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Understanding the Transition from Secondary Education Mathematics to Undergraduate Mathematics

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UNDERSTANDING THE TRANSITION FROM SECONDARY EDUCATION MATHEMATICS TO UNDERGRADUATE MATHEMATICS

By
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Abstract

Michigan Technological University had a collective 28% drop, fail, or withdraw rate in four predominantly first-year mathematics classes for the fall semesters from 2011 to 2015, with 58% of students dropping, failing, or withdrawing from College Algebra I in the fall of 2013. A survey was distributed via email to the 2015-2016 first year class of Michigan Tech in an attempt to determine why students struggle in making the transition from high school to undergraduate mathematics class, and what instructors can do to make this transition easier for students. It was found that the time between a student's last high school mathematics course and their first at the university was not influential on student struggles. The first mathematics class taken at Michigan Tech was related to some differences in struggle, but the student's highest level of mathematics before arriving at the university and the grade a student received in their first mathematics class at Michigan Tech were fairly significant factors. Over all students surveyed, the factors found to be most difficult included the clarity of lectures, the students' ability to study for tests and exams, and working with an online mathematics homework system.

Chapter 1
Introduction

Many students find that making the shift from secondary education to post-secondary education is difficult (Lu, 1994). Not only is it troublesome for a portion of students to adjust to a new environment, but there is also a change in the demands of classes, and students can struggle coping with these changes (Brown & Cross, 1997). Stage and Kloosterman (1995) found that an unusually high number of students do not perform well in their first college mathematics course.

Michigan Technological University has a retention rate of 87% from first to second year. Drop, fail, and withdraw (DFW) rates indicate that first year mathematics courses are particularly difficult for students ("Michigan Tech Undergraduate Admissions Fast Facts," n.d.). DFW rates in the fall semesters from 2011-2015 showed that 28% of students dropped, failed or withdrew from College Algebra I, Precalculus, Calculus with Technology I, or Calculus Plus with Technology I, all of which are predominantly comprised of first year students. Most concerning is the fact that, on average, the DFW rate over the same time period for College Algebra I was 48%, with a 58% DFW rate in fall of 2013.

One goal of this research was to find out what makes the transition from high school to college mathematics courses at Michigan Technological University so difficult for many students, especially considering that over 60% of the undergraduate student population is majoring in some form of engineering ("Michigan Tech Undergraduate Admissions Fast Facts," n.d.). By looking into factors that cause students to struggle in their mathematics classes, it may be possible to discover ways that instructors can ease the passage for first year students into their university mathematics classes, which is why another goal of this research was to delve into techniques instructors could use to make this transition easier for first year students.

Research Questions

This research was designed to answer the following questions:

- What are the factors that cause students to struggle in their first mathematics class at Michigan Tech?
    - How do these factors differ among students who:
        - Enrolled in different first mathematics courses at Michigan Tech?
        - Have different lengths of time between their last high school mathematics course and their first mathematics course at Michigan Tech?
        - Have different highest-level high school mathematics classes?
        - Received different grades in their first mathematics class at Michigan Tech?
- From the students' perspective, what might instructors at Michigan Tech do to ease the transition from high school mathematics courses to university-level courses?

Chapter 2
Literary Review

There are several factors that contribute to student success in the mathematics classroom. These factors include, but are not limited to, student confidence, instructor characteristics, and student behavior. In the following sections, these and other factors will be explored by looking at the research already present in these areas.

Student Factors Related to Success in Mathematics

There have been several studies that suggest that student confidence is a key factor in their success in college mathematics (Dowling, 1979; Fennema & Sherman, 1976; House, 1995, 2000; Randhawa, Beamer, & Lundberg, 1993). Increasing students' confidence in their mathematical skills and lowering their anxiety towards mathematics can increase their success rates in mathematics courses (Clute, 1984; Fennema & Sherman, 1976). According to Reyes (1980), students with lower mathematics anxiety have higher confidence in the classroom, and are more likely to work with their instructors directly than their less-confident counterparts. Understanding the factors that students feel contribute to their struggles in the mathematics classroom might allow instructors to put them at bay in hopes that it relieves some of the students' anxiety and boosts their confidence. In doing so, students may increase their achievement in the classroom.

Classroom Structure

As stated above, a student's math anxiety can affect their success in the classroom. One factor that can affect students' math anxiety is the structure of a class or lecture. According to Jackson and Leffingwell (1999), the pace at which lectures are given contributes to student anxiety. In a study that included interviews with first year college students, more than one-fifth of the 38 students suggested that instructors need to slow down. Other suggestions included having a more lenient grading system and having clearer, better-put-together lectures (Boyles, Frayer, Ljumanovic, & Swenson, 2011). By paying attention to student reactions to course material, instructors can try to gauge how their students are feeling in order to adapt to the needs of the class.

Instructor Characteristics Related to Student Success

There have also been a number of studies that have shown that instructor characteristics and behavior have an effect on student success (Good, Biddle, and Brophy, 1975; Jackson & Leffingwell, 1999; Rakow, Airasian, & Madaus, 1978; Stage & Kloosterman, 1995). A study of first year students found that students preferred having instructors that seemed happy with their position as the instructor of their given class (Anthony, 2000). Jackson and Leffingwell (1999) found that students were more anxious and less confident in the mathematics classroom when they had an uncaring or unenthusiastic instructor, or when there were language barriers between them and their instructors. Furthermore, students reported that they could tell when an instructor was unhappy with the level of teaching they were given, and felt like they were receiving a lower-quality education from these instructors. These results agreed with Anthony's (2000) study, where students said that they most preferred having an instructor who they could invest in, one who was passionate and showed their love for teaching the subject. Jackson and Leffingwell (1999) suggested that students are more at ease learning new material from lecturers who provided plenty of examples that were clearly worked out with all steps shown. Based on these results, it would follow that instructors who emphasize that they care about their students and their learning may be able to lower students' anxiety towards mathematics in the aim of increasing overall achievement in the class.

Student Behaviors

Students are aware that it is not only instructors who can make it difficult to be successful in university mathematics. In the study by Boyles et al. (2011), over half of the surveyed students said that spending more time on homework would have helped them be more successful. The same group of students also believed that using the free on-campus math tutoring center and talking to their professor outside of usual class time (e.g., utilizing instructor office hours) could have been useful to them. Another study found that students tended to take a "passive approach to learning" (Anthony, 2000, p. 6) meaning that they would take the information given in class as the information they needed to know; they would not necessarily spend additional time to expand on the information talked about

during class. In fact, it has been found that many students have taken to the belief that the mathematics they need to get through the class they are taking can be learned by memorizing the steps, formulas, and algorithms (Stage & Kloosterman, 1995). By buying into this notion, the students do not develop the critical thinking skills needed to comprehend the connections between the different topics of the subject (Bibby, 1985). Often, it was the case that "students taking notes" involved students writing down verbatim what the instructor wrote on the board, assuming that these given pieces were the parts of the content they would need to know in the future. Students would then pack away their notes until it was time to do their homework or study for exams. Even though students regard notes very highly as an important path to success, leaving them stored away shows students' lack of study skills (Anthony, 2000). These studies suggest that although students realize that their choices play a role in their success in their mathematics classes, they are not always using resources to their fullest capacity.

Comparing Student and Instructor Views

Instructors and students in New Zealand were given the opportunity to reflect on their experiences involving first year mathematics courses at the university level in a survey aimed at finding the main reasons behind student achievement and struggle (Anthony, 2000). In the study, students and lecturers were asked to rate their level of agreement with different factors that could contribute to student success. In support of the idea that class design, instructor characteristics/behavior, and student influences all play a role in student success, the given factors were broken into four categories: "course material and design," "lectures," "the student," and "other external factors" (Anthony, 2000, p. 4). It was found that students saw 47% of the success items as being related to student behaviors, whereas lecturers put much more weight on the student, identifying 68% of success factors related to students. Combined, students identified 47% of success items as being related to either the course or lecture structure/design, whereas the instructors only attributed 27% of these factors to student success.

These findings were expressed more clearly when examining how students and instructors ranked some of the individual survey items. Students and lecturers both agreed that students' self-motivation and studying for exams were the top two influences (out of

the 40 given) on high student achievement. Some noticeable differences between student and instructor rankings included the following:

- "assignment completion" was found to be the fourth most influential factor for success by students, but was ranked number 13 by instructors;
- "availability of help" was ranked number six for students, but only 25 for instructors;
- "taking notes during lectures" was ranked number 16 for students, but 31 for instructors;
- "regular practice of examples" was ranked number 20 for students, but much higher, number six for instructors; and,
- instructor of course "has realistic expectations of prior knowledge" was marked as the thirtieth most influential factor by students, but fourth by instructors.

When it came to reasons behind students' struggles in mathematics at the college level, instructors and students again did not fully agree. Lecturers ranked poor study techniques, not putting in enough work, and not having enough background knowledge more highly than students when it came to underperformance. Students rated boring presentations, not attending class, and the lack of relevant material as some of the top reasons behind their struggles (Anthony, 2000). This mismatch in beliefs about the underlying reasons behind struggles goes to show that instructors do not necessarily know why their students are struggling. Clearing up some of these misconceptions may help instructors know how to better aid their students.

Differences between High School and University Teaching

Byers (2010) found that in some cases there is a discrepancy between how ideas are taught in high school versus how they are taught in college, and this can lead to student struggle in college mathematics. An example given was that a student may be taught trigonometry in high school using right triangles, but when they get to college, the instructor may teach trigonometry from a vector point of view. This can cause a disconnect for the student because they had learned the material a different way and might not be familiar with the vector approach, and may struggle connecting the two. In addition, college mathematics classes tend to be more proof-oriented than high school mathematics

classes. In the United Kingdom, it was found that the area in which students struggle the most when it comes to college mathematics is proofs and other abstract thought (Hoyles, Newman, & Noss, 2001). Thus, students could possibly find college mathematics difficult compared to high school mathematics due to the difference in emphasis between the two levels.

Summary

There are several factors that relate to how students perform in the classroom. While many of these factors are student-driven, there are some that are influenced by instructors. If instructors are aware of how their actions can affect students, they may be able to help their students perform better.

Chapter 3

Methodology

Participants

In order to investigate the difficulties that students face when taking their first mathematics courses at Michigan Technological University, a survey was distributed via email to students who were identified as having first-year status during the 2015-2016 school year at the university.

A total of 197 students out of the 1332 from the 2015-2016 first-year class responded to the survey. The students who responded had a wide spread of experiences, from those having taken geometry as their highest level of mathematics in high school to those who went beyond multivariable calculus, from students taking quantitative literacy to multivariable calculus and higher as their first mathematics class at Michigan Tech. There was an overwhelming majority of respondents who had no time off between their last high school mathematics class and their first one at Michigan Tech and some who had multiple years. These students had grades anywhere from A to F in their first mathematics class at Michigan Tech.

Survey

To understand what factors can make the transition from high school to university mathematics difficult at Michigan Tech, a survey was developed based on that developed by Glenda Anthony (2000) of Massey University in New Zealand. In Anthony's study, a survey was given to a pool of 92 students who were at the end of their first calculus course at a university. The survey asked participants to rank a list of factors on a scale from 1 to 5 to indicate how influential they thought each was toward either student success or student failure, where a 1 represented having no influence and a 5 represented having significant influence. A majority of the items present in the survey used in the current study were based off those used in the Anthony (2000) survey. Several of the factor prompts used in the survey were directly from or very similar to those used in Anthony's survey; others were adapted so as to make more sense to Michigan Tech students.

The survey (see Appendix A) had three parts. In part one, participants were asked for four pieces of information related to their mathematics experience: (a) their highest level of mathematics class taken in high school or through a different college before taking a mathematics course at Michigan Tech, (b) the amount of time that had elapsed between their last mathematics class in high school (or at another college) and their first mathematics class at Michigan Tech, (c) the name of the first mathematics course they took at Michigan Tech (if applicable), and (d) the grade they received in their first mathematics class at Michigan Tech. This information was gathered to determine if there were differences in factors that caused difficulty in transitioning to university courses present among students that differed in these areas.

In the second part of the survey, the students were given a list of 33 Likert-scale questions asking them to rate factors that may have had an influence on their experience with, or transition to, their first mathematics class at Michigan Tech. Students were asked to rate the items with respect to the level of difficulty the given factor presented to them. The scale ranged from a rating of one to five, where a one indicated that the student faced no difficulty with the given factor and a five represented that the factor caused significant difficulty for the student. As mentioned before, some of the items in the survey were different than those in Anthony's study. Anthony's study divided the factors into two categories: those related to student success and those related to student failure (Anthony, 2000). Several of the items in the two categories in Anthony's study were extremely similar to one another. For example, "willingness to seek help when needed" was an item categorized as relating to student success, while "failure to seek help when needed" was an item relating to student failure. The survey given in the current study was modified slightly from Anthony's by removing some of the factors deemed repetitive or not necessary for this research. Items such as the example given were combined into a single factor for this study, for example, "asking for help when needed." Some factors thought to be relevant to Michigan Tech students that were not in Anthony's study, such as working with an online mathematics homework system, were also added in the hopes of pinpointing the factors that were affecting success in mathematics classes at Michigan Technological University.

In the third part of the survey, the participants were asked if they had any suggestions as to how instructors might be able to help ease the transition from high school mathematics to undergraduate mathematics courses. This question was left open-ended so students could supply their own answers without prompt.

The survey was distributed to all first year students from the 2015-2016 school year via email. It was open to students for 19 days in the summer of 2016. Ten days after the survey was originally sent out, another email was sent to the students reminding them to complete the survey.

Data Analysis

The survey data collected were first analyzed collectively to examine the results for the entire participant pool. This was done see if there were trends over all students, such as a factor that was rated extremely difficult or extremely easy. The data were then broken down in four ways in order to look for similarities and differences between different student subgroups.

- By the highest level of mathematics taken by the participants in high school (or another college before attending Michigan Tech). The highest mathematics data was divided into two groups—Precalculus and lower or Calculus I and higher. This analysis focused on whether the difficulties students experienced in the transition from high school to college differed based on their mathematics preparation.
- By the math gap of the students; that is, the amount of time elapsed between their last mathematics class in high school and their first mathematics class at Michigan Tech – no gap or some gap. This analysis focused on whether student difficulties differed based on the amount of time they had away from a mathematics classroom before taking a Michigan Tech mathematics course.
- By the first mathematics class they took at Michigan Tech – Precalculus and lower, Calculus I, or Calculus II and higher. This analysis focused on whether there were differences between students who took different courses for their first mathematics class at Michigan Tech.

- By the grade they received in their first mathematics class at Michigan Tech – A through B, BC through CD, and D/F. This analysis focused on whether the difficulties students faced could be related to the grade they received in their first mathematics class at Michigan Tech.

Once the data were divided these ways, an analysis of variance (ANOVA) test was performed on each factor the students were asked to rate. To determine whether the results were statistically significant, a significance level of 0.05 was used in these tests. If a factor had a *p*-value less than 0.05, then the means of the groups were not equal. If there were three groups (such as when the data were divided by grade received) and the result was found to be significant, then an ANOVA test was performed pairwise between groups to determine which factor(s) had a different mean value. Students were also asked to leave suggestions for instructors to help ease the transition from high school to undergraduate mathematics courses. Comments were grouped by the general concept they addressed, such as examples shown in class or getting extra help outside of class. Suggestions that contained more than one general concept were considered to be a part of all of the appropriate comment groups.

Chapter 4

Results

Once all of the data were collected, it was reviewed in several formats. First, the information was analyzed overall: the averages over all participants for each of the given factors. Then it was broken up four different ways: (a) by the highest-level mathematics course taken by the participants before arriving at Michigan Tech, (b) the amount of time elapsed between the last mathematics class the participants took in high school and the first one they took at Michigan Tech, (c) the first mathematics class taken by the participants at Michigan Tech, and (d) the grade received in the participants' first mathematics class at the university. In the following sections, the information gathered from the survey are reviewed in these ways.

Overall

In the second part of the survey, the 195 participants who had taken a mathematics class at Michigan Tech were asked to rate a list of 33 Likert-scale items based on how difficult they perceived the items with respect to their first mathematics class at Michigan Tech. A rating of 1 meant that the given item caused the participant no difficulty, whereas a 5 meant that the item was a significant difficulty for the participant. As Table 1 shows, the average rating given to the items over all of the students surveyed ranged from 1.45 to 2.67. The highest overall average for any single item was given to "clarity of lectures". Close behind, with average ratings of 2.64 each, were "working with an online mathematics homework program" and "my ability to study for tests and exams". "Interesting lectures" and "my desire to deeply understand the material rather than memorizing processes or procedures" were also similarly rated with averages of 2.60 and 2.50, respectively.

On the other end of the spectrum, there were eight factors rated with an average of less than 2.0. These items included "being overconfident" (1.95), "my ability to think mathematically" (1.85), "the availability of help" (1.79), "clear expectations for the class" (1.78), "taking notes in class" (1.76), "the course being relevant to my major" (1.76), "the classroom being orderly and controlled" (1.50), and "regularly attending class" (1.45).

Table 1

Average ratings of factors over all students

Factor	Average Rating
Clarity of lectures	2.67
My ability to study for tests and exams	2.64
Working with an online mathematics homework program	2.64
Interesting lectures	2.60
My desire to deeply understand the material rather than memorizing processes or procedures	2.50
Reading material before each class	2.49
Asking for help when needed	2.45
The number of examples worked out in class	2.39
Self-motivation	2.35
Adapting to the university environment	2.33
Having an appropriate balance of my social and academic life	2.30
Working with ideas presented during class on my own	2.24
Giving consistent effort	2.23
Paying active attention during class	2.22
Well-structured lectures	2.21
Instructor was enthusiastic/inspiring	2.20
Lacking confidence	2.17
My interest in the class	2.15
Pace of course	2.11
Assignments that relate to the lectures	2.05
Instructor was supportive and approachable	2.04
Appropriate workload for the class	2.02
Having adequate background knowledge of the subject	2.02
Completing assignments	2.01

Table 1 (continued)

Factor	Average Rating
Instructor had realistic expectations of my prior mathematics knowledge	2.01
Being overconfident	1.95
My ability to think mathematically	1.85
The availability of help	1.79
Clear expectations for the class	1.78
Taking notes in class	1.76
The course being relevant to my major	1.76
Classroom was orderly and controlled	1.50
Regularly attending class	1.45

Looking at everyone as a whole, it seems as though no one specific item was perceived as especially difficult by students, seeing as the highest rating was a 2.67 out of a scale that went up to 5. However, when the data were broken into smaller categories, it could be seen that there were some fairly significant differences between different groups of students.

High School Course

One way the data were divided was by the highest mathematics course taken by the student before arriving at Michigan Tech. This could be a high school course or a course taken at another college. The participants were divided into two categories: those whose first mathematics class taken before arriving at Michigan Tech was Precalculus or lower, and those whose was Calculus I (Calculus AB) or higher[1]. Since Calculus I (Calculus AB) is often viewed as being a college-level course, breaking up the data this way considers students who had been exposed to a college-level mathematics class before arriving at Michigan Tech, and those who had not. The hope behind this analysis was to determine if

[1] Eleven students reported their highest level of mathematics as being a course that is not in the calculus track, such as a statistics course. These participants were not included in either of the reported groups because it was unclear whether these students had had exposure to college mathematics course material before arriving at Michigan Tech.

the level of mathematics the student was exposed to before arriving at Michigan Tech affected the difficulties the student faced in making the transition to university mathematics.

Breaking the data into these two smaller student subgroups allowed for closer inspection as to how students with different prior levels of mathematics experience viewed various aspects of their transition to university mathematics. Table 2 shows that three items were rated with an above 3.0 average in the Precalculus and below student group. These factors included "interesting lectures", "working with an online mathematics homework program" (both of whose average was a 3.02), and "clarity of lectures" (given a 3.06). The Calculus I and above student group did not rate any factor above a 3.0.

Table 2

Average ratings by highest mathematics class taken before Michigan Tech

	Factor	Precalculus and Below (n = 49)	Calculus I and Above (n = 135)	p-Value
Instructor-centered	Assignments that relate to the lectures	2.22	1.98	0.207
	The number of examples worked out in class	2.65	2.29	0.089
	Well-structured lectures*	2.57	2.09	0.026
	Instructor was supportive and approachable*	2.39	1.90	0.019
	Clarity of lectures*	3.06	2.55	0.016
	Instructor was enthusiastic/inspiring*	2.63	2.06	0.012
	Interesting lectures*	3.02	2.45	0.010
	Clear expectations for the class*	2.18	1.60	0.001
	Appropriate workload for the class*	2.49	1.80	< 0.001
	Classroom was orderly and controlled*	1.96	1.36	< 0.001
	Instructor had realistic expectations of my prior mathematics knowledge*	2.54	1.77	< 0.001
	Pace of course*	2.67	1.88	< 0.001

Table 2 (continued)

	Factor	Precalculus and Below (n = 49)	Calculus I and Above (n = 135)	p-Value
Student-centered	Regularly attending class	1.49	1.40	0.577
	Taking notes in class	1.88	1.71	0.388
	Being overconfident	2.13	1.86	0.184
	Reading material before each class	2.77	2.38	0.085
	Adapting to the university environment*	2.66	2.22	0.041
	Paying active attention during class*	2.53	2.08	0.031
	Working with an online mathematics homework program*	3.02	2.47	0.025
	Having an appropriate balance of my social and academic life*	2.63	2.17	0.024
	Giving consistent effort*	2.57	2.08	0.014
	My interest in the class*	2.53	1.94	0.006
	Asking for help when needed*	2.92	2.26	0.003
	My ability to study for tests and exams*	3.14	2.44	0.001
	My desire to deeply understand the material rather than memorizing processes or procedures*	2.98	2.24	0.001
	Self-motivation*	2.86	2.13	0.001
	Working with ideas presented during class on my own*	2.71	2.05	0.001
	Having adequate background knowledge of the subject*	2.69	1.71	< 0.001
	Completing assignments*	2.51	1.77	< 0.001
	My ability to think mathematically*	2.42	1.61	< 0.001
	Lacking confidence*	2.88	1.83	< 0.001
Other	The availability of help*	2.22	1.62	0.001
	The course being relevant to my major*	2.31	1.56	< 0.001

Note: Differences between the ratings of items with (*) are statistically significant ($p < 0.05$).

Only two of the given factors received average ratings below a 1.50 (exceptionally low difficulty) for either group. "Regularly attending class" was rated as 1.49 by the Precalculus and lower group and 1.40 by the Calculus I and above group. The more advanced group also rated "the classroom being orderly and controlled" extremely low, with a rating of 1.36, even though the other group gave it an average rating of 1.96.

Some factors were given similar ratings between the two groups. These items include "regularly attending class", as discussed above, "being overconfident" (average rating 2.13 by the lower-level students and 1.86 by the higher-level students), and having "assignments that relate to the lectures" (average rating 2.22 by the lower-level students and 1.98 by the higher-level students).

In contrast, some factors were given extremely different ratings by the two groups. "Lacking confidence" had over a one-point difference between the average ratings (2.88 by the Precalculus and below students and 1.83 by the Calculus I and above students). "Having adequate background knowledge of the subject" also had a wide spread between average values; the lower-level students gave it an average rating of 2.69 and the upper-level students gave it a 1.71.

For every factor, the average rating given by the students whose highest mathematics class taken before arriving at Michigan Tech was Precalculus or lower was higher (more difficult) than their counterparts whose highest mathematics class was Calculus I or higher. However, out of the 33 factors, only 27 of these had differences in ratings that were found to be statistically significant between the groups using an analysis of variance (ANOVA) test (significance level 0.05). The factors that were deemed statistically significant have been marked with an asterisk in Table 2.

Looking at the list of 27 factors that were found to have different means, 16 of them were student-centered factors, including: "self-motivation", "the student's ability to study for tests and exams", "completing assignments", "asking for help when needed", and "paying active attention during class." However, nine other factors deemed statistically significant were influenced by the instructor: "clarity of lectures", "well-structured lectures", "the instructor being enthusiastic/inspiring", and "the instructor having realistic expectations of my prior mathematics knowledge." The two factors external to the teacher

and student— "the availability of help" and "the course being relevant to my major"— were also found to be statistically different between the groups.

Math Gap

Another way the data were broken down was by whether the students had a math gap—that is, time elapsed between their last mathematics class before Michigan Tech and their first at the university. For example, some participants took a math class their senior year of high school, then took a math class their first semester at Michigan Tech with no break in between. That would be a math gap of 0. Others may not have taken a math class their last year of high school, but did take one during their next to last year of high school and during their first semester at the university, so their math gap would be 1 year. For this analysis, the information gathered from the survey was divided into two groups: those with a math gap of 0 (no math gap) and those with a math gap greater than 0[2]. This division allows for comparing whether there were differences between the ratings given by those who went straight from taking a mathematics class in high school to taking a mathematics class at Michigan Tech and those who took time away from mathematics classes before taking one at Michigan Tech.

There were some differences between how students with different math gaps rated the Likert-scale questions, but most items were rated quite similarly between the two groups. Interestingly, while there was the clear pattern in the previous section that the students who took lower-level mathematics in high school rated the given factors as more difficult than their higher-level counterparts, this was not the case when comparing math gaps. As Table 3 shows, 19 of the 33 factors were ranked more difficult by students with a math gap greater than 0, and the remaining 14 were ranked more difficult by the students with no math gap.

When the information received from participants was divided this way, there were no items that received an average rating over a 3.0 for either group. In fact, the highest ranked item was "clarity of lectures" which received an average rating of 2.74 by the

[2] There were two participants that did not report whether or not they had a math gap, so these students were excluded from analysis in this section.

students with no math gap. The participants with a math gap rated "my ability to study for tests and exams" the highest (most difficult), giving it an average rating of 2.73. Two items received ratings below a 1.50. "Regularly attending class" was rated 1.41 by students with a math gap and 1.46 by students with no math gap. Participants with no math gap also rated "the classroom being orderly and controlled" extremely low, giving it a 1.49. Students with a math gap gave this item a similar rating of 1.53.

Table 3

Average ratings by math gap

	Factor	Math Gap = 0 (n = 156)	Math Gap > 0 (n = 37)	p-Value
Instructor-centered	Instructor was supportive and approachable	2.05	2.03	0.913
	Classroom was orderly and controlled	1.49	1.53	0.826
	Assignments that relate to the lectures	2.05	2.11	0.771
	Clear expectations for the class	1.77	1.84	0.744
	Interesting lectures	2.63	2.53	0.685
	Pace of course	2.10	2.19	0.670
	Instructor had realistic expectations of my prior mathematics knowledge	2.04	1.94	0.669
	Instructor was enthusiastic/inspiring	2.24	2.11	0.590
	The number of examples worked out in class	2.44	2.17	0.248
	Clarity of lectures	2.74	2.46	0.230
	Appropriate workload for the class	2.08	1.81	0.181
	Well-structured lectures	2.28	1.92	0.129
Student-centered	My interest in the class	2.16	2.17	0.965
	Giving consistent effort	2.23	2.24	0.944
	Working with ideas presented during class on my own	2.25	2.19	0.815
	Reading material before each class	2.49	2.56	0.779
	Regularly attending class	1.46	1.41	0.764

Table 3 (continued)

	Factor	Math Gap = 0 (n = 156)	Math Gap > 0 (n = 37)	p-Value
Student-centered	My desire to deeply understand the material rather than memorizing processes or procedures	2.49	2.57	0.745
	My ability to study for tests and exams	2.63	2.73	0.672
	Lacking confidence	2.16	2.28	0.650
	Having adequate background knowledge of the subject	2.01	2.11	0.628
	Asking for help when needed	2.48	2.32	0.547
	Taking notes in class	1.73	1.89	0.472
	Working with an online mathematics homework program	2.68	2.47	0.452
	Adapting to the university environment	2.38	2.19	0.448
	My ability to think mathematically	1.82	2.00	0.394
	Being overconfident	1.90	2.11	0.340
	Paying active attention during class	2.16	2.43	0.243
	Completing assignments	1.95	2.27	0.135
	Having an appropriate balance of my social and academic life	2.37	2.00	0.104
	Self-motivation	2.28	2.68	0.094
Other	The availability of help	1.77	1.86	0.647
	The course being relevant to my major*	1.69	2.11	0.049

Note: Differences between the ratings of items with (*) are statistically significant ($p < 0.05$).

Four of the items were ranked so similarly between the two groups that the difference between the averages of the groups was less than or equal to 0.05. These items include the following: "the instructor was supportive and approachable", "giving consistent effort", "my interest in the class", and "working with ideas presented during class on my own."

The greatest differences in ratings between the students with a math gap and those without a math gap were attributed to the factors "the course being relevant to my major" and "self-motivation." "The course being relevant to my major" was rated a 2.11 by students with a math gap and 1.69 by students with no math gap, a difference of 0.42. This was the only difference deemed statistically significant with a *p*-value of 0.049. "Self-motivation" was ranked 0.40 higher by students with a math gap than those without a math gap (2.68 compared to 2.28), but this difference was not found to be statistically significant.

First Michigan Tech Mathematics Course

The data were also analyzed in terms of the first mathematics course the participants took at Michigan Tech. For this analysis, the participants were divided into three groups: those whose first course was Precalculus or lower, those whose first course was Calculus I, and those whose first course was Calculus II or above. This data can be seen in Table 4. Overall, there seemed to be a trend in which the students whose first mathematics class at Michigan Tech was Precalculus or below rated the items as more difficult than those who took Calculus I, and those who took Calculus I rated the items as more difficult than those who began in Calculus II or above, though this was not always the case. An example where the averages did not follow this trend came with the item, "the number of examples worked in class." This factor was given the highest rating by students who began with Calculus II and above, with a rating of 2.48, and the next highest rating was given by the Precalculus and below group with a 2.40. Calculus I students rated this item lower than the other two groups, giving it an average of 2.33.

The students whose first mathematics class at Michigan Tech was Precalculus or below gave self-motivation an average rating of 3.24, while the Calculus I students gave it a 2.34 and the Calculus II and higher students gave it a 2.00. This item had the second largest gap between the highest and lowest scores among all of the given factors.

Interestingly, the Precalculus and below students were the only group to rate any item with an average of 3.0 or above, and of the 33 items given, they rated five of them this high (difficult): "self-motivation", "my ability to study for tests and exams", "my desire to deeply understand the material rather than memorizing processes or procedures", "my interest in the class", and "interesting lectures." As noted previously, the highest

average rating belonged to the category "my desire to deeply understand the material rather than memorize processes and procedures" with a rating of 3.48.

Table 4

Average ratings by first mathematics course taken at Michigan Tech

	Factor	Precalculus and Below (n = 24)	Calculus I (n = 106)	Calculus II and Above (n = 65)	p-Value
Instructor-centered	The number of examples worked out in class	2.40	2.33	2.48	0.767
	Clarity of lectures	2.80	2.62	2.72	0.764
	Well-structured lectures	2.52	2.17	2.16	0.448
	Pace of course	2.36	2.13	1.98	0.410
	Instructor was supportive and approachable	2.32	2.06	1.89	0.337
	Instructor was enthusiastic/inspiring	2.60	2.13	2.17	0.283
	Assignments that relate to the lectures	2.40	1.99	2.02	0.274
	Interesting lectures	3.00	2.53	2.55	0.263
	Instructor had realistic expectations of my prior mathematics knowledge	2.28	2.06	1.83	0.230
	Appropriate workload for the class*	2.44	2.05	1.81	0.045
	Classroom was orderly and controlled*	1.96	1.46	1.38	0.021
	Clear expectations for the class*	2.24	1.83	1.53	0.017
Student-centered	Regularly attending class	1.64	1.42	1.42	0.603
	Reading material before each class	2.56	2.57	2.34	0.532
	Being overconfident	2.08	2.02	1.80	0.425
	Adapting to the university environment	2.63	2.35	2.19	0.359

Table 4 (continued)

	Factor	Precalculus and Below (n = 24)	Calculus I (n = 106)	Calculus II and Above (n = 65)	p-Value
Student-centered	Working with ideas presented during class on my own	2.52	2.28	2.05	0.227
	Having adequate background knowledge of the subject	2.16	2.13	1.78	0.149
	Working with an online mathematics homework program	3.20	2.50	2.64	0.108
	Lacking confidence	2.64	2.22	1.92	0.071
	Taking notes in class	2.24	1.76	1.58	0.062
	Giving consistent effort	2.76	2.21	2.06	0.051
	Asking for help when needed*	2.80	2.60	2.08	0.023
	Paying active attention during class*	2.84	2.19	2.03	0.021
	Having an appropriate balance of my social and academic life*	2.72	2.39	1.98	0.021
	Self-motivation*	3.04	2.34	2.00	0.003
	My ability to study for tests and exams*	3.20	2.75	2.25	0.002
	Completing assignments*	2.76	1.93	1.84	0.002
	My interest in the class*	3.08	2.07	1.92	0.001
	My desire to deeply understand the material rather than memorizing processes or procedures*	3.48	2.57	2.00	< 0.001
	My ability to think mathematically*	2.52	1.90	1.50	< 0.001
Other	The availability of help	2.00	1.84	1.63	0.276
	The course being relevant to my major*	2.64	1.69	1.53	< 0.001

Note: Items with (*) are statistically significant ($p < 0.05$).

When broken down into these groups, there were two factors that had averages of 1.50 or below: "regularly attending classes" and "the classroom being orderly and controlled." Both the Calculus I and the Calculus II and above groups rated each of these items below a 1.50. With the former, both groups gave it an average rating of 1.42. The latter was given a 1.38 rating by the highest-level students and a 1.46 by the Calculus I students. It is also worth noting that these same two items were the only ones given a rating of less than 2.00 by the students whose first class was Precalculus or below, with "regularly attending class" rated 1.64 and "the classroom being orderly and controlled" rated 1.96.

Using the one-way ANOVA test, it was found that 13 of these factors had differences in ratings that were statistically significant. What this means is that at least one of the group means—for students whose first mathematics class at Michigan Tech was Precalculus or below, those who took Calculus I, and those whose first class at the university was Calculus II or above—was significantly different than the other two. These items deemed statistically significant are marked with an asterisk in Table 4. Once an item was deemed statistically significant, a pairwise ANOVA test (with p value 0.05) was completed in order to determine which group means were different.

Three instructor-focused factors were found to be statistically significant among the groups: "having clear expectations for the class", "appropriate workload for the class", and "the classroom being orderly and controlled." In each case, the Precalculus and below students' difficulty rating was significantly higher than the Calculus II and above group. The associated p-values were $p = 0.004$, $p = 0.017$, and $p = 0.019$, respectively. The Precalculus and below group's average rating for "the classroom was orderly and controlled" was also significantly higher than the average rating given by the Calculus I group ($p = 0.017$), but there was not significant difference found between the ratings given by the Precalculus and below and Calculus I groups for neither "having clear expectations for the class" nor "appropriate workload for the class." Another factor found to have statistically different averages was the item about the course being relevant to the students' major. This factor is neither student- nor instructor-centered, but again, the Precalculus and below students rated it statistically higher (more difficult) than the other two groups ($p < 0.001$ when comparing it pairwise to each of the other groups).

There were a number of student-centered factors for which the Precalculus students' ratings were found to be significantly higher (rated more difficult) than the other two groups: "self-motivation", "completing assignments", "my desire to deeply understand the material rather than memorizing processes or procedures", "my interest in the class", "paying active attention during class", and "my ability to think mathematically."

There were also some student-centered factors that the Calculus II students rated statistically less difficult than the other two groups: "my ability to study for tests and exams, asking for help when needed", "my desire to deeply understand the material rather than memorizing processes or procedures[3]", "having an appropriate balance of my social and academic life", and "my ability to think mathematically."

Course Grade

The final way the data were divided was based on the grade received by the student in their first mathematics class at Michigan Tech. Three groups were again formed: those who received a grade of A, AB, or B, those who received a BC, C, or CD, and those who received a D or F grade[4]. Grouping the data this way brought to light several differences.

As Table 5 shows, every item except for one was given the lowest average rating by the A – B students and the highest rating by the D/F students. The only item that was ranked more difficult by the A – CD students than the D/F students was "being overconfident", which was rated 1.91 by the A – B students, 2.07 by the BC – CD students, and 1.88 by the D/F students.

Most of the items, 28 of the 33, were deemed to have statistically significant different ratings among the groups. These items have been marked with an asterisk in Table 5. In each case where there was a statistically significant difference found when using the ANOVA test to compare the average of the three groups on a single item, a pairwise ANOVA test was also used to determine which group(s) had a different average. In every

[3] When tested pairwise with an ANOVA test, the items "my desire to deeply understand the material rather than memorizing processes or procedures" and "my ability to think mathematically" were found to have been given different averages by all three groups (i.e. No two groups had the same average).

[4] One student did not report a grade and two other students reported receiving a grade other than what is on the A – F scale.

Table 5

Average ratings by grade received in first mathematics course taken at Michigan Tech

	Factor	A, AB, B (n = 132)	BC, C, CD (n = 44)	D/F (n = 16)[5]	p-Value
Instructor-centered	Clarity of lectures*	2.34	3.11	3.88	< 0.001
	The number of examples worked out in class*	2.12	2.72	3.56	< 0.001
	Assignments that relate to the lectures*	1.83	2.40	2.93	< 0.001
	Instructor was supportive and approachable*	1.76	2.33	3.44	< 0.001
	Well-structured lectures*	1.88	2.63	3.88	< 0.001
	Clear expectations for the class*	1.57	1.86	3.25	< 0.001
	Appropriate workload for the class*	1.81	2.19	3.06	< 0.001
	Instructor was enthusiastic/inspiring*	1.98	2.26	3.56	< 0.001
	Interesting lectures*	2.30	2.81	4.19	< 0.001
	Instructor had realistic expectations of my prior mathematics knowledge*	1.76	2.10	3.56	< 0.001
	Classroom was orderly and controlled*	1.35	1.50	2.44	< 0.001
	Pace of course*	1.82	2.48	3.31	< 0.001
Student-centered	Being overconfident	1.91	2.07	1.88	0.731
	Taking notes in class	1.70	1.72	2.13	0.404
	Regularly attending class	1.39	1.58	1.69	0.357
	Reading material before each class	2.40	2.57	2.88	0.335
	Adapting to the university environment	2.22	2.40	2.94	0.098

[5] One student from this group took Calculus II as their first mathematics course at Michigan Tech. Nine took Calculus I and six took Precalculus or lower.

Table 5 (continued)

	Factor	A, AB, B (n = 132)	BC, C, CD (n = 44)	D/F (n = 16)[6]	p-Value
Student-centered	Paying active attention during class*	2.08	2.30	3.00	0.015
	Giving consistent effort*	2.02	2.59	2.81	0.003
	Self-motivation*	2.11	2.64	3.44	< 0.001
	My ability to study for tests and exams*	2.30	3.23	3.75	< 0.001
	Completing assignments*	1.82	2.16	3.06	< 0.001
	Asking for help when needed*	2.22	2.61	3.81	< 0.001
	My desire to deeply understand the material rather than memorizing processes or procedures*	2.15	3.02	3.50	< 0.001
	My interest in the class*	1.80	2.50	3.75	< 0.001
	Having adequate background knowledge of the subject*	1.75	2.37	2.88	< 0.001
	Having an appropriate balance of my social and academic life*	2.11	2.48	3.38	< 0.001
	My ability to think mathematically*	1.52	2.26	3.31	< 0.001
	Lacking confidence*	1.87	2.48	3.75	< 0.001
	Working with ideas presented during class on my own*	1.96	2.67	3.25	< 0.001
	Working with an online mathematics homework program*	2.38	2.81	4.00	< 0.001
Other	The availability of help*	1.57	2.09	2.50	< 0.001
	The course being relevant to my major*	1.59	1.88	2.75	< 0.001

Note: Items with (*) are statistically significant ($p < 0.05$).

[6] One student from this group took Calculus II as their first mathematics course at Michigan Tech. Nine took Calculus I and six took Precalculus or lower.

case where the pairwise ANOVA test was performed, the average of the A – B group was found to be statistically different than the average of the D/F group. Since the D/F group gave a higher average rating to each factor that was deemed to be statistically significant, if the factor had a statistically significant difference among the groups, then the D/F group rated it higher, meaning that they found that factor more difficult than the A – B students.

Every instructor-centered factor was deemed to have statistically significant rating differences among the groups. For four of the twelve instructor-centered factors, the D/F group rated the factor as more difficult as the other groups, but the A-B students and BC-CD students rated the item as not statistically different using pairwise ANOVA tests. These items were "clear expectations for the class", "instructor was enthusiastic/inspiring", "instructor had realistic expectations of my prior mathematics knowledge", and "classroom was orderly and controlled." One item, "assignments that relate to the lectures", received a statistically lower rating from the A-B group than the other groups, while the BC-CD and D/F groups' ratings were not statistically different. In the remaining seven instructor-centered factors, no two groups' ratings were the same. These items include "clarity of lectures", "the number of examples worked out in class", "instructor was supportive and approachable", "well-structured lectures", "appropriate workload for the class", "interesting lectures", and "pace of course."

Fourteen of the nineteen student-centered factors were found to be rated statistically different among the three groups. One of these factors, "paying active attention during class", was given ratings by the A-B and the D/F group that were statistically different using a pairwise ANOVA test, but neither of these groups' rating was statistically different from the rating given by the BC-CD group. Five student-centered factors were rated less difficult by the A-B group than the other two groups: "giving consistent effort", "my ability to study for tests and exams", "my desire to deeply understand the material rather than memorizing processes or procedures", "having adequate background knowledge of the subject", and "working with ideas presented during class on my own." Four factors were rated statistically more difficult by the D/F students. These include "completing assignments", "asking for help when needed", "having an appropriate balance of my social and academic life", and "working with an online mathematics homework program." The

remaining four student-centered factors, "self-motivation", "my interest in the class", "my ability to think mathematically", and "lacking confidence", were all rated differently by each grade group.

There were two factors on the survey that were not instructor- or student-centered, "the availability of help" and "the course being relevant to my major." Both of these items were deemed to be statistically significant. "The availability of help" was rated statistically lower by the A-B group when compared to the other two grade groups, and "the course being relevant to my major" was rated statistically more difficult by the D/F group when compared to the more successful students.

Suggestions from Students

For the last part of the survey, participants were asked if they had any suggestions as to how instructors in the mathematics department could help aid first year students in making the transition from high school to undergraduate mathematics. Of the 198 participants, 87 provided responses in this area. The most popular response (14 respondents) involved the use of examples during class time. One student said, "I think examples in class are a very big plus, they help a lot," and another said to "give harder examples in class." While some students asked for more examples, other asked for "better" examples, citing the fact that some instructors will use examples from the textbook, or change a few numbers. One student puts it this way: "Doing the book examples in class, and only the book examples, does nothing to help students who don't understand the book examples to learn." A handful of students asked that the examples displayed in class be more pertinent to the homework.

The next most common response, with 13 participants mentioning it, had to do with online homework systems. Some suggestions were that online homework not be used at all, while others asked for reminders to complete the homework. One student said that the programs they used "were hard to adapt to", and "if more in class assistance was offered for those programs, that would be [useful to students]." Along the same lines, a different student said that they "went to high school with everything being on paper and [having homework] online was really hard to get use [sic] to." Another student said that "some

classes [had] very poor communication about online homework and it [didn't] line up well with what was due when."

Eleven students commented about the mismatch between what previous mathematics knowledge students have, and what knowledge the students actually possess. Several students expressed that they feel as though instructors believe they have more background knowledge than they actually do. One participant wanted instructors to "[not] assume that everyone learned the same things in high school." They went on to say, "It's alienating to say 'You should have learned [math concept] in high school so this should be easy.' Sometimes, I didn't learn certain things and I felt like my professor would think I was stupid for not knowing a supposedly 'easy' concept." Another participant gave this suggestion for instructors: "Find out what [your students] already know and start from the weakest link and spend a couple days to get the basics covered." Yet another said to "[not] automatically assume [the students'] high school made [them] memorize all formulas and identities," in reference to trigonometric identities. Another suggested to "explain everything, including the things you think are self-explanatory, because they may be new concepts to some students."

Although these were clearly the most common answers given by students, there were a few other comments that were given by several students. Some people asked that more emphasis be put on getting help outside of class, whether through the use of instructor office hours or the Math Learning Center, where students can get free peer tutoring on campus. Several students put the responsibility on the student, saying that having a tutor is a great help, but this was not the only view. As one student suggests for instructors, "Urge [your] students to seek the aid of [Michigan Tech's] various resources even if they dont [sic] feel like they need them because they will significantly ease the transition for the students." Another student said that it is important to "[stress] the importance of office hours, many students don't understand what office hours are and/or are hesitant to use them for fear of what the teacher might think."

A few students asked for more or extra materials in addition to the homework already being given. A student said that the "short pre-lecture assignments [that were used] to explain big ideas [were] helpful for calculus students in [their] opinion." A common

suggestion in this area was ungraded homework or worksheets that could be used as practice. One student wrote that they "would like more material that [they] can access…maybe a set of videos and/or worksheets that are available online for everyone taking a math course." Others suggested that some students take a mathematics class one lower than the one they were placed in. Some students were uncomfortable with the pace of the course, and some were overwhelmed with the amount of work given during the class. One students suggested to "start slow and make a strong foundation for the knowledge to push forward." Another expressed being overwhelmed by Calculus I. They said, "I found the class very fast and I felt as though I was already supposed to know what I was doing…I was quickly overwhelmed."

Chapter 5
Discussion and Conclusion

This research was designed to answer several questions about what causes first year students to struggle in their first mathematics class at Michigan Tech, how these struggles differ among different groups of students, and what instructors at Michigan Tech can do to ease the transition from high school mathematics courses to university-level courses. The data collected led to some interesting findings.

Overall Results

The average ratings of the factors by the entire group of participants showed that no one factor seemed to be excessively difficult to all students. However, of the items rated 2.5 or above, two of them were instructor-focused and three of them were student-focused. This seems to indicate that students are not seeing their struggles as being entirely instructor-related, but are also recognizing that some of their issues are related to themselves.

Some of the high-rated student-centered factors—ability to study for tests and exams, working with an online homework system, and asking for help—could be explained by the fact that most of the first year students attend Michigan Tech right after finishing high school, so several of these factors might be things that students may not have had to handle before. For example, many students mentioned that they had never worked with an online homework program before, which may have caused them to struggle with it their first time. Also, many students may not have had to study as hard before as they did once they arrived at Michigan Tech because the material they learned in high school may have come easy to them. This is supported by Anthony's (2000) findings that suggest that college students may be lacking in study skills. Also, students may not feel comfortable asking for help if they never had to before. It can be difficult for some students who did well in high school to continue their success through their first year at a university.

The highest-rated factor overall was "clarity of lectures", and the fourth highest-rated factor was "interesting lectures"; these were the two highest rated instructor-centered

factors. These two factors are both related to how the instructor approaches the class, not necessarily the instructors themselves. These results suggest that when constructing their lectures, instructors should contemplate, from a student's point of view, if the material they are going to teach will be coherent if they are learning it for the first time and if students would find the way they are being presented the material to be interesting. This may mean that instructors could consider other teaching methods if the material seems dry or boring for students. As mentioned by several students in the written comments, some instructors may offer worksheets, pre-class readings/quizzes, or other supplemental material to get students engaged differently than in traditional lectures. Boyles et al. (2011) received similar feedback in their study, where students suggested that lectures that are put together well are easier to follow.

On the other end of the spectrum, the factors "the classroom was orderly and controlled" and "regularly attending class" both received the lowest overall ratings by the whole group. It should be noted that although the low ratings suggest that students did not think attending class was a factor that caused them difficulty, this does not necessarily mean they attended class. The students, in general, also did not seem to struggle with their courses being relevant to their major or taking notes. These results suggest that the maturity level of college students allows the classrooms to be controlled and not interfere with learning. Additionally, the students seem to be seeing their first mathematics courses at the university as being relevant to their major, and the students are willing to take notes during class as a way to focus or boost their performance.

Results by Subgroup

After being analyzed overall, the data were grouped in four different ways in an attempt to find if there were differences between the reasons different groups of students struggle in making the transition from high school mathematics to university mathematics. Differences in math gap—the time between a students' last high school and first college courses—was not found to be an important influence on the reasons behind student struggles. When divided by the participants' first mathematics class at Michigan Tech, some differences were found, but this did not seem to be a big influence either.

The two biggest differences between student groups came from their highest level of mathematics before arriving at Michigan Tech and the grade they received in their first mathematics course at Michigan Tech. The students whose mathematics class before Michigan Tech was Precalculus or below struggled more, overall, than those who took Calculus I or above before arriving at the university. Likewise, students who received a D/F grade in their first college course struggled with more factors than those who received a BC-CD grade, and the A-B students struggled the least.

High School Course

The highest level of mathematics students took before taking mathematics at Michigan Tech was found to have a large impact on the struggles the students had. All but two of the instructor-based factors were rated significantly more difficult by the students who took Precalculus or below as their highest level of mathematics before arriving at Michigan Tech than by the students whose highest mathematics course was Calculus I or above. Although both groups rated "interesting lectures" and "clarity of lectures" as the factors they struggled with the most (meaning that these factors had some of the highest average ratings for each group), the students who only had Precalculus rated them significantly more difficult. This could indicate that students are not interested in the material or the way it is presented, and possibly that they do not understand the material as it is presented to them. This could be a result of students needing time to become accustomed to university instructors and their ways of teaching, or it could stem from the fact that some international instructors in the mathematics department at Michigan Tech have accents that students may not have experienced before. In fact, of the 60 comments left by the students whose highest level of mathematics was Precalculus or below, five of them were related to their instructor having an accent that made it difficult for the student understand them. These factors may be things that are new to first-year students, and it could take time for the students to adjust them.

Another factor rated more difficult by the students who were in the Precalculus and below student group was "instructor had realistic expectations of my prior mathematics knowledge." Six students from this group left comments related to their instructor not being

familiar with their mathematics background. One student said that they felt as though they had less knowledge than the other students in their class. Another student said that they liked instructors who gave students pretests as a way of finding out what mathematics knowledge students already have. While six of the lower-level students commented about their instructor not having realistic expectations about their prior knowledge, only one of the upper-level students commented on the subject, which could support the difference in ratings between the two groups.

The Calculus I and above student group rated "clear expectations for the class", "appropriate workload for the class", and "pace of course" relatively low, whereas the Precalculus and below students rated them as more difficult. This might be explained by the fact that Calculus classes are typically considered college-level classes, and are often taught with similar expectations to college courses, even when taught in a high school setting. The students who had taken these college-level courses before arriving at Michigan Tech may have an advantage in the fact that they might have had experience with the speed and manner in which a college mathematics course is taught. The lower-level students likely did not have that experience, so this may explain why they struggled with it more. This is supported by Jackson and Leffingwell (1999), who found that the pace of lectures is a factor in student anxiety. If the course is too fast-paced for students, they may get anxious and start to struggle more in the class.

When it came to the student-centered factors, the Precalculus and below students reported more struggle with the online mathematics homework program and studying for tests and exams than the Calculus I and above students. In the written comments, nine of the lower-level students mentioned that they struggled with the online homework program they were using, and only one of the upper-level students mentioned it. It could be the case that the lower-level students do not have the background to be as mathematically accurate as the homework program expects. For example, one student left a comment about how students need to pay attention to the use of parentheses or brackets and union symbols for some of their homework assignments. The students with a higher-level background might have a better grasp of the mathematical notation, so this may not be as much of an issue for them. As far as studying goes, several of the Precalculus and below students mentioned

that they never learned how to study, so when they did not understand all of the material the first time through, they were not sure how to learn it better. Some suggested having instructors teach study skills in order to help students learn more on their own.

First Michigan Tech Mathematics Course

To look at the first mathematics course students took at Michigan Tech, the data were divided into three groups: Precalculus and below, Calculus I, and Calculus II and above. Although difference in the first mathematics course taken at Michigan Tech was not a large influence on student struggle, it is interesting that most of the factors that were found to be statistically different among the three groups were student-centered factors. Among these significant student-centered factors, a majority of them were rated more difficult by the Precalculus group and were focused around the idea of students concentrating and getting their work done. These include "self-motivation", "completing assignments", and "paying active attention during class." These findings suggest that instructors for these lower-level mathematics courses may need to make active attempts to keep students engaged and interested in the class and to help them figure out how to study and seek extra help. This relates to prior research findings that suggest that if student confidence is increased and mathematical anxiety is decreased, then students are more likely to succeed (Clute, 1984; Dowling, 1979; Fennema & Sherman, 1976; House, 1995, 2000; Randhawa, Beamer, & Lunderg, 1993; Reyes, 1980). Thus, if students are given increased encouragement and extra help, they may be more confident in their mathematics, which may help them perform better. Also, based on a study by Boyles et al. (2011), if instructors of these classes encourage the use of outside resources such as their office hours and the Michigan Tech Math Learning Center, their students might take this suggestion as a way of getting help when they need it. Getting extra help may also support the students with completing assignments and studying for tests and exams.

It is interesting that the Precalculus and below students also struggled with their "desire to deeply understand the material", whereas the more advanced students did not. This is similar to the Stage and Kloosterman (1995) findings that suggested that many students attempt to learn mathematics by only learning the formulas and methods rather

than the larger topics. It could be that the classes these students had taken in the past were taught in a way such that each problem has a method for solving it, but in college were being introduced to problems where they need to connect ideas from different topics in order to solve them. The students whose first mathematics course at the university was Calculus I or above may not have felt this same struggle because nearly two-thirds of the Calculus I and all of the Calculus II and above students had experienced college-level mathematics before taking mathematics at Michigan Tech (whether a Calculus class or an AP Statistics class). These students may have already developed the need to deeply understand the material, which tends to be necessary in the higher-level mathematics.

Course Grade

The students were also grouped by the grade they received in their first mathematics class at Michigan Tech. Out of the four highest-rated (and thus most difficult) factors for the D/F students, three of them were related to lectures: "clarity of lectures", "well-structured lectures", and "interesting lectures." It is possible that the instructional methods that are effective for the more successful students do not have the same effect on the students that do not perform as well. The students that do not perform as well may need more structured lessons with clearer examples. Trying to keep the class engaged by creating interesting examples and connecting the material to everyday life or previous knowledge might help students concentrate in class.

Every single one of the instructor-centered factors were found to have statistically different average ratings between the groups, and 11 of the 12 were rated statistically higher by the D/F group than the others. Some of these factors include "appropriate workload for the class", "instructor had realistic expectations of my prior mathematics knowledge", "pace of course", "instructor was supportive and approachable", and "instructor was enthusiastic/inspiring." Part of the reason these students may have struggled with these items, particularly the last two, could be the way the student perceives the instructor. If the instructor is seen as being uncaring or unenthusiastic, students may not feel as confident in the classroom (Jackson & Leffingwell, 1999). In addition, students have been found to prefer learning from instructors who were passionate Anthony (2000). If instructors

showed their desire to teach students, it might help the students be more at ease in the classroom.

These findings suggest several ways that instructors might better support their low achieving students. For example, at the beginning of the semester, it may be useful for the instructor to gauge what mathematics knowledge their students are bringing with them so they know the different knowledge levels of their students. From there, instructors can figure out the strengths and weaknesses of the class, and build their lessons around that. By paying attention to where students are struggling, not only in the beginning, but also throughout the semester, instructors may be able to ease students' worry about the course pacing. Instructors should also be aware of how much homework they are giving students. According to student comments, they sometimes felt overwhelmed by the amount of work they had to do. It could be that it takes the D/F students longer than the other students to complete the work given to them. Instructors could consider measures such as creating worksheets to be completed in class to relieve the homework load, or even doing the homework themselves so they have an idea about how long it will take their students. With so many of the instructor-related factors being rated significantly higher by the D/F students than the others, it is also possible that these students believe it is their instructors' fault for them doing so poorly in classes.

A peculiar finding came from reviewing the comments left by students regarding the number of examples worked out in class. Fifty-six of the A – B students left comments, and ten of them related to the examples shown in class. For example, one student commented that the instructor should do more examples in class, and work through both easy and difficult practice problems after reaching a method in class. Of the 23 students that left comments in the BC – CD group, five of them were example-related. However, none of the D/F students left comments related to examples, even though nine of the sixteen D/F students left comments. This may suggest that it is not the lack of examples, or "good examples," as some students put it, that are one of the biggest reasons for the poor performance of this group of students.

Eight of the nineteen student-centered factors were rated statistically higher by the D/F group than the other groups. These factors include "self-motivation", "completing

assignments", "asking for help when needed", "my interest in the class", "having an appropriate balance of my social and academic life", "my ability to think mathematically", "lacking confidence", and "working with an online mathematics program." Of these factors, the D/F group gave an extremely high rating to working with an online mathematics homework program. Since these students indicated that they struggled with the lectures, they may also not have the mathematical background to do well on the online homework, particularly given that it requires accurate use of mathematical notation. This group of students also indicated that they struggled significantly more than the other groups with asking for help. If these students struggled with the online mathematics homework program early on in the semester and never asked for help, this might have led to them to struggle with it for the rest of the semester. If not already in place, it may be useful for instructors to give students an exercise in the homework programs that allows them to learn how to give the computer mathematical input. It is possible that if the instructors could encourage students to ask for help when needed, or if the instructor showed the students in class how to use to homework program, then the students may have increased confidence in using it, which may help their performance.

Limitations

The survey given for this study was distributed via email during the summer of 2016 to students who were identified as first year students during the 2015-2016 school year. Many students may not check their school email addresses during the summer, which may have led to a smaller sample size. This survey was sent to all first-year students, but it was then their choice if they wanted to complete the survey. Each question was also optional, so it was the students' choice whether or not they wanted to answer each of the questions.

The sizes of the groups, once the data were divided, were not always very similar. For example, 156 respondents had no math gap while 37 did. While 106 students took Calculus I as their first mathematics class at Michigan Tech, 24 took Precalculus or below, and 65 took Calculus II or above. When divided by grade, 132 students reported getting an A, AB, or B in their first mathematics class at Michigan Tech, while 44 got a BC, C, or

CD, and only 16 received a D or F grade. With such a small group size, each individual response has more influence on the average than when the group is larger.

This study only sampled students from one incoming class. If there were more classes sampled, a more well-rounded idea of how students feel would emerge. Also, since this survey was given in the summer, some students may have taken their first Michigan Tech mathematics class during the fall of the previous year, so their thoughts may have changed over the spring semester.

Further Research

The findings of this study indicate that it may be interesting to look into the implications of using an online mathematics homework system. Considering how many students were concerned about using these systems, it would be interesting to find out how other students feel about such systems and what the differences in student understanding and performance exist between using online homework instead of handwritten work. It may also be intriguing to explore what causes students difficulty when working with an online homework program.

It may also be interesting to investigate what types of examples are most useful to students. Some students were upset that their instructors used examples straight from the textbook or only changed a few numbers. They suggested that instructors try to come up with their own examples that are more pertinent to the homework. Others suggested that the examples given in class be harder so the homework seems easier. Trying to figure out what examples really help the students work with and learn the material best would be useful for instructors to know.

Implications

Instructors should keep in mind that different students have different needs. Clearly, based on this research, a lot of students struggle with understanding lectures when they are not perceived as clear. Thus, instructors should consider how to make lessons flow as best as they can. If ideas transition from one to another rather than jumping around, it will likely be easier for students to follow (Boyles et al., 2011). Deriving formulas and equations used may also be a good way to help students understand why a certain method is used for a

particular problem. In fact, four students suggested that instructors show where equations come from and why they work as a way to help students grasp the bigger picture of a lesson.

The findings of this study suggest that instructors for mathematics courses that are higher-level, but still have a fair number of first-year students such as Calculus I, Calculus II, or Multivariable Calculus, should consider incorporating more examples into their lectures, as several of these students feel as though examples are useful to them, based on the suggestions given by these students. This is supported by Jackson and Leffingwell (1999) who found that students prefer when an instructor provides clear examples and the steps needed to solve the problem are explained and shown explicitly.

Instructors should also consider giving students suggestions about how to study for their class. As mentioned above, the factor "my ability to study for tests and exams" received the second-highest rating over all students, but was also in the top two highest-rated items by students whose first mathematics class at Michigan Tech was Calculus I or below. In addition, multiple students' comments said they did not know how to study, so it may be useful for instructors to teach their students how to study for their class. For example, the best way to study for some classes would be to work through the homework problems. In some classes, instructors give out worksheets either as study guides or with extra practice problems that may be useful to students, as some of the participants suggested in their comments. In other classes, the best way to succeed is to study practice exams. Other times, understanding the basics thoroughly is the key to success. If instructors give this guidance in the beginning of the class, it may help students as they work their way through the course material.

If an instructor uses an online homework program, they should consider showing students extensively how to use it. Several students reported feeling uncomfortable using an online program that they are unfamiliar with and it can be very frustrating to students if they get the right answer but do not know how to input it into the computer. Giving students an ungraded introductory exercise could help students get acclimated to the program and may help them down the line. Considering how much difficulty the D/F students had with the online mathematics homework programs, giving students this extra help may aid them in their performance.

Five of the students suggested that they be encouraged to take a lower class than the one they were placed in when signing up for mathematics classes. Clearly not all students will want to do this, but if a student feels like they do not have a strong base of knowledge going into a class, or if they start struggling early in the semester, the instructor could encourage the student to drop down to a lower level class. This course change could help the student review what they may already know, and fill in the gaps of what they do not yet fully understand. This may not be an option all the time, but it could be useful in some cases to help out the students who are not prepared for the course to which they are assigned.

Conclusion

There are several factors that affect how students perform in a mathematics classroom, but the two biggest differences appear to be among students who took different highest mathematics courses before arriving at Michigan Tech and among those who receive different grades in their first mathematics course at the university. If instructors are aware of which students are struggling and why they might be struggling, then they can help students overcome these obstacles. One of the biggest keys is having instructors provide clear, well-organized lectures, as supported by Boyles et al. (2011). Students who want to succeed in the classroom may need some guidance, so if instructors take active steps toward helping these students, there may be more first year students coming out of their first university mathematics classes feeling as though they have met the learning goals of the class. It is up to instructors to give students what they need in order to fully embrace their mathematics potential in the classroom.

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Appendix A: Survey

1. What was the highest level math class you took in high (secondary) school? (If you took math classes through a college while in high school, pick the overall highest level course you took through the college.)
2. How much time had elapsed between your last high (secondary) school math class and your first math class at Michigan Tech? (Examples: If you took math your junior year of high school and not again until your second semester at Tech, report 3 semesters. If you took math your senior year of high school and again your first semester at Tech, report 0).
3. What was the first math class you took at Michigan Tech (if any)?
4. What grade did you receive in your first math class at Michigan Tech?
5. Below is a list of factors that may affect students' transition from high school mathematics classes to those at the university level. For each item, indicate the extent to which it caused you difficulty in transitioning to university mathematics, using a scale ranging from 1 (caused me no difficulty) to 5 (was a significant difficulty for me).
    a. Self-motivation
    b. My ability to study for tests and exams
    c. Completing assignments
    d. Asking for help when needed
    e. The availability of help
    f. Clarity of lectures
    g. The number of examples worked
    h. My desire to deeply understand the material rather than memorizing processes or procedures
    i. Assignments that relate to the lectures
    j. Instructor was supportive and approachable
    k. Giving consistent effort
    l. Well-structured lectures

m. Regularly attending class
n. Taking notes in class
o. My interest in the class
p. Paying active attention during class
q. Clear expectations for the class
r. Appropriate workload for the class
s. Instructor was enthusiastic/inspiring
t. Interesting lectures
u. Having adequate background knowledge of the subject
v. Instructor had realistic expectations of my prior mathematics knowledge
w. Having an appropriate balance of my social and academic life
x. My ability to think mathematically
y. Classroom was orderly and controlled
z. The course being relevant to my major
aa. Reading material before each class
bb. Lacking confidence
cc. Being overconfident
dd. Pace of course
ee. Adapting to the university environment
ff. Working with ideas presented during class on my own
gg. Working with an online mathematics homework program

6. Do you have any suggestions for how instructors can help ease the transition from high school math courses to undergraduate math courses?