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Should I Stay or Should I Go? Persistence in Postsecondary Mathematics Coursework

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This paper draws on self-determination theory (SDT) to explore reasons for college students' decisions to either continue or change directions (and hence their persistence) from their STEM-intending majors. We therefore sought to gain insight into why some college students persisted in their STEM-intending degree programs while others, faced with the same challenge(s), changed majors. Using a phenomenological design, three students were purposefully selected and interviewed using a semi-structured interview guide. A finding from this study is that while challenges are a part of life, individual responses to academic challenges vary depending on how they judge the situation. For the three focal students, decisions about whether to persist in their STEM-intending degree programs involved a complex mix of factors. These were whether they found the challenge worthwhile (i.e., perception of autonomy), had a desire to engage in the STEM program because they found the program worthwhile (i.e., perception of competency) or had adequate support systems available (i.e., perception of relatedness). Implications for university authorities and college professors are highlighted.

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Despite efforts aimed at increasing the number of students pursuing Science, Technology, Engineering, and Mathematics (STEM) programs in college, the United States (US) Department of Education reported that only 16% of high school students are proficient and interested in STEM careers (cited in National Council of Teachers of Mathematics [NCTM], 2014). Also, there are reports that a low percentage of STEM-intending students actually graduate from college with a STEM degree (Ellis, Kelton, & Rasmussen, 2014; Gentry, 2014). For example, a study by King (2015) on whether switching majors happens more in STEM programs compared to non-STEM majors concluded that non-STEM college students had a higher persistence rate compared to students pursuing physical science or engineering partly due to differences in college grade, net background and preparation. She notes that 50% to 55% of students who enter STEM disciplines earn a STEM degree compared to 82% in education and 64% in humanities. Commenting on the phenomenon of low rates of completion in STEM programs, Moss-Racusin, Dovidio, Brescoll, Graham, & Handelsman, (2012) argued that if the current rate persists there will be a deficit of one million workers over the next decade in these fields. As such, there is a need to better understand the reasons for the low rates of students pursuing STEM degrees (U.S.A. President's Council of Advisors on Science and Technology [PCAST], 2010) and the low persistence rates (Ellis et al., 2014; King, 2015). Such a move, it is argued, will ensure that efforts aimed at attracting high school students into STEM programs in college do not turn into a futile exercise—'pouring water into a leaking basket.' This is especially important considering reports that there exist healthy markets for STEM professionals (Ellis et al., 2014; NCTM, 2014) and the need for citizens who are mathematically proficient.

Ellis et al. (2014) noted that whether students persist in STEM programs or not is a function of a complex relationship between the student and contextual factors such as learning or the institutional environment and relational support. For instance, factors such as students' family background and prior learning experiences have been reported to influence students' level of persistence in STEM fields (Ellis et al., 2014; King, 2015; Wolniak, Mayhew, & Engberg, 2012). Also, Gentry (2014) posited that mathematics instruction at the college-level can best be described as "take it or leave it" (p. 1) with the net effect being that a course such as calculus is perceived by students as a filtering course. It appears that a major factor on whether or not a student continues in a STEM degree program depends on his or her performance in calculus. Other factors identified in the literature as contributing to low persistence are a lack of integration into the institutional and academic norms (Ellis et al., 2014) and motivation for pursuing particular STEM programs (Guiffrida, Lynch, Wall, & Abel, 2013).

These studies, and similar others, have provided some insight and explanation into the issues of persistence in STEM programs at the college-level. However, what remains underexplored and therefore requiring further studies is why a group of students exposed to quite similar learning conditions (especially challenging learning conditions) react differently. For instance, why is it that despite unfavorable pedagogical practices in college mathematics classes some students persist in their STEM-intending programs while others drop out? This is the question we sought to answer in this study.

Mathematics Instruction and Students' Persistence in STEM Disciplines

While gaining admission into college is cause for celebration, it comes with several challenges to students (Boyraz, Horne, Owens, & Armstrong, 2013). Some of the challenges that college students face include learning how to fit into an institution's culture and making connections with other people including professors and course mates (social support) while simultaneously being academically successful (Tinto, 1975; Wolniak, Mayhew, & Engberg, 2012). For college students enrolled in STEM programs, a major factor accounting for their decision to switch out of their intended STEM program is related to their experiences learning mathematics (Clarkson, Ntow, Chidthachack, & Crotty, 2015; Ellis, Hanson, Nuñez, & Rasmussen, 2015; Ellis et al., 2014). In a study of two college students pursuing a STEM degree, Clarkson et al., (2015) reported that these students switched their majors due to their negative learning experiences in college mathematics. Ellis et al. (2015), in a study of college students in Calculus I classes, reported that the very nature of homework tasks (i.e., conceptually driven or plug-in items) influenced students' attitude either positively or negatively.

Although a number of studies have highlighted the importance of teaching for conceptual understanding across all levels of education (Ellis et al., 2015, 2014; Lesh & Doerr, 2003), the issue of unfavorable mathematics instruction is quite puzzling considering the numerous instructional reforms. Rather than teaching in ways that support students' conceptual understanding, mathematics instruction continues to adopt a transmission approach. Transmission pedagogy involves mainly lecturing to pass on conventional wisdom and knowledge to students. The task of students is to unproblematically "absorb" the imparted wisdom and knowledge for future use. A major problem with transmission pedagogy is that students learn mathematical concepts and skills in de-contextualized situations (Lesh & Doerr, 2003). In effect, mathematical concepts, skills, and processes are presented as separate from real-world situations leading to issues such as disengagement with mathematics. It is therefore not surprising that students' interest in mathematics wanes as they progress from the elementary through to the college level (Clarkson et al., 2015; Gentry, 2014; Ellis et al., 2014; Johnson, Ellis, & Rasmussen, 2015; Walker, 2012).

A reason for taking a closer look at students' mathematics learning experiences is the possibly negative effects it can have on individuals intending to pursue STEM-related programs in college. This is especially important considering a college mathematics course like Calculus I has been reported to serve as a filter preventing a number of students from pursuing STEM degree programs (Ellis et al., 2014). For some students, their introductory mathematics learning experiences are enough to cause them to switch from their STEM majors (Johnson et al., 2015). Considering the foundational role mathematics plays in students' decision to either persist or leave STEM programs, there is a need to explore student experiences in learning mathematics and how their experiences might have influenced their decision to either continue or change their STEM majors. In this study, we investigated the factors that influenced three college students' decision to persist in their STEM-intending programs in a large Midwestern university, which had effects on their academic and career trajectories.

In carrying out this study, we sought to move beyond studies which tended to focus solely on college students' mathematics learning experiences (e.g., Ellis et al., 2014; Gentry, 2014; Johnson et al., 2015) by also including participants' high school mathematics learning experiences. Such an approach has the benefit of offering an understanding of the nature of the participants' mathematics learning experiences and how these prior experiences and institutional contexts influenced students' motivation to pursue their intended STEM majors. Furthermore, this study adopts a qualitative approach to investigate reasons for students' persistence in response to the call by Ellis et al. (2014) for "… qualitative research designs" to gain greater "insight into potential causal dependence between STEM persistence and classroom experience" (p. 672). Although this study does not seek to provide causal claims, we hope that the data provided and the various assertions made could offer some explanatory mechanism for why some students persist in their intended STEM majors while others change to other areas of study despite sharing quite similar learning experiences. For the purpose of this paper, we describe *persisters* as students who, despite having an option to enroll in any other college program, chose to pursue a STEM program. We further classify students into two groups: *short-term persisters* referring to students who changed their STEM majors some time during their college studies and *long-term persisters* referring to students who declared STEM majors and continued their pursuit of those fields throughout their postsecondary study despite facing somehow similar challenges in their academic pursuit.

Theoretical Framework

According to Dweck (1986), success in any academic pursuit or human endeavor depends on the individual's motivation. Building on the importance of an individual's motivational orientation, a number of studies have been carried out using Tinto's (1975) Model of Student Departure (e.g., Deil-Amen, 2011; Ellis et al., 2014; Wolniak et al., 2012). In these studies, the authors argue that students' perceived academic and social integration into an institution plays a significant role in their decision to change majors. Whether a student chooses to persist or not depends on a number of factors, such as how well they are doing academically (e.g., their sense of competence and desire to persist in their academic pursuit because of self-belief in their academic potential) and a sense of belonging in the institution of learning (including social support systems such as study mates and access to learning support).

While Tinto's model is useful in understanding persistence among college students, critics argue that it does not pay much attention to students' motivational orientation (both intrinsic and extrinsic motivations; Guiffrida et al., 2013; Guiffrida, 2006). Specifically, Dweck (2008) argues that an individual's mindset is crucial in how challenging situations are addressed. In this regard, while individuals with *fixed mindset* (students with an "I cannot do it" mentality) may succumb in the face of difficulty, those with a *growth mindset* (students with an "I can do it" mentality) are more likely to persist and succeed.

Challenges and difficulties are inescapable facts of life whether studying mathematics or any other human endeavor. When individuals are faced with difficult situations, success or failure depends on how s/he reacts to the situation (Nussbaum & Dweck, 2008). In mathematics, it is possible for students to have the same learning experiences and yet have different perceptions about the nature of their experiences (Ellis et al., 2015). Therefore, while extrinsic motivational factors such as career and educational aspirations and external conditions such as race and background characteristics influence students' learning and persistence (Deil-Amen, 2011; Tinto, 1975), attention should also be paid to intrinsic motivational orientations of students (Guiffrida, 2006; Nussbaum & Dweck, 2008) such as their sense of self as doers of mathematics and determination to overcome perceived challenges.

Drawing on self-determination theory (SDT), it was hypothesized that college students' decision to persist in their STEM program depends on how they characterized their mathematics experiences and whether they felt they had agency to overcome the challenging situation. SDT, a motivational theory, is based on the premise that pursuing tasks for the purpose of fulfilling "intrinsic needs is more important to personal growth and learning than the fulfillment of extrinsic needs" (Guiffrida, 2006, p. 453).

Guiffrida et al. (2013) outline three psychological needs that should be met in SDT in order for an individual to satisfy his or her intrinsic motivational needs: (a) *autonomy*, which results when a student chooses to become engaged in a learning situation because the learning tasks and activities are closely aligned with his or her interests and values; (b) *competence*, a need to test and challenge one's abilities; and (c) *relatedness*, a need to establish close, secure relationships with others. In this study, we investigated college students' (a) *perceptions of autonomy*—the desire to engage in mathematics activities and tasks because they find the study of mathematics to be of interest to them and something they can identify with, (b) *perceptions of mathematics competence*—whether to continue with their mathematics course or dropout due to a perceived ability to overcome the challenging mathematics learning experience, and (c) *relatedness*—access to social support systems such as study support (e.g., tutorials) or individuals to support their learning.

Drawing on SDT, we sought to gain insight into reasons for college students' persistence in their intended STEM programs focusing on students who initially enrolled in STEM degree programs but made different decisions about a combination of factors following their experience in precalculus. The overarching research question guiding this work is, What influence do the factors as identified in the SDT (captured in this study as perceptions of autonomy, perceptions of mathematics competence, and perceptions of relatedness) have on college students' persistence in STEM-related degree programs?

Method

A phenomenological design (Cohen, Manion, & Morrison, 2007) was adopted for this study to understand college students' perceptions of their high school and college mathematics learning experiences and their reactions to these experiences**.** To strengthen our claims and explanations, we purposively selected three college students who enrolled in their initial STEM majors with reportedly strong mathematics backgrounds from their high schools. Notably, they were all students of color enrolled in a predominantly White, large Midwestern university, which had effects on their sense of belonging in college. The results from this study reveal that despite participants experiencing similar challenges in college mathematics classes, they made different decisions that affected their career trajectories. Descriptors of the participants are captured in Table 1.

Table 1
Participant Descriptors

Student Name*	Intending STEM Program	Classification
Sydney	Biomedical Engineering	Short-term Persister
Talleah	Mechanical Engineering	Long-term Persister
Blake	Electrical Engineering	Short-term Persister

*pseudonyms

Data Collection

A semi-structured interview was conducted with each participant. With their consent, the interview sessions were audio recorded. Interview sessions lasted about 45 minutes on average. After each interview session, the audio-taped data were transcribed while inserting field notes. In line with the research agenda for this study, the focus was to gain a better understanding of participants' experience with school mathematics at the high school and college levels, availability and effect of support systems on their mathematics, and STEM program learning experience using the idea of topical interviewing (Rubin & Rubin, 2012). Topical interviews are used to gain an understanding of a topic rather than the meaning of a culture, for example. More specifically, participants were asked to describe their mathematics learning experience and attitude towards the subject at the high school and college levels. They answered questions related to possible factors that caused them to either persist or change their initial intended college major. The interview was semi-structured in nature and elicited participants' subjective high school and college mathematics experiences. In view of our reliance on self-reported data we make no claims that the findings reported in this study are generalizable to all students with STEM-intending majors who either persist or switch. What we seek to illuminate with these three purposively selected cases, however, is the complex nature of students' decision-making process in terms of whether or not to persist in their STEM-intending major.

Data Analysis

The analysis involved both within- and cross-case analyses similar to the approach used by Koch, Lundh, and Harris (2015). The first step of the analysis involved writing case profiles for each of the three participants by the first two authors. After writing individual cases, the authors read the case profiles, discussed them for areas of agreement and disagreement to ensure consistency and come to a consensus. After reviewing the case profiles, we analyzed them for possible patterns across cases. Based upon the within- and cross-case analyses, each participant was classified as either short-term persister (i.e., quit intended major) or long-term persister (i.e., stayed in the intended major) based upon the participant's overall stories.

Findings

The findings are presented into two parts. In the first part, we present the case profiles of each of the three participants, Talleah, Sydney, and Blake. The aim is to present, in detail, their individual mathematics learning histories focusing especially at the high school and college levels. Of particular interest is their attitude and persistence in mathematics based upon their learning experiences and access to support systems at both the high school and college level. The second part focuses on cross-case analyses of the three participants to reveal similarities and differences. In the second part, the comparisons made are guided by the research question and the theoretical framework underpinning this study.

Each case provides a summary of each participant's mathematics learning experiences focusing primarily at the high school and college levels. A brief background is provided regarding their perceptions of their mathematics learning experiences, their attitude towards mathematics, support received from school and/or home, and the influence of these factors on their persistence in STEM and careers.

Case 1: Talleah (long-term persister)

Background. At the time of the study, Talleah, an international student, was a junior pursuing a degree in mechanical engineering. Her father is a professor in mechanical engineering in her home country. Talking to her, it was obvious that she really enjoyed learning mathematics and relished the opportunity to help other students learn and succeed in mathematics. This is evident in the following comment by her when asked about her attitude towards mathematics: "I can't remember disliking math. Maybe it's just my nature. It's something that I loved; I always loved to find the reason behind things." She is described as a long-term persister because despite her self-confessed "anxiety" towards mathematics examinations which increased in college, she did not quit in the face of the challenges she faced in calculus 1.

Precollege mathematics learning experiences. At the high school level, there were two types of mathematics programs in Talleah's home country. The first type, known as "general math" course, was a compulsory class for all students irrespective of mathematical competency. It functioned as enabling students to be mathematically literate irrespective of future profession or career. The second type of mathematics was known as "for the math," which, as the name suggests, is for students deemed to be capable of doing advanced mathematics topics such as trigonometry and calculus.

When asked about her experience in these two programs, she described her general math program as "quite interesting." What made it "interesting" had to do with the very nature of the mathematical tasks in which she was engaged. She "really loved solving equations" because it involved a series of steps which meant making "sense of them before you can get the final answer." While she "loved solving equations," Talleah noted having "a little trouble" with trigonometry because she "wasn't really good at remembering shapes and so many rules to remember." The contrast between the two mathematical activities as she experienced them indicates that with linear equations she could "make sense" of the tasks and therefore found it enjoyable. However, with trigonometry, the nature of mathematical activities required memorization of "shapes" and "rules" leading to a memory overload due to her inability to remember all the various shapes and rules. Therefore, while she enjoyed her mathematics classes where she could "derive things personally," she did not enjoy mathematical activities which stressed remembering rules. In general, she described her high school mathematics experience to be mostly repetitive, commenting that "it's all about the same thing—solving equations, dealing with functions with slight additions—so you are just going round and round." In effect, she did not feel challenged enough.

Attitude towards mathematics. Talleah described her mathematics learning experience as being generally positive. On the contrary, mathematical concepts seemed irrelevant to her future career. Her perception about the relative importance of certain mathematics topics and activities to her career aspiration of being a mechanical engineer was not helped by her belief that “you just learned [math] for the sake of doing math.” Talleah understood that “math is always important for you”; however, what made it important was never clear to her. She commented: “I didn’t really see how that mattered in what I wanted to study.” What becomes clear from her high school math learning experience is a clear focus on what she wanted to do in college irrespective of the lack of explicit connection between mathematics and mechanical engineering.

Support Systems. Talleah could be described as having a lot of family and school support that were helpful to her mathematics learning experiences at the precollege level. The first level of support was from her father, a professor in mechanical engineering who was instrumental in her socialization into mathematics at an early age—such as thinking of mathematics as a process. She comments about the role her dad played: “My dad is an engineer and so deals with a lot of math so he tried to teach me that [one’s] process is very important. So at an early stage I didn’t really see math as complicated.”

The second level of support Talleah had regarding her mathematics journey had to do with two of her mathematics teachers who expected that students explain their process and not just present the solution. These invaluable lessons led her to note that “mastering math is not all about getting it correct. You have to be sure of what you are doing and understand it.” Another kind of support she received was serving as a member of her school’s mathematics competition team. She noted that due to the kinds of preparations required for the team to succeed during competitions, she learned mathematical concepts which “were higher than your usual grade level.” In effect, the multilayered support Talleah received made it possible for her to acquire some of the critical habits of mind necessary for mathematical success, such as looking for structure in mathematical tasks and being a reflective thinker (e.g., asking, where did I go wrong and why?). The various supports she received also meant that she did not experience much of a challenge in her high school mathematics courses except dealing with examination anxiety due to her tendency to make “silly mistakes.”

College math learning experience. Talleah described her first year mathematics experience (i.e., precalculus) as mostly “refreshing.” She especially found her second year mathematics classes as “important” because she could see connections to her mechanical engineering courses in terms of applicability. As a result, she “actually paid a lot of attention” in her mathematics classes by making an “effort to see how every math applied to [her] major” in order to “make sense of things [concepts].” Unlike in high school where Talleah’s inability to see the relevance of a mathematical activity caused her to have a negative attitude towards that activity, this was not the case in college. In college, she took it upon herself to make the necessary connections between concept and utility value. Evidence of Talleah exercising agency over her learning is evident from the following comment: “I took a personal effort to just connect what I am learning in my math class to how to apply it [in my major].”

College Support Systems. Talleah noted the importance of support systems for students and especially for “students of color” in a predominantly white institution, which she noted was not “the same” for all demographics of students. Talleah stressed the importance of having what she referred to as a “family base in school,” that is, having friends that “you can see and talk to on a daily basis,” arguing that the “psychology of what is going on around” can negatively affect students. She commented, “If you are the best student it can affect your grades sitting alone in class and doing everything alone.” From Talleah’s accounts, it can be gleaned that doing well in mathematics is not only based upon knowledge of the mathematics being taught but also upon the psychosocial environment. Having friends is not only for the purpose of offering academic needs; for students who are doing well like Talleah, friends offer psychological support. The lack of support systems in college stands in stark contrast to the numerous supports she received in high school.

Case 2: Blake (short-term persister)

Background. Blake was a junior pursuing a degree in urban studies, having switched majors from electrical engineering. Blake described his high school mathematics learning experiences as helping him "develop a foundation to move forward." However, he described his college mathematics learning experience as a "struggle," although that did not immediately stop him from taking four college mathematics courses. He is described as a short-term persister because he switched from his intended major due to a negative experience he had in Calculus I.

Precollege mathematics learning experiences. In high school, Blake took classes such as algebra and precalculus and International Baccalaureate (IB) mathematics which serve as some indication of his strong mathematics background. When asked to describe his high school mathematics experiences, he commented as follows: "I had a really great teacher [during my senior year] who provided material in a way that related to me—he used visuals, things that I can really relate to." Mathematical concepts were taught in ways that appealed to him and had "real world applications" which "reinforced" his interest in mathematics and challenged him to "keep on learning." His reflections on his high school mathematics also indicate how "good" instruction can lay a solid "foundation" for students to have self-belief that they can continue to do mathematics in the future.

Attitude towards mathematics. When asked to describe his attitude towards mathematics, he responded, "It was a positive thing because I knew that learning math I will be able to go further in life because there are lots of applications." His comment highlights the crucial role quality instruction can play in shaping the academic and career trajectories of a learner. In his case, it led to his two years in an electrical engineering program in college. Not only did he find the learning of mathematics enjoyable, but also the nature of instruction he experienced made it possible for him to see mathematics as a bridge between his future academic and career aspirations.

Support systems. Blake had a lot of support from his parents, especially his dad at a very early grade. He recounted instances in grade 3 when his dad "pushed" him to learn during the summer so that he was ahead of his class prior to school reopening and also "impressed upon [him] the importance of learning mathematics." Another source of support was from his senior year mathematics teacher. When asked to describe what made this particular teacher "great," he commented, "First time meeting us he established his goal for us [class] and then his personal goal which was to become the greatest math teacher." What endeared this teacher to him was that "he had lots of positive reinforcement" and "asked lots of questions versus telling them what to do." Those practices enabled him to engage in "critical thinking" and "challenged" him "to work more." These levels of support enabled him to "enjoy math" and succeed in precollege mathematics.

College math learning experience. Although Blake started college with a "positive attitude" towards mathematics this changed to a negative attitude towards college mathematics during Calculus I. This was because he had to "struggle" through the course. He finally had to drop calculus and ultimately say goodbye to his initial dreams of becoming an engineer. His reason was that "while statistics [applicability] was apparent, calculus wasn't for me, I didn't know the point of using limits and derivatives." His comment about not seeing the "point of using limits and derivatives" is noteworthy considering that throughout high school and in his first year college precalculus experience his interest in mathematics had been piqued by an appreciation of its real world applications. This led to his questioning how "to apply all the methods to [his] field," highlighting the correlation between his perceived utility value of mathematical concepts and motivation to learn.

Partly due to his negative experience in Calculus I, he became disillusioned and "lost motivation" for becoming an electrical engineer. As he aptly captured it, "after two years I felt I needed to move into a different direction." However, the decision to switch majors was an emotional challenge in the form of not being sure of himself, requiring that he take a year off school to "rediscover his passion." At the end of the year-long break he decided that "working with people" was his passion, leading to his new major, urban studies. In summary, while Blake noted being overwhelmed with the course load, his calculus 1 experience played a great role in his decision to change major. He reported anxieties during mathematics examinations and also a loss of desire to pursue his initially intended STEM major due to the negative experiences in calculus 1.

College support systems. For Blake, having support systems (i.e., a community) was really important considering that he came from a "low socioeconomic background and a minority population." Specifically, he stressed the importance of having a community with members that "look like you [similar other]" pursuing a STEM program, noting that it has the potential to help the learner to be "more motivated and think that it is highly possible to pursue a STEM program and be successful." Explaining further, he commented that when an individual gets to the "point of struggle and things are really hard, they [individuals] are more likely to be deterred," which happens when "learning mathematics." A sense of belonging in a learning community can help the individual through the challenging times and remain motivated.

Case 3: Sydney (short-term persister)

Background. At the time of the study, Sydney was a senior pursuing a degree in environmental science. Sydney's mathematics learning experiences at both the high school and college levels can best be described as mixed. This is because she did not find the learning of mathematics to be "smooth sailing" at any of these levels. However, she challenged herself by taking an extra mathematics class, having satisfied high school mathematics requirements for graduation. She is described as a short-term persister because she switched from her intended major, which was biomedical engineering, due to a negative experience in Calculus I.

Precollege mathematics learning experiences. Learning mathematics in high school for Sydney had its highs and lows. While geometry was her most liked subject, Algebra II was her least liked high school subject. The reason for geometry being her most liked subject was due to the "content" and the nature of instruction which involved her geometry teacher making use of "activities and real life examples," making the mathematical concepts "real" to her. The nature of mathematics instruction she experienced in geometry caused Sydney to develop an "interest" in geometry. We see how the nature of mathematics instruction can spike students' interest in the subject.

Attitude towards mathematics. While she developed an interest in geometry and looked forward to going to class, she described her Algebra II mathematics classroom as "intimidating" due to a lack of "good grasp" concepts taught. Sydney's responses to questions about her mathematics learning experiences revealed that not doing well in mathematics can be deeply emotional and troubling for students. In the case of Sydney, her inability to "grasp" what was being taught meant that she "usually wanted to skip it [Algebra II class] or find an alternative place to go." However, skipping classes, according to her, was not an option either. She comments about her dilemma as follows: "It was kind of a catch-22, if I skip I'll fall even further behind but I don't like it so what do I do?" In summary, Sydney's precollege mathematics learning experiences can be described as topsy-turvy. However, she persisted by taking an extra mathematics course despite having satisfied the high school mathematics graduation requirements at the time.

Support systems. Sydney did not have much home support and the level of support she received at the high school varied from class to class. In this regard, it appears that her achievement in a particular mathematics class correlated with the amount of support she received from her teachers. When asked how she felt whenever it was time for geometry, she commented, "I looked forward to it. I had friends in the class. I felt like I was excelling and if I didn't understand something, the teacher was really, really open with staying after school." In her response, Sydney stressed the various levels of support and alternatives made available to her. First of all, she had friends who ostensibly supported her learning. Secondly, the geometry teacher was "open" to offering after school support to students who might need it. She contrasts these levels of support with those pertaining to her Algebra II class as follows:

> Being in the classroom, it felt intimidating because I didn't feel supported. I didn't feel like I was in a place where I could really ask questions and the teacher didn't stay after class. I was a very slow worker and sometimes the lesson would go too fast for me so rather than actually learning and getting the chance to work problems out, I was just trying to keep up.

In her Algebra II class, the lack of support was flagged repeatedly by Sydney. First, the classroom environment was “intimidating” instead of being supportive of her. Secondly, the pace of lessons was such that it became a matter of “just trying to keep up,” instead of “actually learning.” Without any opportunity to freely ask questions in class, Sydney struggled in the Algebra II class. Additionally, she avoided asking questions in class, possibly to save face since she was “constantly falling behind.”

College math learning experience. Sydney took a Precalculus and a Calculus I course during her freshman and sophomore years. Similar to her high school mathematics experience, Sydney’s college mathematics learning experience can best be described as mixed. For instance, while she looked forward to her precalculus class, the same cannot be said of her calculus class. What made her look forward to her precalculus course was the structure of the class, which involved two days of lecture and three days for discussions. She liked this arrangement because it offered her many opportunities to get assistance when she “didn’t grasp something during lectures.” It also highlights the importance of providing students increased learning opportunities outside of formal lectures where students get to share ideas so that no one is left trying to do “catch up” all the time.

Sydney’s calculus class, on the other hand, presented her with a challenge. One major challenge she faced was the mathematical “language,” which made “understanding the material being taught” difficult. The language barrier meant that she tried to "learn everything during discussion," which was not an easy task. She asked rhetorically, "What do you discuss when you have no idea what was taught?" She saw attending of lectures as a matter of "urgency" and remained "hopeful that things will be better." Unfortunately, these measures were not enough to see her through as evident from the following interaction:

> *Interviewer*: What made you take that decision that maybe the math is going to be a problem?
>
> *Sydney*: Math never came easy to me but I have worked at it and that's how I was able to maintain good grades. Then getting into calculus, it got to a point where I felt like it was to weed people out, I guess I was weeded out. . . . Seeing that this is calculus 1, and I needed to go up to calculus 4 for the track that I was on I just didn't feel like the benefit was worth it.

From her rather elaborate response, it is argued that persistence is a good thing only when the end goal is beneficial to the individual. As a result, after "weighing costs and benefits," Sydney came to the conclusion that "the benefit" was not "worth it," knowing that she was "going to struggle with math the entire undergraduate years." She, therefore, switched to environmental science because, as she put it, "I can accept the science but me and the math didn't really hit it off too well."

College support systems. Sydney acknowledged that "there were so many resources in college that it did make it a lot more feasible [to succeed] in comparison to high school." In her precalculus class, for instance, she had a lot more class time for discussions in addition to the tutorial sessions and office hours. However, the presence of extra support systems were not enough to prevent her from switching majors from biomedical engineering to environmental science, although still in the STEM pipeline. The following comment about her experience as a student of color and a female in a STEM field may provide some insight into why these resources did not have the expected impact on Sydney.

Interviewer: You have referenced your background as a student of color in a STEM field can you explain what you mean by that?

Sydney: Students of color within STEM fields are both academically speaking and even career wise widely, widely underrepresented. So I think sometimes when you're getting into these fields if you don't have the proper support and the proper resources, it's very easy for it to feel much excluded. I think that it's important to have resources for these demographics

Sydney's response indicates that resources for her, a student of color and a female in a male-dominated field, goes beyond organizing class discussions, tutorials, and office hours. For her, "proper support" and "proper resources" involve an intentional effort on the part of professors and university administrators to cater for the unique challenges that students in the minority face. There is a need for her not to fall victim to the "numbers game" (Inzlicht & Good, 2006). The numbers game works by causing minority students to be constantly aware of their underrepresentation and have a sense of isolation and other emotional challenges as noted by Talleah.

Cross-case Analyses

In this section, we present the findings across the three cases. This is done by addressing each of the research questions underpinning this study (i.e., what influence do the factors as identified in the SDT [captured in this study as perceptions of autonomy, perceptions of autonomy, and perceptions of relatedness] have on college students' persistence in STEM-related degree programs?) and how the participants compared in relation to the theoretical framework used.

Autonomy. Autonomy, as stated earlier, refers to a student who chooses to be engaged in a mathematical activity (or a learning situation) because the activities are closely aligned with his or her interests and values (Guiffrida et al., 2013). All three students, Talleah, Blake, and Sydney reported having a positive experience learning mathematics in classes where the instructional practices enabled them to understand concepts and real life applications. In the case of Blake and Sydney, the use of manipulatives aligned with their learning styles. In contrast, these students "struggled" when they found it difficult to understand the mathematical activities they were engaged in (Boaler, 2008; NCTM, 2014; PCAST, 2010). Despite the challenges some of them faced in high school, all three remained interested in doing mathematics because it aligned with their future career trajectory.

As noted by Ellis et al. (2014), uninspiring mathematics pedagogy plays a major role in students' decision to drop out of their intended majors in college. This was the case for Blake and Sydney who had to change their STEM majors following their negative experiences in Calculus I. In the case of Sydney, the mathematical "language" made it difficult to understand what was being taught while Blake struggled to see the connection between Calculus I and his intended major. As Sydney aptly captured it, she had to weigh the "costs and benefits" and concluded that it was not "worth it," especially with the possibility of more of the same challenges. Both chose to drop out of their intended majors because they had lost the motivation to do post-Calculus I. Talleah remained interested in her mechanical engineering program as she found ways to align the mathematical activities to her major (career).

Competence. Competence was conceptualized as students' need to test and challenge their abilities (Guiffrida et al., 2013). At the high school, Talleah and Sydney faced varying levels of challenges, which caused them to test and challenge themselves. Talleah, for example, had "a little trouble" engaging in mathematical activities which seemed irrelevant to her future career and taking mathematics classes whose relevance was not explicitly communicated to her. She took them because "mathematics is something important." With regards to Sydney, the comment that "math never came easy" to her, but she "worked hard to obtain good grades" exemplifies how she challenged herself to succeed in mathematics at the high school level despite "falling behind" and playing "catch up." While she had no trouble engaging in mathematical activities where the nature of instruction made it possible for her to understand what was being taught, she had to put in the necessary effort in courses where the nature of instruction was "uninspiring" (Ellis et al., 2014, p. 662). Blake, on the other hand, did not have to challenge his mathematical competence since he had teachers who caused him to develop deep interest in mathematics.

Ellis et al. (2014) highlighted the importance that students' experience in Calculus I plays in their decision to persist in their intended majors and go on to graduate, noting that students have to take a calculus sequence, Calculus I–4. In effect, a negative experience in Calculus I, the foundational phase, could foreshadow trouble in subsequent courses in the sequence and students' determination to persist. Calculus I definitely presented a challenge to participants. Both Talleah and Blake mentioned that their professors did not make explicit connections between the mathematical concepts and their engineering majors. Talleah, however, made the effort to make the connections between the two disciplines since those connections enabled her to "make sense" of what she was learning. Blake became disillusioned by the lack of connections (Ellis et al., 2014), which was exacerbated by the high-risk nature of examinations (King, 2015). In the end, both Blake and Sydney concluded that the effort was not worth it, especially when they had more calculus classes to take and considering its cost in terms of the emotional challenges (e.g., "a catch 22") and possible effect on graduating with a good class.

Relatedness. A number of studies have highlighted the importance of students' sense of belonging and its relationship with their persistence (Deil-Amen, 2011; Ellis et al., 2014; Tinto, 1975). In this sense, students have a need to feel connected to others in their learning environment and establish a community of learners where both their social, emotional, and academic needs are fulfilled. A sense of isolation, in this regard, can prove detrimental to students.

At the high school level, all three participants reported receiving support from their teachers. They had teachers they could relate to and who challenged them to succeed at their highest levels possible. These teachers were accessible to them in class and after school, thereby increasing their learning opportunities. Moreover, Blake and Sydney credited their interest in mathematics to some of their teachers. In addition, Blake and Talleah had strong parental influence and support at an early age. Their mathematics socialization started with their parents, who stressed the importance of mathematics, how mathematics should be learned, and the importance of persistence. For all three, the presence of people they could relate to played a critical role in their mathematics learning and success. Specifically, in the case of Sydney, there appeared to be a reciprocal relationship between her sense of belonging and achievement (Deil-Amen, 2011; Martinez & Deil-Amen, 2015). She did well in classes when she could relate to the teacher and classmates but struggled in classes where she found the learning environment to be unfriendly and intimidating.

At the college level, all three participants stressed the importance of having a "family base," especially for them as students of color[1] in a predominantly white institution. All participants stressed the lack of representation on campus and in their academic disciplines, highlighting a need for both ethnic and academic identities (Walker & Syed, 2013). As Talleah captured it, not having friends that a student could talk to leads to a feeling of isolation, which can have negative effects on the academic output of even the best students. In the case of Talleah and Sydney, being female students in a male-dominated field, finding persons they could relate to was a challenge. They therefore noted that the presence of similar others in their programs who would have encouraged them would have helped them greatly (Klopfenstein, 2005; Reid, 2013).

Discussion

In this paper, we presented the cases of three college students who made different decisions based upon their college mathematics learning experience using self-determination

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[1] Race was not a factor in choosing them and not a focus in this paper.

theory (Guiffrida et al., 2013). We showed that for two of the participants (short-term persisters), while prior learning successes may have been an important factor in their decision to pursue STEM-related degree programs in college (e.g., Ellis et al., 2014; Gentry, 2014; King, 2015; Tinto, 1975), this factor appeared not to be a strong enough reason for them to persist in their intending STEM majors. We highlight three contributions made in this paper in gaining insight into the phenomenon of dropout in STEM programs and the role mathematics (i.e., calculus) plays in this regard.

A contribution of this paper is the use of both a cross sectional and a qualitative design as recommended by Ellis et al. (2014) to provide insight into participants' mathematics learning experiences at both the high school and college levels. It is argued that when mathematics instruction does not enable students to make sense of concepts and limited attempts are made by instructors for students to see the relevance of mathematical concepts, they are more likely to be disengaged. We, therefore, contend that students' long term persistence in college depends on whether they find the mathematical activities they are engaged in relevant or worthwhile to pursue.

A second contribution this paper makes is to highlight the complex relationship between persistence and students' intrinsic motivation. The use of the self-determination theory (see Guiffrida et al., 2013) enabled us to gain insight into how individual students responded to challenges in their calculus class and its effect on their intended STEM program. That is, whether a student chooses to become engaged in mathematics by taking more mathematics classes (i.e., need for autonomy) and is willing to challenge him/herself (i.e., exhibit competence) depends on whether they find the effort required to execute the task worthwhile. Short-term persisters reported the constant battle (i.e., emotional challenges) to attend lecture and writing mathematics examinations. Talleah, the long-term persister, found a way to make the mathematical tasks worthwhile to engage in and was still motivated to become a mechanical engineer. While it is good to encourage students to persist (Yeager & Dweck, 2012), avoidance of challenging tasks or situations by students is not always a defense mechanism (Nussbaum & Dweck, 2008). It could be a matter of students weighing the relative benefits of going through or avoiding a learning situation and making a judgment call. Pedagogically, this study highlights the effect of unengaging pedagogy on students' STEM career decisions (e.g., Clarkson et al., 2015; Ellis et al., 2015; Johnson et al., 2015).

A third contribution is the theoretical framework used, which enabled us to document the ways teaching, learning, and social factors interact to influence students' decisions. By documenting students' sense of belonging (i.e., perception of relatedness), we argue that for these students their minority status (either by gender or race) was a challenge for them in their academic pursuit. It is argued that doing well academically goes beyond organizing tutorials, holding class discussions, and giving homework (Ellis et al., 2015). Students battling the "numbers game" (Inzlicht & Good, 2006) due to their minority status especially in STEM programs which have particular histories would like to have a "family base" on campus in addition to the more academic support offered.

Overall, while this study makes a contribution in terms of understanding some of the reasons for students either staying or switching majors, there are a number of limitations. First of all, the small sample size means that broad generalizations cannot be made as to why some students switch majors. As such, we do not claim a causal relationship between the three constructs in the SDT and persistence. A second limitation has to do with a lack of classroom observations of mathematics teaching as experienced by participants either at the high school or college classes. This means that there was reliance on self-reported data from semi-structured interviews. However, we believe that the findings are valuable to the field of college mathematics learning experiences and its effect on STEM graduation rates. The three cases revealed that the learning environment is important in shaping how students react to challenges. While some students are able to go the extra mile to make adjustments in their learning in order to keep going, not all students are able to do so. As such, academic advisors and college professors should provide intentional institutional support. It would be helpful for professors, course instructors, and college administrators to pay attention to issues of mathematics instruction, supporting social cohesion integration in further efforts to create welcoming learning environments.

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