Exploring Affective Dimensions of Women's Experiences in the Secondary-Tertiary Transition in Mathematics

Seyda Uysal
Florida State University

Kathleen M. Clark
Florida State University

This report describes a pilot study conducted in Spring 2019. We set out to accomplish two tasks. First, through semi-structured interviews, we sought to understand characteristics of women and underrepresented minority (WURM) undergraduate mathematics majors' experiences pertaining to the secondary-tertiary transition (STT) in mathematics. Second, we designed and implemented a supportive intervention to address aspects of the STT that emerged from the outcome of the interviews. We draw upon Di Martino and Zan's (2010) three-dimensional model of attitude, which reifies the role of affect in the STT, and focuses on students' vision of mathematics, perceived competence in mathematics, and emotional disposition towards mathematics. In this report, we present data from three WURMs' perspectives to document three related dimensions in the STT and discuss whether and how our intervention supported these students' transition.

Keywords: affective dimensions, secondary-tertiary transition, women in mathematics

The secondary-tertiary transition (STT) in mathematics learning has attracted many researchers' attention from a variety of contexts (e.g., Clark & Lovric, 2008; De Guzman et al., 1998; Gueudet, 2008; Tall, 2008; Thomas et al., 2015). The STT has been commonly attributed to the knowledge gap in mathematics that students experience when introduced to advanced mathematics. These difficulties, cited as the "transition problem", have been predominantly connected to cognitive difficulties relevant to conceptual-epistemological change (Witzke et al., 2016) and/or under-preparedness in school mathematics (Wade et al., 2016). De Guzman et al. (1998) identified potential difficulties that impact students' success during the STT in mathematics education from the perspectives of (a) cognitive and epistemological, (b) social and cultural, and (c) didactical, all of which helped to scrutinize numerous challenges that undergraduate mathematics majors face. Further, Di Martino and Gregorio (2019) investigated the STT from affective dimensions, which added a new perspective to explore the phenomenon. Considering affective aspects of learning, the intersectionality in one's identity increases the complexity of the STT phenomenon. Investigating affective factors can shed light on how gender, race, ethnicity, and educational backgrounds can play a role during the STT. Recognizing mathematics as a historically masculine-dominated academic community (Solomon, 2012), the current report aims to explore the salient elements of women and underrepresented students' (WURMs) lived experiences by addressing the affective aspects.

Literature Review

After more than two decades, the STT in mathematics has been problematized as discontinuities in institutional levels between secondary school and university mathematics related to changes in the nature of mathematics (Gueudet et al., 2016), advanced and formal mathematical thinking (Tall, 2008), mathematical discourse (Sfard, 2007), and learning and teaching practices between the two institutions (Bosch, 2014). Alcock and Simpson (2002) expressed the complexity of difficulties in the STT as an amalgam of multiple transitions. Kajander and Lovric (2005) referred to the STT as a complex phenomenon involving multiple issues that need to be addressed. Gueudet (2008) articulated the STT almost as a rupture.

Recently, Di Martino and Gregorio (2019) reflected on it as a crisis that students undergo from a perspective of affective domains by taking beliefs, attitudes, and emotions toward mathematics into account. Various underlying factors during the STT may lead students to feel alienated (Hernandez-Martinez, 2016; Solomon & Croft, 2016) and even drop out (Andrà et al., 2011; Di Martino & Gregorio, 2019; Rach & Heinze, 2017). Rarely, the challenges in the STT compelled students to develop diverse strategies for sense of belonging and attainment to be able to persist in the major (Holmegaard et al., 2014; Solomon, 2012).

Institutional inequity, gender gap, and stereotype threat constitutes barriers for WURMs to persist in STEM majors (Master & Meltzoff, 2016). Recognizing the multi-layered nature of identity, several studies recommended looking at experiences of WURMs in mathematics with an emphasis on the intersectionality (Eddy & Brownell, 2016; Starr, 2018). In this paper, we discuss various experiences of WURMs who have been traditionally positioned as underrepresented participants of mathematics communities in institutions of higher education in the US. Yet, the body of literature which examines how gender and intersectionality play a role during the STT is limited. To address this issue, our research question was: In what ways do WURM students articulate their vision of mathematics related to their perceived competence and emotional response to the STT in mathematics?

Theoretical Perspectives

Many scholars have recognized the importance of affective factors that play a part in learning mathematics (e.g., DeBellis & Goldin, 2006; Di Martino & Zan, 2010; McLeod, 1992). Previous studies in mathematics education attempted to include affective factors in examination of cognitive processes (e.g., Mandler, 1989), yet a few of them focused on the interplay between these affective and cognitive aspects. Even though several scholars have taken the affective domains into consideration, the majority of research is primarily concerned with the role of beliefs during problem-solving activities (e.g., Schoenfeld, 1985) rather than investigating the interaction among beliefs, attitudes, and emotions. Di Martino and Zan (2011) conceptualized attitudes as a bridge between emotions and beliefs in a three-dimensional model of attitude (TMA). The TMA views attitudes as an outcome of interconnections among and between the subjective components of vision of mathematics (i.e., beliefs on the nature of mathematics), perceived competence (i.e., beliefs about self), and emotional disposition toward mathematics (Di Martino & Zan, 2010). Di Martino and Zan (2010) described the vision of mathematics based on whether students refer to the role of reasoning (i.e., relational understanding) or sets of rules for memorization (i.e., instrumental understanding) in reflecting on their mathematics engagement (Skemp, 1978). Next, the perceived competence in mathematics is related to students' beliefs about their success, which depends on different factors such as grades, teachers' appreciation, and/or understanding. Finally, the emotional disposition toward mathematics captures positive or negative feelings when students reflect on their relationship to mathematics (Di Martino & Gregorio, 2019). Students describe their experiences with mathematics by using expressions such as like, dislike, apprehension, or joy when they tell their story (Di Martino & Zan, 2010). Investigating the underlying reasons for these emotional expressions is a useful method in understanding students' attitudes. Di Martino and Zan (2010) claimed that students often refer to one or more of these dimensions when elaborating on their story of mathematics. Students tend to connect their cognitive difficulties to affective factors such as interest, enjoyment, and perceived competence (Di Martino & Gregorio, 2019; Furinghetti et al., 2013; Liston & O'Donoghue, 2010). Beliefs about mathematical competence and feelings about

mathematics become even more critical when looking at the experiences of women (Sax et al., 2015; Solomon et al., 2011) in gendered mathematical environments.

Method

Settings and Participants

We conducted a small pilot study in 2019 Spring with 12 participants who were either pure mathematics (PM) majors or double majors in PM and secondary mathematics teaching (SMT). In this report, we present findings from three female students (Table 1), whose experiences highlight the key aspects of our findings. Our aim was to gain insight into the salient features of the STT for students enrolled in a southeastern university in the US, particularly from WURMs' standpoint. First, we interviewed students to capture their STT experiences along three dimensions of interest (emotional disposition towards mathematics, vision of mathematics, and perceived competence in mathematics). Next, an analysis of the interviews aided our design of a supportive intervention, which confronted aspects of the STT via an examination of the (historical) changes in the nature of mathematics (in this case, related to the concept of derivative). Data collected during the four-session seminar (each session was three hours in duration) include survey responses, video recordings of seminar sessions, and student reflection diaries. In this study, we focused on a small portion of data from the interview and seminar (reflection diaries from days 1 and 4) to report our initial observations related to the three aforementioned dimensions of the STT. In our analysis, we adopted a grounded theory approach by following open, axial, and selective coding to group students' responses according to three dimensions of our theoretical framework (Charmaz, 2006). We reduced the raw data into smaller units to take analytical descriptive notes for "explicating implicit actions and meaning" (Charmaz, 2006, p. 50). Next, we recorded useful quotes from the participants to illustrate their affect-related experiences. In the next section, we highlight our initial findings on how WURM students articulated their STT experiences with university mathematics, as well as how our intervention contributed to their perception of the STT.

Table 1. Selected participants and data sources (WURM pilot study, 2019).

Students	Major/Year	Data Sources
Karine	PM/Sophomore	Interview, Reflections, Survey
Malya	PM & SMT/Junior	Interview, Reflections, Survey
Evelyn	PM & SMT/Senior	Interview, Reflections, Survey

Preliminary Findings

In this report, we present episodes from Karine, Malya, and Evelyn to address the three dimensions from the perspectives of WURMs. We note that Karine identified herself as Latina, Malya as Black, and Evelyn as White. We first discuss the vision of mathematics to capture how changes in the nature of mathematics impacted students' emotions. Second, we provide excerpts pertaining to students' perceived competence and highlight their accompanying emotional responses. Finally, we discuss the seminar intervention and highlight students' emotional disposition toward advanced mathematics courses and whether and how the seminar contributed to their transition experiences.

Vision of Mathematics

In the interview, we asked students to discuss their STT experiences. We observed that students expressed certain challenges by emphasizing changes in the nature of mathematics by contrasting school and university mathematics. Initially, the students were not aware of the STT. After discussing the phenomenon with them, students were able to recognize its impact on their experiences. In the following excerpts, Evelyn and Malya similarly articulated that the transition had begun when they were introduced to more advanced courses (e.g., after Calculus 3), while they perceived lower division courses as an extension of secondary school mathematics.

> The real transition didn't really happen for me until I started to take the major level of math classes. Because I feel for the most part like, the [Calculus sequence was] pretty much formula-based and the things were still tangible. … we're still using numbers, whereas now I feel it's a completely different strain of math; it is all theoretical; it is all proof-based and it is just something very different. (Evelyn, Interview 2019)

Malya also stated that the STT was rough for her, especially after Calculus 3, despite her good preparation in high school. Also, she explicitly reflected her emotional dispositions in coping with difficulties during the STT. Later, she found some resources for support. Also, it is worth noting that Malya attributed her struggle in the STT to her inner mathematics abilities, which also captures her lower perceived competence in mathematics.

> I think it [the transition] was rough, but I also think that it wasn't as rough as it could have potentially been. … entering Calc 3 right after [the] first semester here…was bad. Like, I know that was bad, but I also think that I had resources here on campus. At least the resources that I was able to gain access to and find easily here that made me feel like I wasn't doing as terribly as I could have… I feel like a lot of the transition that was bad for me was kind of like a mind thing. It wasn't that I couldn't do it. It was just that I was thinking I couldn't do it and thinking that made me feel more reluctant to do my homework and more reluctant to ask for help and basically just talk about the things that were going on and knowing that I was struggling, but it didn't feel comfortable enough to bring up the struggle to anyone. (Malya, Interview 2019)

We also captured emotionally charged utterances from Evelyn's interview, which were similar to how Malya articulated her experience. Surprisingly, we detected that the professor privileged a passing grade rather than understanding of content. The following excerpt illustrated Evelyn's inner unsettled feeling, which also reflected that she valued understanding in mathematics for success as opposed to solely receiving a passing grade.

> I find that like, every semester, I panic because I think I am failing the class. I get stressed out because I am not doing well on these tests. I am getting like 60s. But then, the professors are always like: Yeah, that's average. Don't worry about it. We are going to just curve the grade. So then, I end with these B-plusses, a couple of Cs, and [in] so many harder [classes]. And, I feel like, I struggle in the next class because I didn't do well on the first class and then everything builds, and it's just like a snowball effect. I feel like the transition won't end until I graduate because I am still struggling to really handle this new strain of mathematics that I am dealing with. (Evelyn, Interview 2019)

Karine's reflections on the STT in mathematics seemed less emotionally laden compared to Evelyn's and Malya's. One can expect students to reflect on their emotions more often when confronted with the changes in the nature of mathematics, which began after the Calculus 3 sequence for Evelyn and Malya. As a sophomore, Karine might not have spent as much time in the major to make sense of how courses will look as she advances in course taking. In the following excerpt, Karine highlighted some changes in her vision of mathematics related to university mathematics courses.

> I guess this stuff at the beginning of the course isn't that big of a jump. It's like functions. It's set theory, which we've been using set notation for a long time. The concept of functions and mapping and stuff that comes up in Linear Algebra. It's more theoretical, but it's not like this huge jump. It's just kind of phrasing it in a different way and looking at it from a different angle, [like] the metric spaces… At the beginning of the semester, the proofs class was like, 'Oh my gosh' But then… I've gotten the groove of things. I was like, okay, I'm going to start having a schedule for when I'm going to work on this homework. … That's when I started talking with this math friend. … We spend like three hours going through this stuff for this class. And then, once we leave that initial kind of like, 'oh gosh, what are we doing?' sort of thing then, I was like, okay, this isn't really too bad. (Karine, Interview 2019)

Karine's experiences in dealing with the abstract nature of mathematics showed a necessary change in vision of mathematics, as well as learning and studying strategies. It seems that Karine was fully cognizant that she needed to put forth more effort to overcome difficulties that arose in the STT related to the nature of mathematics. Additionally, it is worth noting that she sought to engage in mathematics conversations with one of her peers which might be an indication of her need for academic and social support. Overall, considering these three students' reflections, it is reasonable to argue that mathematics majors need social and academic support. They might need to share experiences and notice common challenges about mathematics in their program of study. These ideas led us to organize a seminar in 2019 to create a small academic space for these women to talk about their mathematical experiences and dispositions.

Perceived Competence in Mathematics

We noticed that students expressed conflicting beliefs about their perceived competence, which seems to be linked to increasing abstractness in the nature of mathematics. Specifically, Evelyn and Malya reflected on changes in the nature of mathematics after Calculus 3 and how their perceived competence was influenced by this change in upper division mathematics courses. Karine also mentioned how this change in the nature of mathematics "[shook] her confidence" and led her to seek additional help to cope with the STT. Accordingly, we detected that students reflected on their emotions at varying levels. Depending on variances in lived experiences of these three women, their emotional reaction levels were also notably different.

> In Calc 3, ODE and Linear Algebra, yes, I did feel like that [confident]. Because there were clear steps that could help me. And, we were still using numbers. But then in the major-related classes, I do not feel competent or confident with my work. I find that I am … just writing down stuff that we went over in class. And hoping that somehow it makes sense and is a good enough proof to prove something. (Evelyn, Interview 2019)

Malya expressed similar sentiments regarding her perceived competence while taking Calculus courses. Interestingly, we noticed that Malya pointed out her lower confidence before Calculus 3, which seems different from Evelyn's experience. Considering opportunities and the intersectionality, Malya's high school preparation might not have sufficiently prepared her for lower division mathematics courses (Wade et al., 2017).

> I don't know if it's [my confidence that has] changed because… even though I am confident about … anything less than Calc 3 now, I do remember it in the moment while taking them, I was not so confident about it. And so, I think, my confidence levels have been about the same while I'm taking the courses at least. (Malya, Interview 2019)

We identified similar patterns in Karine's reflection on perceived competence in her mathematics experiences. Even though Karine stated that being surrounded by other good students is intimidating, she viewed them as a resource for improving her knowledge.

> Sometimes I do feel like, oh my gosh! I made a really dumb mistake on an integral, or I had to look up something that I knew where that should have been really obvious. So then… that just shakes my confidence. But … I don't really let it get to me because just why would I do that? That's just a waste of my time. …and then seeing other people… I guess better or more advanced in math, sometimes it's like, oh geez, that's intimidating. But it's also why am I worried about that? They can help me. (Karine, Interview 2019)

As seen from the excerpts, each of the three women mentioned that at some point there were times when they did not feel as confident as they had previously. Interestingly, we observed connections between increasing abstractness in mathematics and students' inclination to question their mathematical competence (Di Martino & Gregorio, 2019). This tendency often prompted their unproductive emotions.

The Intervention Seminar: Students' Emotional Reflections on the STT in Mathematics

During the first seminar session, we asked students to reflect on their STT experiences in the major. We captured evidence of affective dimensions in the STT that influenced our participants' mathematical experiences and emotional dispositions. We observed that the seminar positively contributed to their experiences in the STT regarding emotional dispositions when dealing with more advanced mathematics. Creating a safe, collegial space for mathematics majors seemed to encourage them to engage in mathematical activities such as thinking, feeling, and talking about mathematics. Notably, Evelyn expressed loneliness considering the lack of representation of women in various mathematical spaces and different hardships in her transition.

> Knowing that there is a name to this phenomenon is comforting. When dealing with "the transition problem," I often felt alone in this transition, especially being surrounded by mostly men who did not seem to have this problem. (Evelyn, Seminar 2019, Day 1)

Similarly, Malya's reflection on the first day provides evidence that even though she was not aware of a transition phenomenon in mathematics, it resonated with her. Malya touched upon the prerequisite knowledge related to secondary school mathematics that did not warrant success to proceed to advanced university mathematics (Rach & Heinze, 2017). Malya's reflections

highlighted her views on the different nature of mathematics in the two institutions as well as a necessary adjustment of learning strategies (Clark & Lovric, 2008).

> I feel like this transition is similar to a well-known undercover secret. A lot of folks acknowledge that there is this period of transition between school and university, yet they are not doing much about it. There seems to be a lack of effort in attempting to shorten or lessen the "transition." My teachers warned me about how much more studying I would need to do and how schoolwork is nothing like university-course work. I understand that going to college is not for everyone, but for those who are going to college, I think it is important for them to have that exposure (Malya, Seminar 2019, Day 1)

On the fourth day, we asked students how the seminar was useful in dealing with challenges in their mathematics program when the changes in the nature of mathematics were considered. Karine stated that the seminar was helpful for her to develop more productive attitudes toward dealing with advanced mathematics. She also commented on how the academic content of the seminar was useful for her to gain a better understanding of an important mathematical concept that will benefit her in course work. Karine's reflection was an exemplar of mathematical confidence, which seemed to be uplifted by conceptual support provided in this seminar.

> I feel more confident and excited with regards to my 4000-level math classes next semester, including Analysis. I definitely feel like I have a better grasp of the derivative and differential as a mathematical object, which is a huge relief since deep down there was still that last bit of confusion of what a derivative actually was and how it came to be. It was amazing! I loved every part of it. (Karine, Seminar 2019, Day 4)

Moreover, Evelyn pointed out her positive attitudes toward advanced mathematics after the seminar, which previously did not seem to be so. From a pre-service teacher perspective, Evelyn commented on in-class practices that did not benefit her conceptual understanding, especially for upper-level mathematics courses. Group discussions and interactions were important for her to become more open to abstract mathematics.

> This seminar improved my attitudes toward transition. When dealing with formal mathematics, I was miserable and struggled a lot. After the seminar, I am a little more open to dealing with abstract mathematics. I think if there was a little more discussion, explanation, or collaboration, like the seminar, then I think I could have gotten more out of the class. I think this seminar was really useful. (Evelyn, Seminar 2019, Day 4)

Implications

This pilot study suggests that STT experiences might differ across country contexts. Also, we conjecture that WURMs' STT experiences vary based on high school preparation, year in the mathematics major, and gender. Using affective aspects of the STT is promising for capturing students' vision of mathematics and perceived competence. Our research provides valuable insights into perseverance strategies and support mechanisms that WURMs need in coping with challenges and how they configure their new mathematical space. We posit that future studies should examine more deeply how academic and social support interventions can contribute to WURMs' mathematical experiences in STT, while considering the notion of identity.

References

Alcock, L., & Simpson, A. P. (2002). Definitions: Dealing with categories mathematically. *For the Learning of Mathematics*, *22*(2), 28–34.

Andrà, C., Magnano, G., & Morselli, F. (2011). Drop-out undergraduate students in mathematics: An exploratory study. In B. Roesken & M. Casper (Eds.), Current State of Research on Mathematical Beliefs XVII. Proceedings of the MAVI-17 Conference September 17–20 (pp. 13–22). Professional School of Education, Ruhr University Bochum.

Bosch, M. (2014). Research on university mathematics education within the Anthropological Theory of the Didactic: Methodological principles and open questions. *Research in Mathematics Education*, *16*(2), 112–116. https://doi.org/10.1080/14794802.2014.918346

Charmaz, K. (2006). *Constructing grounded theory: A practical guide through qualitative analysis.* Sage.

Clark, M., & Lovric, M. (2008). Suggestion for a theoretical model for secondary-tertiary transition in mathematics. *Mathematics Education Research Journal*, *20*(2), 25–37. https://doi.org/10.1007/BF03217475

Debellis, V. A., & Goldin, G. A. (2006). Affect and meta-affect in mathematical problem solving: A representational perspective. *Educational Studies in Mathematics*, *63*(2), 131–147. https://doi.org/10.1007/s10649-006-9026-4

De Guzman, M., Hodgson, B., Robert, A., & Villani, V. (1998). Difficulties in the passage from secondary to tertiary education. *Proceedings of the International Congress of Mathematicians* (Vol. 3, pp. 747–762). Documenta Mathematica. https://www.ime.usp.br/~vhgiusti/dificuldades_passagem.pdf

Di Martino, P., & Gregorio, F. (2019). The mathematical crisis in secondary–tertiary transition *International Journal of Science and Mathematics Education*, *17*(4), 825–843. https://doi.org/10.1007/s10763-018-9894-y

Di Martino, P., & Zan, R. (2010). "Me and maths": Towards a definition of attitude grounded on students' narratives. *Journal of Mathematics Teacher Education*, *13*(1), 27–48. https://doi.org/10.1007/s10857-009-9134-z

Di Martino, P., & Zan, R. (2011). Attitude towards mathematics: A bridge between beliefs and emotions. *ZDM Mathematics Education*, *43*(4), 471–482. https://doi.org/10.1007/s11858-011-0309-6

Eddy, S. L., & Brownell, S. E. (2016). Beneath the numbers: A review of gender disparities in undergraduate education across science, technology, engineering, and math disciplines. *Physical Review Physics Education Research*, *12*(2), 1–20. https://doi.org/10.1103/PhysRevPhysEducRes.12.020106

Furinghetti, F., Maggiani, C., & Morselli, F. (2013). How mathematics students perceive the transition from secondary to tertiary level with particular reference to proof. *Nordic Studies in Mathematics Education*, *17*(3–4), 91–106.

Gueudet, G. (2008). Investigating the secondary-tertiary transition. *Educational Studies in Mathematics*, *67*(3), 237–254. https://doi.org/10.1007/s10649-007-9100-6

Gueudet, G., Bosch, M., Disessa, A. A., Kwon, O. N., & Verschaffel, L. (2016). *Transitions in mathematics education ICME-13 topical surveys*. Springer.

Hernandez-Martinez, P. (2016). "Lost in transition": Alienation and drop out during the transition to mathematically-demanding subjects at university. *International Journal of Educational Research*, *79*, 231–239. https://doi.org/10.1016/j.ijer.2016.02.005

Holmegaard, H. T., Madsen, L. M., & Ulriksen, L. (2014). A journey of negotiation and

belonging: Understanding students' transitions to science and engineering in higher education. *Cultural Studies of Science Education*, *9*(3), 755–786. https://doi.org/10.1007/s11422-013-9542-3

Kajander, A., & Lovric, M. (2005). Transition from secondary to tertiary mathematics: McMaster University experience. *International Journal of Mathematical Education in Science and Technology*, *36*(2–3), 149–160. https://doi.org/10.1080/00207340412317040

Liston, M., & O'Donoghue, J. (2010). Factors influencing the transition to university service mathematics: part 2 a qualitative study. *Teaching Mathematics and Its Applications*, *29*(2), 53–68. https://doi.org/10.1093/teamat/hrq005

Mandler, G. (1989). Affect and learning: Causes and consequences of emotional interactions. In D. B. McLeod & V. M. Adams (Eds.), *Affect and mathematical problem solving: A New perspective* (pp. 3–19). Springer. https://doi.org/10.1007/978-1-4612-3614-6_14

Master, A., & Meltzoff, A. N. (2016). Building bridges between psychological science and education: Cultural stereotypes, STEM, and equity. *Prospects*, *46*(2), 215–234. https://doi.org/10.1007/s11125-017-9391-z

McLeod, D. B. (1992). *Research on affect in mathematics education: A reconceptualization.* In D. A. Grouws (Ed.), *Handbook of research on mathematics teaching and learning: A project of the National Council of Teachers of Mathematics* (pp. 575–596). Macmillan Publishing.

Rach, S., & Heinze, A. (2017). The transition from school to university in mathematics: Which influence do school-related variables have? *International Journal of Science and Mathematics Education*, *15*(7), 1343–1363. https://doi.org/10.1007/s10763-016-9744-8

Sax, L. J., M, A. K., Riggers-Piehl, T. A., Whang, H., & Paulson, L. N. (2015). "But I'm not good at math": The changing salience of mathematical self-concept in shaping women's and men's STEM aspirations. *Research in Higher Education*, *56*(8), 813–842. https://doi.org/10.1007/s11162-015-9375-x

Schoenfeld, A. H. (1985). *Mathematical problem solving*. Academic Press.

Sfard, A. (2007). When the rules of discourse change, but nobody tells you: Making sense of mathematics learning from a commognitive standpoint. *Journal of the Learning Sciences*, *16*(4), 565–613. https://doi.org/10.1080/10508400701525253

Skemp, R. R. (1978). Relational understanding and instrumental understanding. *The Arithmetic Teacher*, *26*(3), 9–15. http://www.jstor.org/stable/41187667?origin=JSTOR-pdf

Starr, C. R. (2018). "I'm not a science nerd!" STEM stereotypes, identity, and motivation among undergraduate women. *Psychology of Women Quarterly*, *42*(4), 489–503. https://doi.org/10.1177%2F0361684318793848

Solomon, Y. (2012). Finding a voice? Narrating the female self in mathematics. *Educational Studies in Mathematics*, *80*(1–2), 171–183. https://doi.org/10.1007/s10649-012-9384-z

Solomon, Y., Lawson, D., & Croft, T. (2011). Dealing with "fragile identities": Resistance and refiguring in women mathematics students. *Gender and Education*, *23*(5), 565–583. https://doi.org/10.1080/09540253.2010.512270

Tall, D. (2008). The transition to formal thinking in mathematics. *Mathematics Education Research Journal*, *20*(2), 5–24. https://doi.org/10.1007/BF03217474

Thomas, Mike O. J., de Freitas Druck, I., Huillet, D., Ju, M.-K., Nardi, E., Rasmussen, C., & Xie, J. (2015). Key mathematical concepts in the transition from secondary school to university. In S. J. Cho (Ed.), *The Proceedings of the 12th International Congress on Mathematical Education* (pp. 265–284). Springer. https://doi.org/10.1007/978-3-319-

12688-3_18
Wade, C. H., Cimbricz, S. K., Sonnert, G., Gruver, M., & Sadler, P. M. (2016). A comparison of mathematics teachers' and professors' views on secondary preparation for tertiary calculus. *Journal of Mathematics Education at Teachers College*, *7*(1), 7–16. https://doi.org/10.7916/jmetc.v7i1.782
Wade, C. H., Sonnert, G., Sadler, P. M., & Hazari, Z. (2017). Instructional experiences that align with conceptual understanding in the transition from high school mathematics to college calculus. *American Secondary Education, 45*(2), 4–21. https://digitalcommons.brockport.edu/cgi/viewcontent.cgi?article=1022&context=ehd_facpub
Witzke, I., Struve, H., Clark, K., & Stoffels, G. (2016). Überpro – a seminar constructed to confront the transition problem from school to university mathematics, based on epistemological and historical ideas of mathematics. *Journal Of Educational Research, 2nd Thematic Issue*, 66–93. http://www.edu.uowm.gr/site/system/files/menon_issue_2nd_special_052016.pdf