes (e.g., shifts in math identity), by including social markers like race and gender as explanatory variables (e.g., Voigt et al., 2022). Garcia, López, & Vélez (2018) discuss the five main tenets of QuantCrit theory: (1) the centrality of racism in society and that racism is difficult to capture using quantitative methods, (2) numbers are not neutral and can be used to perpetuate deficit narratives, (3) human categories are often socially constructed and require a critical interpretation, (4) data cannot speak for itself and must be informed by experiential knowledge, and (5) results from statistical analyses are not valuable unless they are used to promote social justice.

A situated interpretation of data is fundamental to QuantCrit analysis (Garcia, López, & Vélez, 2018). For instance, variables that capture social markers like race or gender must be viewed as measuring the impact of racism (not race) or sexism (not sex) on outcomes. Similarly, variables encompassing language identities should be viewed as capturing the impact of language bias on students' experiences. Furthermore, Van Dusen and Nissen (2019) argue that by using p-values as sole indicators of significance, statistical models can ignore potentially meaningful effects that pertain to underrepresented groups. Instead, they advocate for the use of other metrics like including standard errors and confidence intervals to indicate significance. Finally, quantitative findings should be supplemented with rich qualitative data that capture students' voices and lived experiences (Garcia, López, & Vélez, 2018).

## **METHODS**

### **Data Source**

The data presented in this paper is part of a larger, mixed-methods study which explores the experiences of multilingual students in undergraduate pre-calculus and calculus courses. This study took place at a large, public, research university in the United States that has been designated as a Hispanic-Serving Institution. The qualitative portion of this study consisted of semi-structured interviews with twenty-eight multilingual undergraduate students. The data for this paper stemmed from the quantitative portion of this study. In this phase of the study, students from 45 sections of pre-calculus, calculus I, calculus II, and calculus III were surveyed about their experiences in their

math courses ( $n = 579$ ). The survey included several existing instruments from the literature which measured critical aspects of students' course experiences, like *comfort speaking in class* (Henning et al., 2019), *comfort being oneself in class* (Eddy et al., 2015), *mathematics identity* (Cass et al., 2011), and *recognition*, which is defined as "perceived recognition by others as being a good mathematics student" (Cass et al., 2011, p. 2). The survey also included student demographic questions about their race/ethnicity, gender identity, and language identity.

The also survey gauged the frequency that active learning was used in students' math courses. Although active learning can encompass many different approaches, at the university where this study was conducted, the most common approach for implementing active learning was using group work. Therefore, this study, operationalizes active learning to mean classroom learning that takes place through peer collaborations. To measure the frequency of this, the survey included the *student interaction and collaboration scale* (Walker & Fraser, 2005).

### Data Analysis

General linear and logistic regression models were used for the preliminary analysis of survey data. All analyses were done using the R statistical software package. Any incomplete surveys were omitted, leaving  $n = 464$  surveys that were analyzed.

To operationalize facets of students' course experiences from a Sociopolitical lens, which considers power and identity, numerous variables were included in the survey. These variables assessed students' comfort in class, sense of belonging, and mathematics identity. Findings from the study's qualitative analysis of student interviews were then used to inform the selection of a subset of explanatory and response variables to be included in the regression models. The explanatory variables that were selected included: *comfort speaking in class*, *mathematics identity*, *course level* and *frequency of active learning*. Social markers were also included such as race, gender, international student status, first generation status. Language identity markers included students' home language and the language students' felt most comfortable doing math in. Confirmatory factor analysis was used to assess the fit of instruments from the survey by examining how well items loaded.

#### *General linear regression models*

Two general linear regression models were fit to the data. The first model had *comfort being oneself in class* as the response variable and the second model had *recognition as a good mathematics student* as the response variable. The same explanatory variables described in the previous section were included in both models. Following the recommendation of QuantCrit scholars (Van Dusen & Nissen, 2019), AICc was used to perform model selection. The best-fit model for each response variable is shown in equation (1) and (2) respectively.

|  |
|--|
| $\begin{aligned} \text{comfort being} &= \text{intercept} + \text{course level} + \text{math identity} & (1) \\ \text{oneself} &+ \text{active learning} \times \text{comfort speaking} \end{aligned}$ |
|--|

|   |   |  |     |
|---|---|--|-----|
| <i>recognition<br/>as a good<br/>math student</i> | = | intercept + <i>course level</i> + <i>math identity</i> +<br><i>race</i> + <i>comfort speaking</i><br>+ <i>active learning</i> × <i>home language</i> | (2) |
|---|---|--|-----|

### *Logistic regression model*

The explanatory variable *comfort speaking during class* was retained in both linear regression models and was a main theme in the qualitative analysis. Therefore, a separate analysis of this variable seemed warranted. A logistic regression model was fit to the data, using *comfort speaking during class* as the response variable with the same explanatory variables used in the previous models. AICc was also used for model selection and the best-fit model is shown in equation (3).

|  |   |  |     |
|--|---|--|-----|
| <i>comfort<br/>speaking<br/>in class</i> | = | intercept + <i>course level</i> + <i>math identity</i> +<br><i>active learning</i> + <i>gender</i> + <i>language<br/>preference for doing math</i> | (3) |
|--|---|--|-----|

## **RESULTS**

This section will first discuss the results of the logistic regression model fitted to predict comfort speaking in class and then provide results from the linear regression models for predicting *comfort being oneself in class* and *recognition as a good math student*. These variables represent critical aspects of students' classroom experiences.

### **Logistic regression model: comfort speaking in class**

The factor variable for *comfort speaking in class* had four levels: very uncomfortable, uncomfortable, comfortable, and very comfortable. Table 1 provides the model's logistic regression estimates, expressed in odds ratios. The model suggests that students who preferred doing mathematics in a language other than English were on average, almost half as likely (OR = 0.44) to report feeling comfortable speaking during class (95%CI [0.20, 0.95]), while holding all other predictors constant. This suggests that classroom learning environments may have privileged students who previously learned mathematics in English, allowing them to feel more comfortable communicating.

Women were also less likely to report feeling comfortable speaking in class compared to men (OR = 0.59, 95%CI [0.40, 0.88]). Drawing from QuantCrit theory, this result demonstrates the impact of sexism in undergraduate mathematics classrooms, and its impact on women students' comfort speaking during class.

Active learning was associated with a higher probability of students' reporting to be comfortable speaking in class (OR = 1.46, 95%CI [1.18, 1.81]). The OR estimate indicates that when the frequency of active learning was increased by one unit, students were on average approximately one and half times more likely to report feeling comfortable speaking in class, while holding all other predictors constant.

| <b>Estimates:</b>                                      | Confidence intervals |      |       |      |         |
|--|----------------------|------|-------|------|---------|
|  | Odds ratio estimate  | 2.5% | 97.5% | SE   | p-value |
| <b>Course features</b>                                 |                      |      |       |      |         |
| Calculus I   | 0.86                 | 0.53 | 1.38  | 0.24 | 0.53    |
| Calculus II-III  | 0.52                 | 0.31 | 0.87  | 0.26 | <0.01   |
| Frequency of active Learning                           | 1.46                 | 1.18 | 1.81  | 0.11 | <0.001  |
| <b>Social markers</b>                                  |                      |      |       |      |         |
| Cis woman  | 0.59                 | 0.40 | 0.88  | 0.20 | <0.01   |
| Gender non-Conforming                                  | 0.88                 | 0.22 | 3.80  | 0.72 | 0.86    |
| <b>Math identity markers</b>                           |                      |      |       |      |         |
| Preferring to do math in a language other than English | 0.44                 | 0.20 | 0.95  | 0.39 | <0.05   |
| Math identity  | 4.06                 | 2.81 | 5.93  | 0.19 | <0.001  |

**Table 1: Logistic regression estimates for comfort speaking in class, in odds ratios with confidence intervals**

In addition, the model suggests that students in Calculus II, and III were less likely to report feeling comfortable speaking during class, compared to students in pre-calculus (OR = 0.52, 95% CI [0.31, 0.87]). Mathematical identity was also strongly associated with a higher probability of reported comfort speaking in class (OR = 4.06, 95% CI [2.81, 5.93]) For instance, when students' math identities increased by one unit, they were four times more likely to feel comfortable speaking.

### **Linear regression models: measuring other aspects of students' experiences**

#### *Comfort being oneself in class*

The continuous response variable *comfort being oneself in class* ranged from [0, 4], where scores greater than two reflect positive comfort being oneself in class. The intercept estimate ( $\beta = 2.72$ , 95% CI [1.92, 2.67]) suggests that on average monolingual students who were very comfortable speaking in class and were not exposed to active learning reported having slightly positive comfort being oneself in class.

Being comfortable speaking was a salient predictor of comfort being oneself in class. For example, students who reported being very uncomfortable speaking, on average

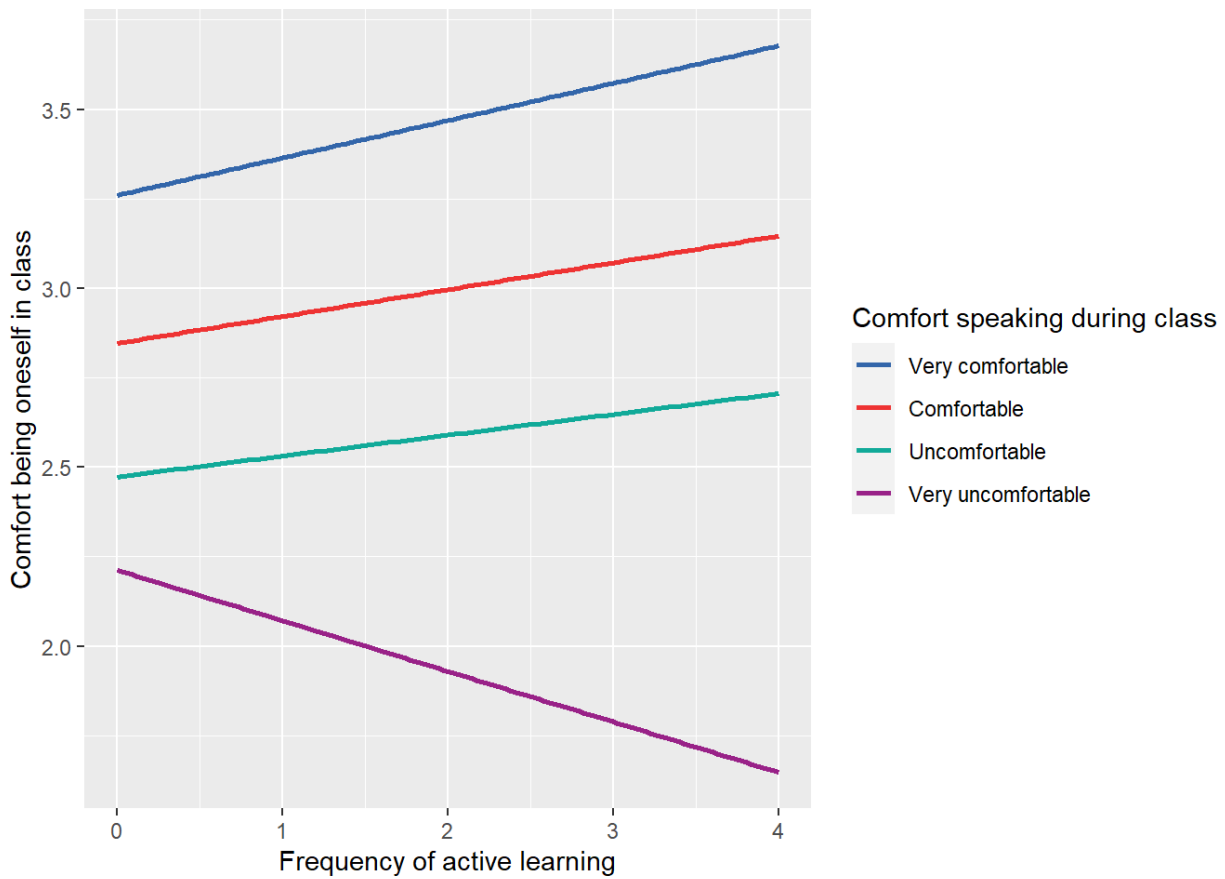
scored 1.05 units lower on the comfort being oneself scale than students who reported being very comfortable ( $\beta = -1.05$ , 95% CI [-1.37, -0.73]).

Figure 1 shows the interaction effects for active learning and comfort speaking in class. For students who reported being very comfortable, comfortable, and uncomfortable speaking, the slope estimates are positive. Therefore, students in these groups experienced an average increase in their *comfort being oneself* score when the frequency of active learning increased. On the other hand, students who reported being very uncomfortable speaking in class experienced a further decrease in their *comfort being oneself* score when active learning was used ( $\beta = 0.10 - 0.25 = -0.15$ , 95% CI [-0.34, 0.05]).

| <b>Estimates:</b>                    | Confidence intervals |       |       |      |         |
|--------------------------------------|----------------------|-------|-------|------|---------|
|                                      | Coefficients         | 2.5%  | 97.5% | SE   | p-value |
| (intercept)                          | 2.72                 | 2.47  | 2.99  | 0.13 | <0.001  |
| <b>Course features</b>               |                      |       |       |      |         |
| Calculus I                           | -0.10                | -0.2  | 0.006 | 0.06 | <0.1    |
| Calculus II-III                      | -0.23                | -0.35 | -0.11 | 0.06 | <0.001  |
| Frequency of active Learning         | 0.10                 | 0.003 | 0.21  | 0.05 | <0.05   |
| <b>Comfort speaking</b>              |                      |       |       |      |         |
| Comfortable                          | -0.41                | -0.64 | -0.19 | 0.11 | <0.05   |
| Uncomfortable                        | -0.79                | -1.04 | -0.54 | 0.13 | <0.001  |
| Very uncomfortable                   | -1.05                | -1.37 | -0.73 | 0.16 | <0.01   |
| <b>Math identity markers</b>         |                      |       |       |      |         |
| Math identity                        | 0.33                 | 0.24  | 0.41  | 0.04 | <0.001  |
| <b>Interactions</b>                  |                      |       |       |      |         |
| Active learning × comfortable        | -0.03                | -0.14 | 0.09  | 0.06 | 0.62    |
| Active learning × uncomfortable      | -0.05                | -0.18 | 0.91  | 0.07 | 0.51    |
| Active learning × very uncomfortable | -0.25                | -0.47 | -0.02 | 0.11 | <0.05   |

**Table 2: Regression estimates for comfort being oneself in class with confidence intervals**





**Figure 1: Interaction effects of active learning and comfort speaking during class on predicting comfort being oneself**

### *Recognition as a good math student*

The continuous response variable *recognition as a good math student* ranged from [0, 4], where scores greater than 2 reflect positive recognition by others. Students who reported having a home language other than English were less likely to report feeling like their peers recognized them as being good at math ( $\beta = -0.23$ , 95%CI [-0.42, -0.04]). As expect, *math identity* was also strongly correlated with higher *recognition* scores ( $\beta = 1.02$ , 95%CI [0.90, 1.13]). Students that identified as being middle eastern or Asian also on average reported being less likely to be recognized by others as a good math student, holding all other variables, like math identity, constant. This was most significant for Middle Eastern students ( $\beta = -0.50$ , 95%CI [-0.81, -0.18]).

| Estimates:<br>(significant only) | Confidence intervals |       |       |      |         |
|----------------------------------|----------------------|-------|-------|------|---------|
|                                  | Coefficients         | 2.5%  | 97.5% | SE   | p-value |
| (intercept)                      | 0.03                 | -0.19 | 0.25  | 0.11 | 0.80    |

|                                  |       |       |       |      |         |
|----------------------------------|-------|-------|-------|------|---------|
| <b>Course features</b>           |       |       |       |      |         |
| Calculus I                       | 0.17  | 0.004 | 0.33  | 0.08 | <0.05   |
| Calculus II-III                  | 0.36  | 0.17  | 0.50  | 0.08 | <0.001  |
| <b>Math identity markers</b>     |       |       |       |      |         |
| Math identity                    | 1.02  | 0.90  | 1.13  | 0.06 | <0.0001 |
| <b>Language identity</b>         |       |       |       |      |         |
| Home language other than English | -0.23 | -0.42 | -0.04 | 0.09 | <0.01   |
| <b>Social markers</b>            |       |       |       |      |         |
| Asian                            | -0.20 | -0.40 | 0.01  | 0.10 | <0.1    |
| Middle Eastern                   | -0.50 | -0.81 | -0.15 | 0.16 | <0.05   |

**Table 3: Regression estimates for recognition as a good math student with confidence intervals (only significant estimates are included)**

## DISCUSSION

Using a QuantCrit approach, this study examines the experiences of students in undergraduate math courses, focusing on their comfort speaking in class, comfort being themselves in class, and recognition by peers as being *good* mathematics students. The study sought to identify aspects of students' identities that shaped their experiences in the classroom, particularly students' language identities. Findings indicate that students who preferred to do math in a language other than English were less likely to feel comfortable speaking in class. Additionally, students whose home languages were not English felt less likely to be identified by peers as being *good at mathematics*. These findings suggest that classroom language biases can impact students' comfort in the classroom and access to being positioned as mathematically competent.

Active learning also influenced students' experiences. On average, higher frequencies of active learning were associated with students reporting that they feel more comfortable communicating in the classroom. However, the model indicates that students who reported being very uncomfortable speaking in the classroom, felt even less comfortable when active learning was used. This suggests that speaking is a significant part of navigating the active learning classroom and that students experienced active learning differently based on their comfort speaking during class. Further analysis is needed to investigate multilingual undergraduate mathematics classrooms and best practices for implementing active learning in these spaces to affirm and support all students.

## REFERENCES

Cass, C. A., Hazari, Z., Cribbs, J., Sadler, P. M., & Sonnert, G. (2011). Examining the impact of mathematics identity on the choice of engineering careers for male and

- female students. *2011 Frontiers in Education Conference*, (pp. F2H-1-F2H-5). <https://doi.org/10.1109/FIE.2011.6142881>
- Eddy, S. L., Brownell, S. E., Thummaphan, P., Lan, M. C., & Wenderoth, M. P. (2015). Caution, student experience may vary: social identities impact a student's experience in peer discussions. *CBE—Life Sciences Education*, *14*(4), ar45-ar45. <https://doi.org/10.1187/cbe.15-05-0108>
- Garcia, N. M., López, N., & Vélez, V. N. (2018). QuantCrit: Rectifying quantitative methods through critical race theory. *Race Ethnicity and Education*, *21*(2), 149-157. <https://doi.org/10.1080/13613324.2017.1377675>
- Gutiérrez, R. (2013). The sociopolitical turn in mathematics education. *Journal for Research in Mathematics Education*, *44*(1), 37-68. <https://doi.org/10.5951/jresemathe>
- Henning, J. A., Ballen, C. J., Molina, S., & Cotner, S. (2019). Hidden identities shape student perceptions of active learning environments. *Frontiers in Education*, *4*. <https://doi.org/10.3389/feduc.2019.00129>
- Planas, N., & Civil, M. (2013). Language-as-resource and language-as-political: Tensions in the bilingual mathematics classroom. *Mathematics Education Research Journal*, *25*(3), 361-378. <https://doi.org/10.1007/s13394-013-0075-6>
- Rios, J. N. (2022). Active Learning in the Language Diverse Undergraduate Math Classroom. In S. Smith Karunakaran, A. Higgins (Eds), *Proceedings of the 24<sup>th</sup> Annual Conference on Research in Undergraduate Mathematics Education* (pp. 454-462), Boston, MA. <http://sigmaa.maa.org/rume/RUME24.pdf>
- Takeuchi, M. A. (2016). Friendships and group work in linguistically diverse mathematics classrooms: Opportunities to learn for English language learners. *The Journal of the Learning Sciences*, *25*(3), 411-437. <https://doi.org/10.1080/10508406.2016.1169422>
- Van Dusen, B., & Nissen, J. (2019). Associations Between Learning Assistants, passing introductory physics, and equity: a QuantCrit Investigation. *Physical Review*, *16*(1), 010117. <https://doi.org/10.1103/PhysRevPhysEducRes.16.010117>
- Voigt, M., Hagman, J. E., Street, C., Guglielmo, J., Martinez, A., & Tremaine, R. A. (2022). Quantitative Critical Analysis of Instructional Practices and Math Identity. In S. Smith Karunakaran, A. Higgins (Eds), *Proceedings of the 24<sup>th</sup> Annual Conference on Research in Undergraduate Mathematics Education* (pp. 666-674), Boston, MA. <http://sigmaa.maa.org/rume/RUME24.pdf>
- Walker, S. L., & Fraser, B. J. (2005). Development and validation of an instrument for assessing distance education learning environments in higher education: The Distance Education Learning Environments Survey (DELES). *Learning Environments Research*, *8*(3), 289- 308. <https://doi.org/10.1007/s10984-005-1568>