Qualitative analysis of students' perceptions of their self-efficacy in a flipped integral calculus course

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Abstract

Students' perceptions of their confidence in their ability to complete a task, known as self-efficacy, affects student effort and persistence (Bandura, 1978). Self-efficacy increases with improvements in learning methods and is a good predictor for success (Zimmerman, 2000). Classroom dynamics also impact students' self-efficacy by allowing for different kinds of self-efficacy opportunities (Sawtelle et al., 2012a). Previous research indicates that self-efficacy is context-specific (Bong and Skaalvik, 2003) and that male and female students benefit from different sources of self-efficacy (Zeldin et al., 2008); (Sawtelle et al., 2012b). In this study, we analyzed interviews from 12 students enrolled in a flipped integral calculus course to understand their perceptions of self-efficacy and how these perceptions impact their learning experiences. Findings reveal that experiences in previous math courses, particularly high school, impacted students' perceptions of their self-efficacy in math both positively and negatively, active learning increased students' confidence in their ability to do math from their perspective, and verbal persuasion (implicit encouragement) increased students' confidence and was seen as a helpful way to learn.

1 Introduction

Self-efficacy is the belief one has in their ability to complete a task, and can encourage or prevent one from trying new or challenging tasks. By flipping the traditional classroom model, we are able to examine more effectively how consistent, active interaction with a professor and undergraduate learning assistant provide self-efficacy opportunities to students, and learn how these opportunities affect students' learning experiences. Because self-efficacy is greatly affected by previous experiences with similar tasks (Bong and Skaalvik, 2003) and is a good predictor of student performance and persistence in mathematics (Pajares and Miller, 1994); (Zimmerman, 2000), it is important to understand how a flipped classroom structure can provide for more opportunities to increase students' confidence and self-efficacy, and which flipped classroom supports are most beneficial to students.

2 Literature Review

From the literature on self-efficacy, we know that men and women benefit from different sources of self-efficacy - women benefit more from vicarious learning experiences and verbal persuasion, whereas men tend to benefit more from mastery experiences (Sawtelle et al., 2012a). We also know that individuals with high self-efficacy are more likely to choose to attempt a task (Bandura, 1978), persist through difficulties, and persevere over time (Sawtelle et al., 2012a).

Many studies that compare student performance in lecture versus flipped classroom versions of the same course have been completed (Day and Foley (2006), Gross et al. (2015), Maciejewski (2015), Stone (2012)), and show that compared to lecture-based instruction, students in flipped classrooms have greater and improved grades (Adams and Dove, 2018), perform better on exams and concept

inventories and fail less (Freeman, 2014), and that "the positive effects of the flipped class are most pronounced for students with lower grade point averages and for female students" (Gross et al., 2015).

However, most studies do not look at the design of the flipped classroom itself (O'Flaherty and Phillips, 2015). This leaves instructors without a good framework for designing their own flipped classroom structures, negatively impacting chances for students to truly benefit from a flipped course. Students who are given video lectures outside of class are better prepared than students given only textbook readings (De Grazia et al., 2012).

Active learning has been shown to positively impact self-efficacy (Sawtelle et al., 2010), which is "a key predictor of achievement and retention" in math and science (Fencl and Scheel, 2005). Problem-based learning is active learning (Prince, 2004) but when combined with collaboration with peers, can have significant impact on "self-efficacy and classroom climate" (Fencl and Scheel, 2005). Active learning can provide for opportunities for students to become more comfortable in classroom environment and university through interaction with peers. "Insufficient interactions with peers can lead to a low commitment to the university" and may lead to changing majors or leaving college (Zwolak et al., 2017).

3 Background

The course in this study was Calculus II for the Mathematical and Physical Sciences, also known as Math 152, run in the summer of 2018. The class met three evenings each week for a total of 8 weeks, and was held in an active learning classroom on the College Avenue campus. The students in the course were mostly incoming sophomores and juniors, and many were retaking the course. In the flipped model, students worked through video tutorials at home, often using online interactive applets. Each 2hr 45min in-class session included a student-created summary of the main points from the videos, a brief quiz for accountability of the content outside of class, time spent at two or three rotating stations working through WebAssign homework, workshops, and any other material with the professor or the learning assistant, depending on the difficulty of the material. Each class session also included a second brief quiz on the WebAssign work, and enough time to finish remaining problems, or begin a new set of material.

4 Methods

This study uses mixed methods to investigate the relationship between a flipped classroom environment and student self-efficacy and learning experiences. We sought to answer two research questions:

1. How does the self-efficacy of math/physical students in a flipped Calculus 2 course change over the course of one semester? (Quantitative)

2. What is the perception of math/physical science students regarding the use of a flipped teaching strategy in a Calculus 2 course? (Qualitative, the focus of this thesis)

In order to answer the second question students were asked near the end of the course if they would participate in a brief, anonymous interview about the course as well as how they thought prior experiences with math may have affected their feelings toward math. Twelve students agreed to be interviewed and were asked the following questions (taken from Monterrosa et al. (2015)):

1. Tell me a story that explains something about the type of student you are in math. In other words, share with me something that happened to you that involves this subject and perhaps your parents, teachers, or friends.

    - How did this affect your mastery of math classes? (follow-up)

2. Describe the best teacher you've had in math. What made her (or him) so good?

3. Think about how math makes you feel. You probably haven't been asked to think about that before. When you are given a math test, how does that make you feel? How do you feel when you are given a math assignment?

4. Earlier you rated your math ability on a scale of 0 to 9. How would you rate your confidence in math now? Why?

5. What could make you feel more confident about yourself in math?

Each interview lasted about ten minutes, and was audio recorded using a digital recorder. The interviews were then transcribed by hand. Three researchers used open coding for the initial round of coding, highlighting key words and/or phrases that seemed important to each researcher. All initial codes were added to a spreadsheet, resulting in over 900 items. Subsequent rounds of coding used grounded coding which allowed categories to emerge from the 900 individual codes. During the first rounds of coding, a frequency count was determined for all of the open codes. The highest frequency categories seen were confidence (55 times), in-class activities (54 times), feelings toward or about math (51 times), activities outside of class (43 times), pre-college experiences (34 times), and specific courses mentioned (33 times). These became the four larger encompassing categories described in section 4.1. Examples of how the three researchers initially coded the same paragraph are given in figures 1, 2, and 3 below.

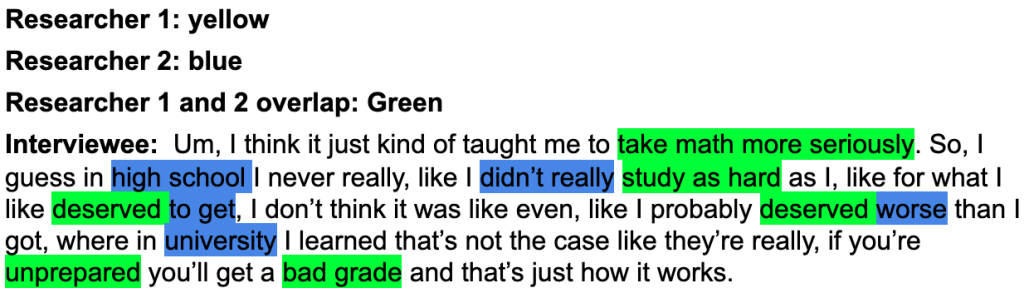

Figure 1: Coding comparison between researchers 1 and 2.

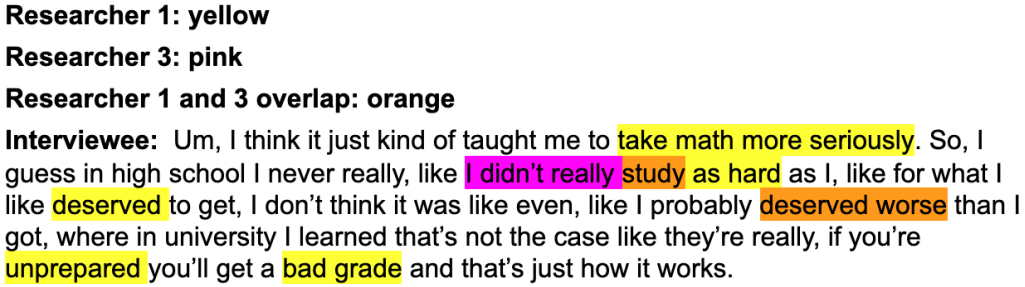

Figure 2: Coding comparison between researchers 1 and 3.

Researcher 2: blue

Researcher 3: pink

Researcher 2 and 3 overlap: purple

Interviewee: Um, I think it just kind of taught me to take math more seriously. So, I guess in high school I never really, like I didn't really study as hard as I, like for what I like deserved to get, I don't think it was like even, like I probably deserved worse than I got, where in university I learned that's not the case like they're really, if you're unprepared you'll get a bad grade and that's just how it works.

Figure 3: Coding comparison between researchers 2 and 3.

4.1 Coding Scheme

To make later rounds of coding more consistent among the researchers and to transform the codes for analysis, a coding scheme was created using the four main categories as a foundation, and including the three self-efficacy opportunities seen in the interviews. The scheme was created in a way such that if in an interview a student mentioned a course, an activity, their confidence, and associated feelings in the same sentence or paragraph, that multiple codes could be used in such a way as to be distinct while also thorough. Due to the potential for complex multi-level codes, the codes were limited to two brief sub-levels. Because each code potentially is related to a student's experience, only the most relevant code are also be coded for a student's experience itself, and any additional codes do not include a third level code (see Table 1 below). The coding process using the scheme was most easily accomplished using a software program called Nvivo.

Using the Nvivo software, the researchers are able to more easily code for multiple different codes on the same line of text, while keeping each code distinct, since even a three-sentence paragraph can have half a dozen distinct codes. For example, from transcript D:

Ok. So, I guess, in high school, I was like, very much like, top of the class, like worked really hard and everything, so math like really came easy to me my whole life. So, I was a good student, I would always study, make sure like grades were on top of it, and now like I came here, like, it's very much like a wakeup call. So, I mean now like I know it's like people like, my professors have talked to me about like, possibly having like math anxiety, now, and stuff, so it's definitely like now I feel like I kind of avoid it a little bit more, but um, yea, it's like definitely different for me now.

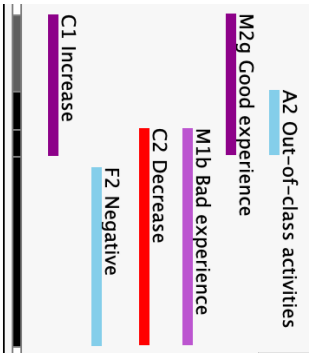

Figure 4: Example of a coded paragraph using Nvivo.

For reference, the codes in the above paragraph are (left to right): C1 increase in confidence; F2 negative feelings described; C2 decrase in confidence; M1b university/college course mentioned, bad experience; M2g high school course mentioned, good experience; and A2 out of class activity.

Table 1: Coding scheme for interview analysis, with the four main categories as well as self-efficacy opportunities identified.

Category	Code	Description
Activities mentioned	A1	In class activity.
	A1g	In class activity, good experience.
	A1n	In classactivity, neutral experience.
	A1b	In class activity, bad experience.
	A2	Out of class activity.
	A2g	Out of class activity, good experience.
	A2n	Out of class activity, neutral experience.
	A2b	Out of class activity, bad experience.
Confidence	C1	Increase in confidence
	C1g	Increase in confidence, good experience.
	C1n	Increase in confidence, neutral experience.
	C2	Decrease in confidence.
	C2n	Decrease in confidence, neutral experience.
	C2b	Decrease in confidence, bad experience.
Feelings toward or about math	F1	Positive feelings described.
	F1g	Positive feelings described, good experience.
	F1n	Positive feelings described, neutral experience.
	F2	Negative feelings described.
	F2n	Negative feelings described, neutral experience.
	F2b	Negative feelings described, bad experience.
	F3	Neutral feelings described.
Courses mentioned	M1	College or university course.
	M1g	College or university course, good experience.
	M1n	College or university course, neutral experience.
	M1b	College or university course, bad experience.
	M2	High school course.
	M2g	High school course, good experience.
	M2n	High school course, neutral experience.
	M2b	High school course, bad experience.
	M3	Middle school or elementary school course.
	M3g	Middle school or earlier course, good experience.
	M3n	Middle school or earlier course, neutral experience.
	M3b	Middle school or earlier course, bad experience.
Self-efficacy opportunity	O1	Mastery Experience
	O2	Verbal Persuasion
	O3	Vicarious Learning Experience

In creating the scheme, care had to be taken to maintain accuracy of the codes while preserving the simplicity of the process as much as possible. To that effect, a set of guidelines accompany the coding scheme:

- Confidence includes descriptions of student confidence ("I'm not very confident"), as well as phrases that give clues about confidence without directly specifying ("math comes easy to me", or "I don't think I can do it"), and are coded for descriptions of increases or decreases. Examples from the transcripts are "I ended up realizing I knew more than I thought" and "I took I guess an equivalent class at school and I did a lot worse" (both from transcript A). Confidence was coded a total of 72 times over all transcripts.

- Activities include both in-class and out-of-class activities. These range from doing homework problems, specific mention of assignments or problems, workshops, exams and quizzes, viewing lecture videos before class; to studying, working in groups, practice, and even just thinking about calculus while taking part in other activities. Activities were coded a total of 29 times over all transcripts.
- Feelings toward or about math include the more direct "I like/don't like math" type phrases, more subtle clues about stress, anxiety, comfort level, and avoidance, and less obvious clues about needing to practice often, giving up, lectures being boring, and math being busy work. Feelings were coded a total of 79 over all transcripts.
- Courses mentioned include any mention of previously taken math courses in a university setting, community college, high school, or elementary school. Courses mentioned were coded 50 over all transcripts.

5 Results

Using quantitative data from pre- and post- surveys, we found that students' self-reported self-efficacy increased from the start of the term to the end of the term. The results showed a statistically significant increase in students' math-related school subjects self-efficacy from pre-survey ($M = 5.69$, $SD = 1.44$) to post-survey ($M = 6.25$, $SD = 1.30$) conditions; $t(22) = 2.52$, $p = .019$. This result tells us that at the conclusion of the flipped course, students felt more confident that they could earn an A or B in college courses that involve mathematics. These results are consistent with what I have found in my qualitative work, analyzing interviews from 12 students in the class. Data from the quantitative analysis also shows that students' exam averages in summer 2018 were approximately 3-4% higher per exam with harder exams given during this same semester.

Our findings from the qualitative analysis are:

- Experiences in previous math courses, particularly high school, impacted student perception of their self-efficacy in math both positively and negatively
  - Example 1: "I guess one of the teachers who I was closest with in high school like helped me get into math a lot because my sophomore year algebra 2 teacher and like he really helped me get into math."
  - Example 2: "In high school, I was ... very much ... top of the class, ... worked really hard and everything, so math ... really came easy to me my whole life. So, I was a good student, I would always study, make sure like grades were on top of it, and now like I came here, ...it's very much like a wakeup call...my professors have talked to me about ... possibly having like math anxiety, now, and stuff, so it's definitely like now I feel like I kind of avoid it a little bit more."
- Active learning increased students' confidence in their ability to do math from their perspective
  - Example 1: "This is like really like positively impacts like my grade are so much better, I understand the material so much better, able to ask the questions, like I feel comfortable asking the questions because we're interacting with the professor, and the LA or the TA like the entire time, like it's not just for like two minutes if you approach them at the end of class or everything, so it's definitely a lot better for me."
  - Example 2: "I think that increased my confidence, because I know that then like I understood my question, like the subjects that pertained to like the topics in my question, I knew I understood those like very well because I had the opportunity for ten minutes to just talk about those with other people, just work about that problem."

- Verbal persuasion (implicit encouragement from teachers) increased confidence and was seen as a good way to learn.
  - Example 1: "I had a teacher that would really like just make you like, put a question on the board and you just have to answer it even if you have no idea how to do it, just like try. And a lot of times I would just look at the problem like I don't know how to do that but if I would even like try if I didn't know, I ended up realizing I knew more than I thought. So, I guess the teacher goes in with the attitude of like trying instead of just completely just like not doing it because you didn't know how, is a good way to learn I guess."
  - Example 2: "Having a teacher right in front of you and if you have a question, I think the only thing that's, that's the barrier in that situation is the student being scared to ask a question. But being in an environment where you're encouraged to ask questions that's much more helpful."

Students commented on their appreciation of having two people to ask for help during class: "my grades are so much better, I understand the material so much better, able to ask the questions, like I feel comfortable asking the questions because we're interacting with the professor, and the LA the entire time, like it's not just for like two minutes if you approach them at the end of class or everything, so it's definitely a lot better for me."

Most students found the flipped classroom approach more favorable than the lecture approach, noting how their understanding has improved: "I think this is the most I've actually understood calc 2 and before then I didn't even, I followed everything the formula but now I know the reasoning of everything," and "I think I understood the concepts a lot more and I knew when to use uh one formula versus the next um I understood even everything's formulae but I know the reason why I'm using this formula."

Eleven out of 12 students rated their confidence levels as higher than at the beginning of the course: "it definitely increased 'cause he, he at the same time we learned calc 2 he also taught us how to, how the calc 2 can connect with applications. Outside applications and he actually showed it in class. And that's the reason you know you will be using all that stuff in your career that you will be choosing", "Same thing I think it has increased for me too because usually like I'm used to teachers that just say alright this is your problem, do it, figure it out ... and also it is better for me 'cause of civil engineering I will be working hands on especially with that like buildings, houses, bridges anything that will just help me out. So more confidence the better I'll do." One student stated their confidence level was the same as at the beginning of the course.

The three self-efficacy opportunities were identified a total of 11 times across the interviews:

- Eight mastery experiences (coded O1), all of which were associated either with increases in confidence (C1), positive experiences, or both.
  - Example 1: "And a lot of times like I would just look at the problem like I don?t know how to do that but if I would like even like try if I didn?t know, I ended up realizing I knew more than I thought."
  - Example 2: "I guess just like honestly getting the validation from getting a good score makes me feel more confident."
  - Example 3: "Yeah, like for example, if I can solve this one particular question on like this topic, and I was able to do it without any help, I feel pretty confident in that topic overall."
- One verbal persuasion (O2) was identified and associated with a positive experience.
  - Example: "?most of the time you?d be on the right track and then it would just be like her bringing you to like the next step I guess."

- Two vicarious learning experiences (O3) were identified and associated with positive experiences.
  - Example 1: "I think that increased my confidence, because I know that then like I understood my question, like the subjects that pertained to like the topics in my question, I knew I understood those like very well because I had the opportunity for ten minutes to just talk about those with other people, just work about that problem"
  - Example 2: "I guess on just like a psychological level seeing someone in the same group or maybe level as me doing it just builds confidence in saying I can do it?

6 Discussion

The most notable codes from each category in the final round of coding were:

- A1g (in class activity, good experience) was coded 12 times, more than twice as often as A2g (out of class activity, good experience).
- C1 (increase in confidence) was coded 38 times, 8 associated with a good experience. This was over twice as many as C2 (decrease in confidence), which was coded only 15 times, 8 of which were associated with a bad experience.
- F2 (negative feelings described) was coded 24 times, 8 associated with a bad experience, while F1 (positive feelings described) was also coded 24 times, 13 of which were associated with a good experience.
- M2 (high school course mentioned) was coded 27 times, 16 of which were associated with a good experience. However, M1 (college or university course mentioned) was coded 20 times, eight of which were associated with good and eight with bad experiences.

Following the success of this flipped course as a pilot study, in the fall semester of 2019, all 27 sections of Precalculus 115 were modified to match the flipped course format. The relationship between self-efficacy opportunity and increases in confidence/positive experiences should not be ignored when designing undergraduate courses. Fostering positive communication between students and instructor, as well as giving lots of opportunity for practice in an environment where students can work cooperatively and ask questions appears to have a significant positive impact on student confidence and self-efficacy. This kind of positive experience can also affect students' persistence in math and other STEM areas. In this study, we found that students' experiences in previous math courses impacted their perceptions of their self-efficacy. Because self-efficacy is a good predictor of student success and persistence (Zimmerman, 2000); (Pajares and Miller, 1994), it is important to create learning environments which will create opportunities for improvements in student self-efficacy.

7 Future Work

Future work in this area would include additional sections for broader participation, and further study of students' learning outcomes to determine how they relate to self-efficacy opportunities. The author would very much like to perform similar studies in physics classroms.

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