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Understanding College Students' Use of Written Feedback in Mathematics

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ABSTRACT

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Many teachers want to help their students develop a growth mindset about their ability to do mathematics. Research has shown, however, that teachers simply do not know how to promote growth mindsets in their classrooms. Existing research suggests that one way teachers can support students' development of a growth mindset is through the written feedback they provide students. This study combines the research done on students' mindsets and written feedback to examine the interaction between student mindset and written feedback by analyzing written feedback provided to students in a College Algebra class and how students used that feedback based on their homework resubmissions and their interviews. This study suggests that students do not use their written feedback relative to their mindset towards learning mathematics, but rather that their definitions of success in a mathematics class drive their interpretation and use of their written feedback. This study also suggests that students' definitions of success in mathematics contribute to their mindsets towards learning mathematics. Findings from this study inform teachers about how students interpret and use written feedback in a mathematics class. Teachers should provide students with opportunities to change their definitions of success in mathematics, which may change their mindset towards learning mathematics.

Keywords: written feedback, growth mindset, definition of success, mathematics, college algebra

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CHAPTER ONE: INTRODUCTION

Despite what some students may believe, teachers want their students to be successful. They want their students to feel like they can do mathematics and approach mathematics problems they do not know how to do with an open mind and a willingness to persist. Ideally, teachers want their students to have growth mindsets. I define a growth mindset as the belief that a person's intelligence is malleable and that smartness and intellectual abilities can increase with hard work, regardless of setbacks one may face (Blackwell et al., 2007; Boaler, 2015; Claro et al., 2016). Conversely, then, I define a fixed mindset as the belief that intelligence is innate and unchangeable (Blackwell et al, 2007; Dweck 2016). In addition to their desire to work hard, students with growth mindsets achieve higher grades in school in certain circumstances (Blackwell et al, 2007). I have seen teachers who, knowing this, have tried to alter the way they phrase things in class and even the posters they hang on their walls in the hopes of helping their students develop a growth mindset. Despite their best efforts, however, students still have fixed mindsets. Research has shown that teachers, although they try, do not actually know how to promote growth mindsets among their students (Kunz, 2020).

I personally became aware of this fact while helping my sisters with their mathematics learning. I have always wanted my sisters to be successful in their attempts to solve mathematics problems and have positive experiences with math. However, they often compared themselves to my mathematical achievements and classified themselves as "not math people". In their minds, they could not do math because they were not born with that particular ability. This belief resulted in negative mathematical experiences for them and the conclusion that they would never be successful in mathematics. After learning about growth and fixed mindsets, I recognized fixed mindsets in my sisters and tried to help them develop a growth mindset towards mathematics. I

tried encouraging them to work hard and keep trying when they made mistakes. Despite my best efforts, every time I sat down with my sisters to work on math, I was confronted with their despair about their abilities to be successful in the subject. I quickly learned that no matter what I said to them or did with them, they still had fixed mindsets. I was stuck in a place where many teachers are with their students; I did not know how to help my sisters develop growth mindsets.

What I soon came to notice was something that Dewitt brings up in his article. Dewitt (2015) explains that teachers need to do more than just say things they hope will inspire a growth mindset. Teachers need their actions to match and add to the growth mindset words they use. Sun (2015) suggests that one of those actions that might need to change is the feedback students receive on their work. Teachers often give feedback to students to either confirm the correctness of a solution or to inform students of the incorrect solution. Feedback is most commonly written on homework and tests or spoken in class. I again noticed my sisters' fixed mindsets when they would stress about a homework assignment and explain to me that they would never understand the material the homework was practicing. I would sit with them and show them that they really did understand, and that they could work hard to understand the pieces they were missing. I would tell them that they could learn to do mathematics just like anyone else and they would always respond with some example of a past assignment or test where they thought they knew what they were doing and the feedback they got from their teacher convinced them otherwise. I could see that they were unknowingly using the feedback provided to perpetuate their own fixed mindsets.

The natural response to my observations and the suggestions of Dewitt (2015) and Sun (2015) is to provide students with the kind of feedback that would help encourage them to develop their growth mindsets. Unfortunately, research has not been conducted to identify what

types of feedback support a growth mindset in a mathematics classroom. Feedback in general, as Weaver (2006) states, is an "under-researched area" (p. 391) in education. Not many studies have examined the relationship between student mindset and written or verbal feedback. In mathematics education specifically, there has been some research on how students respond to verbal feedback (Li et al., 2016), however students' responses were not linked to their mindsets. Research on verbal feedback in the mathematics education community is more prevalent than research on written feedback, however it is still limited. Research on written feedback has been conducted in areas outside of mathematics (Cohen et al., 1999), but again, this research is not linked to students' mindsets.

Because of the lack of research on written feedback in general and its possible connection with student mindsets, this study will investigate how students use written feedback relative to their mindsets regarding their mathematical abilities. Ideally this study would investigate what types of written feedback that promote a growth mindset among mathematics students. However, due to the difficulty in measuring mindset and the many other possible factors contributing to mindset that would be hard to control, I decided to switch directions and examine how students use written feedback relative to their mindsets towards learning mathematics. By identifying how students with a growth or fixed mindset use the feedback provided to them, teachers may then be able to tailor feedback provided to fixed mindset students so that they use it more like the students with growth mindsets. The hope would then be that those students with a fixed mindset begin to develop a growth mindset because of how they use the feedback provided to them. Thus, this study will not look to definitively claim that a particular type of feedback will promote a growth mindset, but rather will identify how students with either a growth or fixed mindset use

feedback provided to them with the hope that by understanding how students use feedback, we can provide them with feedback that will encourage them to use it to develop a growth mindset.

CHAPTER TWO: BACKGROUND

Literature Review

In this chapter, I will argue that there is a potential relationship between students' mindsets and their use of written feedback. To make this argument, I draw on existing research about growth mindsets and written feedback to develop a framework for identifying how students use the written feedback provided to them relative to their mindsets.

Student Mindset

Dweck (2016), defines a growth mindset as the belief that "talents can be developed" (p. 2). Similarly, Boaler (2015) defined a growth mindset as the belief that "smartness increases with hard work" (p. ix). Both of these definitions include the idea that mindset is a belief. Researchers have shown that it can be difficult to change a person's belief (e.g., Nespor, 1987; Rokeach, 1968). However, other researchers have shown that mindset can change (e.g., Blackwell et al., 2007, Boaler, 2019). This suggests that the beliefs associated with mindset may be different than other beliefs a student might hold. Proponents of mindset theory suggest that mindset is a continuum (Yeager & Dweck, 2020). This implies that people can have both a growth and a fixed mindset, or in other words, a student can believe both that their intelligence increases as they work hard and that their intelligence is fixed (Boaler, 2019; Dweck, 2016; Moore, 2018). This would mean that the mindset a student chooses to employ at a given moment is dependent on the context of the moment. Additionally, attribution theory, which is a precursor to mindset theory, states that what students claim as the causes for their actions is dependent on the context the student is in (Weiner, 2010). For example, a student may have a growth mindset about their ability to write papers for an English class, but not about their ability to do mathematics. Further, a student may have a growth mindset about learning mathematics, but that growth mindset may

be conditional on how the teacher interacts with them each day. Thus changing the student's context may result in changing the student's mindset.

For a student, changing their context would imply changing what happens in the classroom. This means that "teachers hold an incredible amount of influence" (Boaler, 2019, p. 98) on students' mindsets. What a teacher says or does can send different messages to students about what causes their successes or failures in class (Weiner, 2010). One way the teacher may influence their students' mindsets in a mathematics class is through their focus on either the process or on the solution. Often in mathematics classrooms, the teacher focuses on getting the answer correct and showing the right answer to the class. This focus on answers may push students to care only about their performance and whether they got the answer right or not, which is a belief generally held by students who have a fixed mindset (Blackwell et al., 2007). When a teacher chooses to focus on the process it took to get to the solution, or even show many different solution paths for the same problem, students may begin to see the value in their thinking, even if it is incorrect. As students begin to value their thinking and the process they took to get their answers, they may begin to develop a growth mindset when learning mathematics (Boaler, 2015; Robinson, 2017). The focus on process rather than the answer encourages hard work and persistence, which ultimately helps students develop a growth mindset (Boaler, 2015; Claro et al., 2016; Robinson, 2017; Yeager et al., 2019). Because of this, having the teacher focus on the process in class may positively affect student mindset.

Another way teachers influence student mindset is how they respond to mistakes. Research has shown that students who have a growth mindset view their mistakes as learning opportunities (Blackwell et al., 2007; Boaler, 2015). When a teacher penalizes a student or makes a student feel bad for the mistake they made, students get the idea that mistakes are not

useful and should be avoided at all costs. This pushes students to believe that they could lose their "smartness" status by making a mistake so they often choose to avoid more difficult tasks, which ultimately results in a fixed mindset (Boaler, 2015; Claro et al., 2016). This move has also been seen with preservice teachers who want to avoid looking "dumb" and therefore direct conversations away from topics that challenge their understanding (Plummer & Peterson, 2009). However, when a teacher values students' mistakes and encourages students to learn from their mistakes, the teacher demonstrates how to view mistakes as part of the learning process. By developing this view of mistakes, students work towards developing a growth mindset (Boaler, 2015; Robinson, 2017). This view of mistakes also signals to the student that the teacher is not giving up on them because they struggled to do the right process or get the right answer, which in turn helps students practice their own perseverance through difficulties. These experiences result in the students believing that the harder they work, the more they can learn and grow, which is how others have defined a growth mindset (Blackwell et al., 2007; Boaler, 2015; Dweck, 2016; Robinson, 2017).

Although Dweck's mindset theory is widely accepted and promoted, not all researchers agree with her claims. Sisk et al. (2018) and Brez et al. (2020) attempted to replicate Blakewell et al.'s (2007) study of a mindset intervention in schools; specifically, increasing student achievement after engaging students in a growth mindset intervention. Both of these studies were unable to replicate the claim that having a growth mindset increased student achievement in school and the authors concluded that growth mindsets were far too overemphasized in schools around the country. Similarly, Hendrick (2019) argues that teaching students about growth mindsets may actually hurt how students view their failures in school and that if we want students to be higher achievers, teachers should teach their course content rather than teaching

about mindset. Hendrick (2019) claims that students will get better grades if they actually know the material, not if they believe they can get better grades. Finally, one author suggests that the ultimate goal should be teaching students to be resilient when facing obstacles since studies like those done by Sisk et al. (2018) have found flaws with teaching growth mindsets ("Resiliency", 2018).

While it is true that some studies have not replicated similar results associated with a growth mindset, it does not necessarily follow that mindset theory is not a valuable way to understand how students are thinking about intelligence and learning. Yeager and Dweck (2020) explain that mindset theory is a way to describe responses to setbacks and failures, not to explain or predict student achievement. Yeager and Dweck (2020) also explain that growth mindsets do more for students in some cultures than in others and that a focus of their current research is to understand why that is the case. Bernardo (2021), who studied mindset among Filipino students, found some evidence that students with growth mindsets were higher achievers, however he suggested that mindset should not be thought of as a "cure-all" but rather a tool to help some struggling students. Denworth (2019) suggests that the details surrounding mindset theory be made more explicit to allow for better understanding of mindset and what it hopes to accomplish. Thus, despite the criticisms against mindset theory, there is still value in understanding how students think about the outcomes of their actions and how their context affects their beliefs. Further, the current study seeks to add more understanding of how students with differing mindsets respond to their context, such as the feedback they receive, rather than predicting outcomes based on student mindset.

Teacher Feedback

Although there is little research on the written feedback provided in mathematics classrooms in the United States, I review four studies (Guo and Wei, 2019; Hattie and Timperley, 2007; Rakoczy et al., 2013; Schimmer et al., 2018) conducted in four countries (i.e., China, New Zealand, Germany, and the United States) that identified either written, verbal, or both written and verbal feedback in multiple content areas. It is important to note that only one of the four studies researched written feedback in the United States and that research was not conducted in a mathematics classroom. From this existing research, I synthesized the types of feedback into three groups that teachers use in classrooms around the world: *teacher-centered*, *student-centered*, and *affective*. These groups of feedback include both written and verbal feedback.

The first group of feedback is teacher-centered and is characterized by the teacher providing feedback to students that seemingly does the mathematical work for the students. This feedback tells students exactly what they have done wrong and often will provide the students with the tools or directions to make the corrections. When students receive teacher-centered feedback, there is no need for them to put in any effort to learn from or improve upon their work. The following types of feedback: social comparative (Rakoczy et al., 2013), task-level (Hattie & Timperley, 2007), verification, directive (Guo & Wei, 2019), deficiency-based, and corrective feedback (Schimmer et al., 2018) were considered teacher-centered. Table 1 provides a description and example of each of these types of feedback.

The second group of feedback is student-centered and allows the student to put in work after receiving feedback. In this case, the teacher provides students with just enough feedback to help them see their mistakes and to move forward in spite of their mistakes. Student-centered

feedback focuses more on the process the student took to get to their solution and how the student can adjust their process to be successful in the future. The following types of feedback: self-regulation, process-level (Hattie & Timperley, 2007), process-oriented (Rakoczy et al., 2013), and scaffolding feedback (Guo & Wei, 2019) were considered student-centered. Table 2 provides a description and example of each of these types of student-centered feedback.

Table 1

Descriptions and Examples of Teacher-Centered Feedback

Type of Feedback	Description	Example
Social Comparative (Rakoczy et al., 2013)	Feedback assesses correctness of student work and compares their score to others' in their class	Your grade: 85% Average grade: 79%
Task-Level (Hattie & Timperley, 2007)	Feedback focused on “how well a task is being accomplished”. Assesses what the student was asked to do. Includes directions to acquire “more or different information.” (p. 91)	"You need to include more information about the Treaty of Versailles" (p. 90)
Verification (Guo & Wei, 2019)	Feedback is either “affirming or denying” the validity of a students' answer (p. 266)	Marking something right or wrong
Directive (Guo & Wei, 2019)	Feedback is a “direct answer or solution to students' questions or problems” (p. 266)	You need to multiply by 2 here to get the right answer
Deficiency-Based (Schimmer et al., 2018)	Feedback focuses on “what the student did wrong” and does not give a way to improve (p. 78)	grades/ just putting a red line through the answer and taking off points
Corrective (Schimmer et al., 2018)	Feedback corrects mistakes and there is no effort from the student required to correct their mistakes	fixing all the spelling mistakes in a paper instead of telling the student there are spelling mistakes and they should check their work

Table 2

Descriptions and Examples of Student-Centered Feedback

Type of Feedback	Description	Example
Self-Regulation (Hattie & Timperley, 2007)	Feedback "implies autonomy" (p.94). Feedback is internal - student generated. Feedback encourages students to go back and evaluate their work. Feedback helps students develop the ability to self-assess	"You already know the key features of the opening of an argument. Check to see whether you have incorporated them in your first paragraph" (p. 90)
Process- Level (Hattie & Timperley, 2007)	Feedback is aimed at the processes and understanding used to complete the task.	"This page may make more sense if you use the strategies we talked about earlier" (p. 90)
Process-Oriented (Rakoczy et al., 2013)	Feedback identifies strengths and weaknesses and provides a way for students to bridge the gap;	You can do the following well: (lists the processes the student can do well). You could improve in the following areas: (lists where the student could improve). This is how you can improve: (provides students with a strategy to improve their work). "Every learner has strengths and weaknesses. In the next test, you can improve if you consider our tips." (p. 67)
Scaffolding (Guo & Wei, 2019)	Feedback provides cues and hints to help the student come to the conclusion on their own	It looks like there is a mistake in your simplifying. Can you find it?

The final group of feedback is affective and is directed more towards the student as an individual rather than the mathematics they have done. Other common names for this group of feedback are praise or criticism. The following types of feedback: teacher praise and teacher criticism (Guo & Wei, 2019) were considered affective. Table 3 provides a description and example for each type of affective feedback.

Table 3

Descriptions and Examples of Affective Feedback

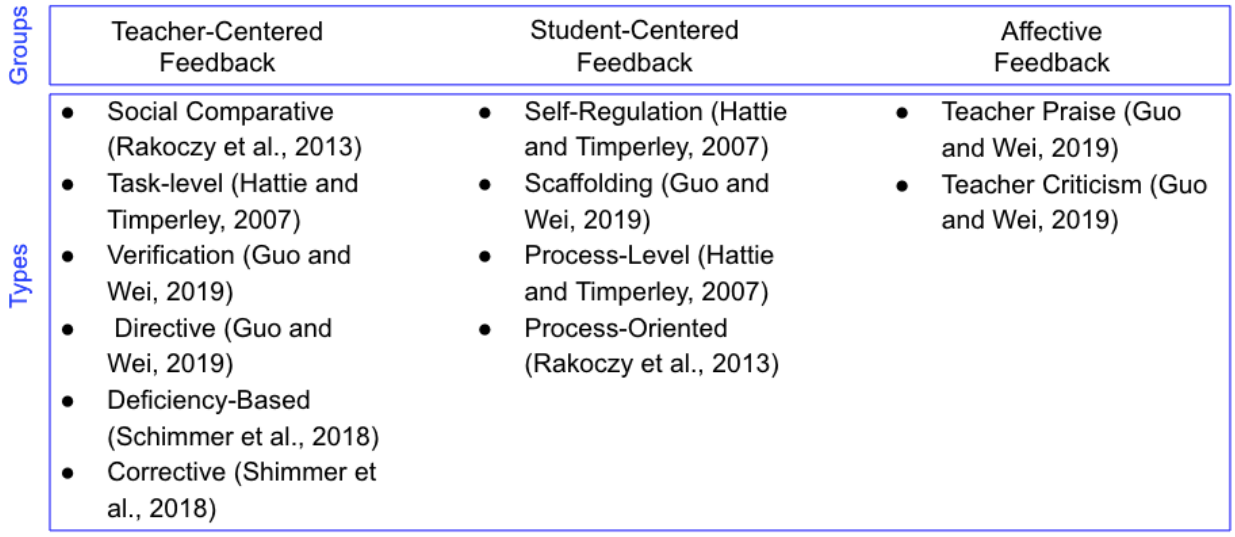
Type of Feedback	Description	Example
Teacher Praise (Guo & Wei, 2019)	Feedback provides positive responses to students for their good work	"Nice job"
Teacher Criticism (Guo & Wei, 2019)	Feedback offers negative responses to students such as "disapproval, disgust or rejection" (p. 266)	"That's wrong"

Summary

In summary, I identified three groups of written and verbal feedback reported in the literature (Guo & Wei, 2019; Hattie & Timperley, 2007; Rakoczy et al., 2013; Schimmer et al., 2018). These three groups are teacher-centered, student-centered, and affective feedback. In each group, there are multiple types of feedback that were identified by researchers around the world. Figure 1 summarizes the three groups and the different types of feedback within each group across the four research studies.

Figure 1

Illustration of the Types of Feedback in the Literature



Characteristics of Effective Feedback

Each of the studies (Guo & Wei, 2019; Hattie & Timperley, 2007; Rakoczy et al., 2013; Schimmer et al., 2018) related the type of feedback given to student achievement in the classroom and overall effectiveness of the feedback relative to student growth and achievement. Researchers (Hattie & Timperley, 2007) have defined effective feedback as feedback that answers the questions "Where am I going?" "How am I going?" and "Where to next?" (p. 86). In this sense, effective feedback focuses on the process students go through and not simply the answer they give (Hattie & Timperley, 2007; Schimmer et al., 2018). This can also be seen in the studies conducted by Guo and Wei (2019) and Rakoczy et al. (2013) when they chose to focus on feedback to encourage students to be self-regulated learners and move forward in their learning after receiving feedback. Overall, effective feedback helps students see where they are and how to move forward in their learning.

Another characteristic of effective feedback is that it is used as a means of communication between the student and the teacher (Schimmer et al, 2018). This implies that the feedback is taken seriously by both the teacher and the student and that both parties view feedback as a source of important information. When the teacher gives the feedback, they tell their students what they have done well and where they need to improve. Effective feedback uses this opportunity to give students information about their learning without overwhelming them. When students receive the feedback, they see it as an indication of what their next step needs to be. Thus effective feedback provides a way for teachers to communicate a "game plan" to students as they seek to improve their understanding.

Hattie and Timperley (2007) also include in their description of effective feedback the idea that effective feedback triggers a positive and productive response from the students. In

other words, effective feedback does not lead students to think less of themselves, but encourages them and helps them see the positive aspects of their work. Similarly, Schimmer et al. (2018) stated that effective feedback "has the potential to help students develop a growth mindset" (p. 85) when implemented correctly. Dweck (2016) explains that everyone has both a growth and fixed mindset and that fixed mindset triggers can push a person to use their fixed mindset over their growth mindset. Given that Hattie and Timperley (2007) describe effective feedback as a trigger for a positive response and that Schimmer et al. (2018) suggest a possible relationship between feedback and mindset, it would seem that one could also consider growth mindset triggers and that feedback could be either a growth mindset or fixed mindset trigger for students.

Summary

In summary, effective feedback, as defined by Hattie and Timperley (2007) and Schimmer et al. (2018), is feedback that (a) focuses on the process students go through rather than the answer they give (Hattie and Timperley, 2007; Schimmer et al., 2018), (b) creates a means of communication between the student and the teacher (Schimmer et al., 2018), and (c) triggers a positive and productive response from the students (Hattie & Timperley, 2007). Feedback that incorporates these characteristics has been found effective in relation to student achievement (Hattie & Timperley, 2007; Schimmer et al., 2018). However, effective feedback has not been studied relative to student mindset.

Finally, it is important to note that in relation to feedback, finding the one and only perfect type of feedback to use in every classroom may not be as easy as it seems. Schimmer et al. (2018) explained that finding the perfect way to provide students with feedback is difficult because feedback is effective in its specific context. That is, feedback that works well in one

classroom with one group of students may not always work well in another classroom. This means that any study seeking a specific outcome by altering feedback must acknowledge that the outcome may not always happen in every classroom. Thus for this study, I look to identify potential ways students use written feedback relative to their mindsets rather than claiming that a particular type or group of written feedback will promote a growth mindset among students.

Framework

In this section, I present a framework based on the previously cited research that is used to frame the study. This framework combines the research on effective feedback and on growth mindsets to create a lens through which both written feedback and student's mindset can be examined.

Effectiveness of Three Groups of Feedback

Based on the definition of effective feedback given by Hattie and Timperley (2007) and Schimmer et al. (2018), teacher-centered feedback and affective feedback are not considered effective feedback. Neither teacher-centered nor affective feedback focus on the process the student went through to get their answer. Further, neither teacher-centered nor affective feedback provide a means of communication between the student and teacher since both types of feedback provide students with either an evaluation of the correctness of their work or the teacher's feelings towards the student relative to their work. Additionally, teacher-centered feedback often is used by students to compare themselves with their peers rather than to learn and grow (Boaler, 2008) and affective feedback, which is directed towards the student as an individual, can be used to fuel their definition of self. In other words, neither affective nor teacher-centered feedback triggers a positive response from students. Finally, affective feedback has been identified as

"rarely effective" by Hattie and Timperley (2007, p. 102). Thus, teacher-centered feedback and affective feedback are not considered effective feedback.

Conversely, according to the definition provided by Hattie and Timperley (2007) and Schimmer et al. (2018), student-centered feedback is considered effective feedback. Student-centered feedback draws attention to the process the student went through to get the answer, whether correct or incorrect. By using student-centered feedback, the teacher communicates to the student where to look and reminds them what they have learned to help them improve. Additionally, student-centered feedback highlights what the student has already done well and provides a way to move forward. This means that student-centered feedback is intended to help students think more highly of their work, which ultimately results in students having a more positive response to the feedback they receive. Thus, student-centered feedback is considered effective feedback.

Summary

In summary, of the three groups of feedback I identified from the literature, only student-centered feedback is considered effective feedback. Although there may be occasions when teacher-centered and affective feedback are useful in a classroom, they are not considered effective feedback according to the definition given by Hattie and Timperley (2007) and Schimmer et al. (2018).

Characteristics of a Growth Mindset

A growth mindset, which I define as the belief that intelligence is malleable and that smartness and intellectual abilities can increase with hard work, regardless of setbacks the person may face (Blackwell et al., 2007; Boaler, 2015; Claro et al., 2016), has three characteristics that are agreed on in the research. These characteristics are indications that a student tends to use a

growth mindset in a specific context. Thus if students exhibited these characteristics when learning mathematics, it could be argued that they tend more towards a growth mindset when learning mathematics than a fixed mindset. The first characteristic is that students are willing to work hard to accomplish a goal (Dweck, 2016; Boaler, 2015; Blackwell et al., 2007). In other words, students choose to persevere through difficult situations and stick to a task longer than a student with a fixed mindset. An example of this is a student not giving up on a difficult problem, even if that problem is taking them longer than anticipated to complete.

The second characteristic of a growth mindset is that the process is more important to a student with a growth mindset than the answer (Robinson, 2017). From this perspective, students will work on a task in order to make sense of the mathematics, not just to get an answer and move on. An example of this is when the student gets the right answer, but is not sure why they did and asks questions about the problem, despite already having the correct answer. This characteristic is related to the previous one because if a student understands that the process of learning is as important as what is ultimately learned, they will work hard to make sure the process makes sense to them. They do not seek only to get to the answer, but to perfect the process it takes to get there, including learning from any mistakes they make along the way.

The final characteristic of a growth mindset is that the student believes they can achieve (Boaler, 2015) or in other words, the student believes that they can learn and be successful because their intelligence is not fixed. It is worth it to these students to focus on the process and to work hard because they believe that there is always the possibility that they can be successful in their efforts. This motivates students to keep working and continue putting in effort. An example of this is when a student gets a failing grade on an exam, but still is willing to put in work to learn the material because they believe they can learn it. For this student, the exam does

not evaluate all that the student has and ever will know, but rather the exam provides information about what the student knew in the moment and says nothing about what the student will continue to learn. This student does not see their intelligence as innate because they believe that they personally have the ability to be successful through hard work. When students believe they can be successful and learn new things, they are willing to take setbacks and learn from them in their process of learning new concepts.

Effective Feedback Aligned with Growth Mindset

Effective feedback, as defined by Hattie and Timperley (2007) and Schimmer et al. (2018) has the most potential to positively interact with students' mindsets because the characteristics of effective feedback align with the characteristics of a growth mindset. The first way effective feedback and growth mindsets align is through the communicative nature of effective feedback. Because effective feedback allows for the teacher to communicate with the students, this type of feedback provides a space for teachers to help each individual student make a "game plan" to move forward and correct their errors, as long as the student is willing to put in the work. When the teacher and the student communicate through the feedback provided, the student can see the path they need to take to progress in their learning. For the student who is willing to persevere, effective feedback helps them see the value in what they have done and the next steps they need to take to move forward in their learning. For the student not yet willing to persevere, effective feedback helps them see the possibility of moving forward in a more reasonable and less overwhelming way. It seems reasonable then, that providing students with effective feedback would support them in working hard to achieve their learning goals.

The second way effective feedback and growth mindsets align is through the focus on process over results. Students with a growth mindset, as previously mentioned, are concerned

about understanding the process in addition to getting the answer correct. When teachers provide students with effective feedback, they correct and comment on the processes the student used in their work more than they do the correct answer. For this feedback, the student needs to show their work in a way that highlights their mathematical process, which implies that the feedback is encouraging the student to focus on showing their process to the teacher if they are not already doing so on their own. It seems that effective feedback would help students start or continue to focus on the process more than the result, which in turn, would support students in developing a growth mindset.

The final way effective feedback and growth mindsets align is through the fact that effective feedback triggers a positive response from the student. Possible positive responses elicited by effective feedback are the student deciding their work is worth their time and that they have the potential to accomplish the tasks they are given. Whether they completed the task correctly or incorrectly, effective feedback can help students see their work as valuable as well as see themselves as future mathematicians. In other words, effective feedback can help students develop the belief that they have the ability to achieve in a mathematics class despite what they may have done incorrectly. Effective feedback can show these students that they are successful because of their own thinking and not just because they got lucky. Effective feedback can help students have a positive outlook on their work and therefore supports the belief that their work has value and potential.

Because of the alignment between effective feedback and growth mindset, it can be concluded that student-centered feedback is also aligned with a growth mindset since student-centered feedback is considered effective feedback. Similarly, teacher-centered feedback and affective feedback are not aligned with a growth mindset because they are not considered

effective feedback. The alignment between student-centered feedback and a growth mindset allows for the conjecture that providing students with student-centered feedback may support their development of a growth mindset. Therefore, I focus my work on the student-centered feedback students received and how they used it relative to their mindsets towards learning mathematics.

Research Questions

As previously established, research has identified types of feedback provided to students and classified them as effective or ineffective. It is established that student-centered feedback is considered effective feedback based on the definition provided in the literature. It is also established that the characteristics of effective feedback align with the characteristics of a growth mindset, thus implying that the characteristics of student-centered feedback align with the characteristics of a growth mindset. Further, it is hypothesized from this alignment that student-centered feedback provides students with the most support in their development of their own growth mindsets, should they choose to do so. However, researchers have not investigated student-centered feedback and how students use it relative to their mindsets towards learning mathematics. For this purpose, I investigated the following research questions:

1. How do students use written student-centered feedback?
2. How do students use written student-centered feedback relative to their mindset towards learning mathematics?

In answering these questions, I hope to provide insight into how students use written feedback that should support them in developing a growth mindset. Answering these research questions will help teachers know where to start when providing feedback to their students as they try to provide helpful, yet positive feedback in their classrooms. This research also provides

a starting place for future researchers to look closer at growth mindsets in the classroom and the effects of written feedback on students' development of a growth mindset towards mathematics.

CHAPTER THREE: METHODS

The purpose of this study was to investigate how students used written student-centered feedback they received on their written homework in their mathematics class, and specifically, to determine how students use student-centered feedback relative to their mindsets towards learning mathematics. To do this, I interviewed four college students enrolled in a College Algebra class about the written student-centered feedback they received on their homework and how they used it. This chapter describes the context, participants, data collection, and data analysis used to answer the research questions.

Context

The four participants of this study were selected from one section of College Algebra using Pathways College Algebra (Carlson, 2020) at Brigham Young University (BYU). Participants were purposefully selected from this class because their written homework was not graded on a correct or incorrect response, rather written feedback was provided to students to deemphasize the correct answer and focus students' attention on the processes they were learning. Students were also given the opportunity to redo their assignments based on the written feedback they received. It is important to note that those who graded the assignments had no formal training on giving effective or student-centered feedback; however, the instructor and TAs in this section worked together to provide feedback that helped students see their mistakes without correcting them since students were allowed to resubmit their homework with corrections. Additionally, both graders assigned to the selected section of College Algebra were new to grading for this class and had no experience giving the written feedback that was expected of them. The graders used a check plus/check/check minus system to help the students know where they were in their understanding of the material. A check plus meant that the student

had mastered the mathematical concept being assessed, a check meant that the student understood the mathematical concept being assessed, and check minus meant that the student still needed help with the mathematical concept being assessed. A number score was later assigned based on perceived student understanding, but only after the students had a chance to interact with the feedback and rework the problems. Because feedback was a focus for the students in this course, interviewing them allowed me to focus solely on the feedback and less on the grade students received. This allowed me to see how students used their feedback, if they used it at all.

Selection of Participants

Participants for the study were selected to be interviewed based on five pieces of information: (1) their consent to participate, (2) their self-assessed mindset towards learning mathematics, (3) the teacher's evaluation of students' mindsets towards learning mathematics, (4) the feedback they received on their homework, and (5) their utilization of the homework redo policy. All students in the selected section of College Algebra received information regarding the study, including the requirements to participate and the possibility of participating in one interview. Students were then asked to indicate their willingness to participate in the study on a consent form. Only students who returned a consent form indicating their willingness to participate were considered part of the selection pool for the interview.

Once students indicated their willingness to participate, they completed a student mindset survey with statements adapted from Sun's (2015) student mindset survey (see Table 4) to identify their mindset towards learning mathematics. The statements were modified to reference the individual taking the survey rather than people in general to avoid situations where the student may have a growth mindset about how others learn, but not about themselves

individually. The students indicated on a Google Form to what level they agreed with each statement through a six-point Likert scale with one representing strongly disagree and six representing strongly agree. Students' score for question four was reversed so that a low average score indicated a growth mindset and a high average score indicated a fixed mindset. The average for the selection pool was a 1.94 out of 6 indicating that most of the selection pool evaluated themselves as having a growth mindset. Since mindset can be thought of as a continuum (Yeager & Dweck, 2020), it was possible that some students tended towards both a fixed and growth mindset while learning mathematics. Thus, for my study I purposefully selected students with more extreme average survey scores relative to their peers so those who I interviewed more likely used either a growth or a fixed mindset exclusively when learning mathematics.

Table 4

Student Mindset Survey Adapted from Sun (2015)

1. You have a certain amount of math intelligence, and you can't really do much to change it.
2. There are limits to how you can improve your basic math ability.
3. You can never do well in math, even if you try hard.
4. You can be good at math if you work hard.

Participants were also selected based on their instructor's evaluation of students' mindset, which provided another indication of student mindset to further increase the likelihood that the participants used either a growth or fixed mindset exclusively. I provided the instructor with the definitions I used for growth and fixed mindsets at the beginning of the semester and asked her to take a few weeks to become acquainted with her students and then identify which students in

her class she considered to have either a growth or fixed mindset. I then compared the instructor evaluation of mindset with the student mindset survey results. Since it was possible that some students in the selection pool used both a fixed and growth mindset while learning mathematics, the teacher evaluation of mindset provided another perspective on students' mindsets for the students in the selection pool so that I selected participants for the interview who more exclusively used either a growth or fixed mindset when learning mathematics.

In addition to consistently using a growth or fixed mindset when approaching mathematics, participants were selected based on the written feedback they received on the second, third, fourth, fifth, and sixth written homework assignments of the semester. A prerequisite to receiving written feedback was that the student submitted the homework assignments. This meant students who did not submit homework assignments were omitted from the selection pool. It also was the case that some students submitted every homework assignment but received a check plus on each assignment and were not given any feedback because they already appeared to understand the concept. Thus students who received all check pluses on their homework assignments were also omitted from the selection pool. Although it was expected that the graders for College Algebra provided feedback that resembled student-centered feedback, that was not always the case due to the fact that the graders were new during this particular semester of data collection. For this reason, written feedback provided to the students in the selection pool was collected prior to selecting students to interview and coded as either student-centered or teacher-centered. No affective feedback was given to students on these particular assignments. Additionally, homeworks two and four were considered only to show consistency of each students' homework submissions because the graders were still becoming accustomed to providing feedback for homework two and homework four was graded mostly on completion so

most students did not receive feedback on that assignment. Only students who received mostly student-centered feedback over all five collected homework assignments were considered for the interview.

Finally, because I wanted to know how students used their written feedback, it was also important to ensure that the students selected to be interviewed interacted with their feedback by resubmitting their homework or at least viewing their feedback. Students submitted their assignments through Gradescope (2020), an online homework submission platform, which kept track of student submissions, feedback, and student views for each assignment. If students resubmitted their homework with corrections after receiving feedback, then it was possible that they used the written feedback to help them improve. Taking advantage of the opportunity to redo their homework did not guarantee that the student increased their understanding of the concept or used the feedback, but did increase the likelihood that such actions occurred. Because not many of the students in the selection pool resubmitted every homework assignment, I also considered whether or not the students viewed their written feedback after it was given. Again, viewing the feedback did not guarantee that the student read it or used it in any way, but did increase the likelihood that students used the written feedback.

Summary

Thus, participants in this study were chosen based on the following criteria: (1) they agreed to participate in the study, (2) their student mindset survey score suggested they used exclusively a growth or fixed mindset when learning mathematics, (3) their teacher evaluation of their mindset provided additional insight into their mindset towards learning mathematics, (4) they did all five homework assignments prior to the interview and received mostly student-centered feedback on them, and (5) they viewed and resubmitted with corrections most of the

five homework assignments prior to the interview. From this information, I selected four students to interview from the larger selection pool.

Participants

From the selection pool, four students were chosen for interviews about their thoughts on the written feedback they received on their College Algebra homework. Participants were each assigned pseudonyms to protect their identities. I now present the four participants and justify their selection for the interview.

Autumn, a freshman studying Art, took College Algebra to fulfill a general education credit requirement. Autumn averaged a 4.25 (out of 6) on her student mindset survey, which was the highest average mindset score among all the students in the selection pool. This suggested that Autumn tended towards a fixed mindset when learning mathematics, more so than her peers in her class. The instructor did not feel like she had enough information to evaluate Autumn's mindset, however her high average on the student mindset survey was enough to suggest that she more exclusively used a fixed mindset while learning mathematics than a growth mindset. Thus the lack of teacher evaluation for Autumn was not considered when selecting her for the interview. Of the five collected homework assignments, Autumn received mostly student-centered feedback on three of them, mostly teacher-centered feedback on one of them and no feedback on one because she received a check plus on that assignment. Autumn did resubmissions for all homework assignments that she received written feedback.

Zach, a freshman studying to be a chiropractor, took College Algebra to refresh his memory after not taking a mathematics class for four years. Zach averaged a 1 (out of 6) on his student mindset survey, which suggested that Zach tended towards a growth mindset while learning mathematics. Similarly, the instructor identified Zach as a student who tended towards a

growth mindset. Because his student mindset survey and teacher evaluation both suggested a growth mindset, I suspected that Zach tended exclusively towards a growth mindset when learning mathematics. Of the five collected homework assignments, Zach received student-centered feedback on two of the assignments and no feedback on the other three because he received check pluses on them. Zach resubmitted one of the assignments he received feedback on and viewed the feedback on the other assignment. Although Zach did not receive much student-centered feedback or resubmit many assignments, he received feedback on and resubmitted homework number five, which was the homework just prior to the assignment selected for the interview. Thus it was determined that his exposure to student-centered feedback was recent enough that he could have valuable responses to the interview questions.

Lizzy, a communication disorders student, took College Algebra as a requirement for her major. Like Zach, Lizzy averaged a 1 (out of 6) on her student mindset survey and the instructor identified her as having a growth mindset when learning mathematics. Thus I suspected that it was likely that Lizzy tended exclusively towards a growth mindset. Of the five collected homework assignments, Lizzy received no feedback on one assignment because she received a check plus, exclusively student-centered feedback on two assignments, and an equal amount of student-centered and teacher-centered feedback on the other two assignments. Thus I concluded that Lizzy received mostly student-centered feedback. Lizzy resubmitted two of the four assignments she received feedback on and did not resubmit or view the feedback provided on the other two assignments. Although Lizzy did not resubmit or view all of her assignments after receiving feedback, the frequency of student-centered feedback she received and her growth mindset made her a candidate for an interview.

Maddie, a first semester transfer student studying communication disorders, took College Algebra because her advisor told her she needed it for her major. Maddie averaged a 2.25 (out of 6) on her student mindset survey, which was low enough to suggest that she tended towards a growth mindset when approaching mathematics. However, as a reminder, the average student mindset survey score for the selection pool was 1.94, indicating that her score was on the higher end of her class. Additionally, Maddie's instructor identified her as having a fixed mindset and there were only four other students in the selection pool who scored higher than her on the student mindset survey. Because of this, Maddie was selected with the thought that she might tend more towards a fixed mindset when approaching mathematics than her peers and that through the interview, I could reassess and confirm her mindset. Of the five homework assignments collected, Maddie received no feedback on one assignment because she received a check plus, exclusively student-centered feedback on two assignments, and an equal amount of student-centered and teacher-centered feedback on the other two assignments. Maddie only resubmitted one assignment, but did view her feedback on all other assignments. Thus I determined that Maddie had exposure to student-centered feedback and could talk about her experiences using the feedback she received.

Data Collection

Data collected for this study were the written feedback given on five homework assignments, one interview with each participant about that written feedback, and the student submission and resubmission associated with that same written feedback. Written feedback was downloaded from Gradescope (2020), an online homework submission platform used in the class. This allowed all written feedback and student submissions for any assignment to be downloaded and accessed throughout the semester as well as data on whether or not the students

viewed their feedback. Collecting written feedback provided to the four participants allowed me to analyze the feedback they received and provided context to the interview responses.

Interview data consisted of one 30-minute interview with each participant about their experiences with the written feedback they received on their homework, which was audio and video recorded to allow for analysis. Three of the four interviews were conducted over Zoom, while the fourth interview was conducted in person. Interviews were conducted after the sixth written homework assignment of the semester, which was in the middle of the exponential unit in the class. Students had learned about percent change, growth/decay factors, and compound interest. Participants were compensated for their time with a $15 Amazon gift card upon completion of the interview. Interviews referenced the individual student work and feedback from their most recent homework assignment with written feedback (i.e., sixth one) as well as generally about how they used the feedback they received on the prior assignments. The focus of the interview was how the participants perceived the feedback they received as well as how they used or did not use the feedback. Additionally, the interview provided data to support the findings of the student mindset survey and teacher evaluations of mindset to confirm the mindset assigned to each participant. The general interview protocol used with each participant is in Appendix A; however, questions were added, phrased differently, presented in a different order, or omitted entirely relative to the student work and responses during the interview.

Student work was collected from Gradescope (2020) where students submitted their homework and their resubmissions after viewing the feedback. Student work was only collected from the assignments participants were interviewed about. Maddie, Autumn, and Lizzy were interviewed about the sixth homework assignment of the semester. Thus, their initial submissions of homework number six and Autumn's resubmission of homework number six were collected

and analyzed with their interview responses. Zach was interviewed briefly about homework six, since he earned a check plus and did not receive feedback on homework six, but was mostly interviewed about the feedback he received on homework number five. Thus his initial submission of his work and his resubmission for homework number five were collected and analyzed with his interview responses.

Data Analysis

Data collected for this study were analyzed in different ways. The written feedback was analyzed for the group of feedback the student received (i.e. student-centered, teacher-centered, or affective). The unit of analysis was an instance of feedback provided to students on each homework assignment. An instance of feedback was defined based on the grading rubric developed for each homework assignment. Figure 2 displays the rubric for question 40 on homework number six. For this problem, the rubric grouped parts a, b, and c indicating that the graders gave feedback for all three parts of this problem together. Thus an instance of feedback for this problem was the feedback pertaining to all three parts of the problem. Figure 3 provides an example of an instance of student-centered feedback given to a student. Figure 4 provides an example of an instance of teacher-centered feedback given to a student.

Each instance of feedback was coded for the type according to the definitions of student-centered, teacher-centered, or affective feedback discussed in chapter 2. The instance of feedback in Figure 3 was coded as student-centered feedback because the feedback focuses on the understanding necessary to answer the problem and directs the student's attention to the mathematical concept. With this instance of feedback, the student must return to their notes or seek out additional help to correct their mistake. Additionally, the instance of feedback in Figure 4 was coded as teacher-centered feedback because the feedback evaluates the correctness of the

student's answer and then gives directions on how the student should correct their mistake. With this instance of feedback, there is no need for the student to put in any work to correct their own mistake.

Figure 2

Example of a Homework Rubric for Homework Question 40

Question	Question	Answer	Important Concepts
40	Determine the specified growth factors for the following relationship. Write your answers in exponential **and** decimal form (round to the nearest thousandth). The number of buffalo in a wildlife preserve at time t months after its initial measure is given by $f(t) = 49(.97)^{2t}$. a. 1-month decay factor:	$(0.97)^{2(1)} = .9409$	**Students will understand and be able to recognize growth/decay factors whether in exponential form or in decimal form.** ✔- : - Students find incorrect values for both of the decay factors ✔: - Students correctly show the decay factor in one form (decimal or exponential) but not the other - Students find correct values for either a or b but not the other ✔+: - Students correctly show the decay factor in both exponential **AND** decimal form - AND students correctly identify part c
	b. ½-month decay factor:	$(0.97)^{2(0.5)} = .97$	
	c. Circle the statement(s) below that describes(s) the behavior of the function above: i. An initial number of 49 buffalo decreases by 3% every ½-day. ii. An initial	iii. An initial number of 49 buffalo decreases by 5.91% every 1-month	

The interviews were analyzed using an open-coding approach to identify themes in student responses such as students' mindsets towards learning mathematics, students' views of mathematics and what makes someone successful in mathematics, students' interpretations of their feedback, and students' use of their feedback. The unit of analysis for the interviews was a

student response to a question asked by the interviewer. An example of a student response to an interview question is Zach's response to the question "What qualifies being successful for you?" He said, "*Um, I would say just… understanding the material well enough to score well on exams and homeworks and stuff like that.*"

Figure 3

Example of an Instance of Feedback Coded as Student-Centered Feedback

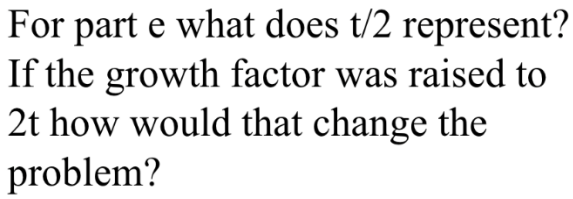
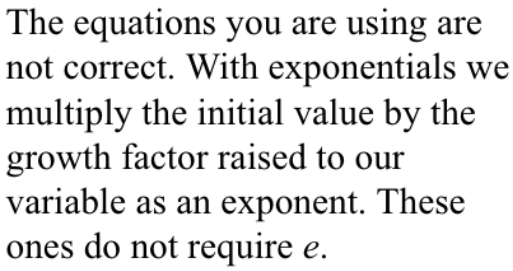


Figure 4

Example of an Instance of Feedback Coded as Teacher-Centered Feedback



To analyze the interviews I first transcribed each interview and then I highlighted students' responses that gave evidence for their mindset towards learning mathematics or that in any way referenced their experience with the feedback they received. For example, for the excerpt of Autumn's interview transcript below, I highlighted it with pink indicating evidence of a fixed mindset, green indicating evidence of a growth mindset and yellow indicating a reference to feedback and/or feedback use.

Interviewer: *Does knowing you'll get feedback like you have been getting this semester help you feel more confident in your mathematical abilities?*

Autumn: *Um… I don't know if it makes me feel more confident? Um, if anything maybe it just makes me feel a little more dependent on my math abilities. Like, I can't get it right without feedback. If that makes sense?*

Interviewer: *Okay. Um… yeah that makes sense. Why? Can I… ask why you would say that? I mean, I guess you kind of responded to that already, but can you elaborate more?*

Autumn: *Yeah. From my track record, usually on the homework assignments my… I don't get the questions right, and so… if I didn't get feedback then I just would… be getting them wrong. And so… in order to get, like, a good grade on the homework… I depend on the feedback.*

Interviewer: *Okay that makes sense. Um then, so this is kind of a similar question… Does knowing you'll get feedback similar to how you've been getting… make you more confident or less confident when you're working out the problems?*

Autumn: *I would say yeah because then I'm less likely to get frustrated because I know that … eventually I'll figure it out with the … feedback, so yeah.*

I then used a spreadsheet to organize the highlighted statements into evidence supporting a growth mindset, evidence supporting a fixed mindset, and experiences with the feedback to make it easier to look for trends in the responses. This was done for each of the four participants.

In order to better understand students' experiences with their feedback and how they interpreted and used the feedback they received, I analyzed the student work associated with the feedback students discussed during their interviews. The unit of analysis for the student work was the work for a homework problem as defined in the grading rubric for each homework

assignment. Thus based on the rubric for homework problem 40 on homework six (see Figure 2), a unit of student mathematical work would be the work associated with all three parts of the problem.

To analyze the student mathematical work, I downloaded students' submissions from Gradescope (2020) for the assignment each participant was asked about in their interview. I also located the homework problems they responded to from the Pathways College Algebra student workbook (Carlson, 2020) to provide context for the student submissions. Then, analyzing the work for each problem individually, I identified the mathematics concepts each student understood and what they struggled with based on the evidence provided in their work. For example, Figure 5 shows a homework question and associated student work along with my analysis of the student work. Based on this student's mathematical work, it was evident that they understood compound interest enough to use the equation correctly. They also could identify percent change and an annual growth factor, but could not use either the percent change or the growth factor to describe how the account changed, indicating that this student was struggling to understand growth factors and percent changes in context.

After analyzing the written feedback, student interview, and student mathematical work individually, I compiled all three sources of data to create a more complete picture of students' uses and thoughts of the feedback they received. In addition to the analysis already done for these three sources of data, I identified what the written feedback specifically told or asked each student for each homework problem. For example, Figure 6 shows the feedback provided to the student whose work is shown in Figure 5. In addition to being identified as student-centered feedback I noted that this feedback focused on the student's understanding rather than the procedure and requests that the student explicitly state their reasoning for their answer. I also

analyzed the students' resubmitted work similar to how the initial submission was analyzed (see Figure 5). Finally, I used statements from the student's interview related to the work or feedback associated with each individual homework question to understand their view of each specific instance of feedback. For example, in response to the feedback shown in Figure 6, the student said, "*Well I mean… I didn't understand exactly what she wanted me to do to be more specific. A lot of times it does just say … be more specific. And I'm … not sure how I can be more specific.*" From this I noted that the student did not feel that this feedback was helpful and that although the feedback presented the student with an opportunity to increase in understanding, the student saw it as a request for her to jump through an unnecessary hoop.

Figure 5

Example of Analysis of Student Mathematical Work

HW 6 #50

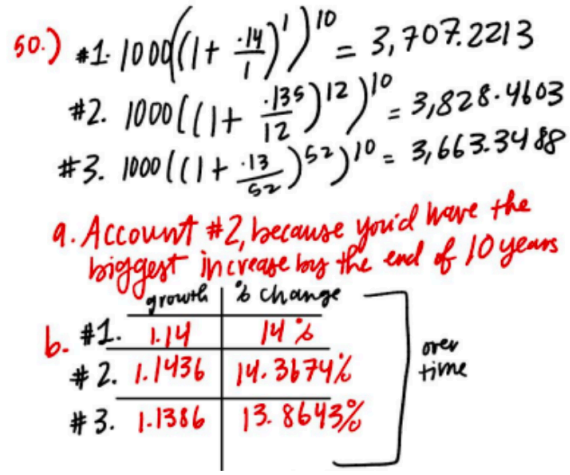
Problem: You just won $1000 in the lottery and you decide to invest this money for 10 years.

a. Which of the three different accounts would you choose to invest your $1000? Provide calculations for each account and justify your reasoning.

- Account #1 pays 14% interest each year, compounded annually (once per year).
- Account #2 pays 13.5% interest per year, compounded monthly.
- Account #3 pays 13% interest per year, compounded weekly.

b. Describe how your money increases as time increases for each account. Be sure to incorporate the annual growth factor and annual percent change into your description

Student Work - First Submission:



- Understands Financial exponential equations and how to use them given a context
- Can identify annual growth factor and % change, but struggles to use those quantities to describe what is specifically happening to the account
  - No evidence of interpreting the values. Student just does the procedure.

Figure 6

Written Feedback Associated with the Student Work Presented in Figure 5

Great work! Remember to be more specific when describing how the money increases over time for each account. I want to make sure that you know how each account is affected and how often too

CHAPTER FOUR: RESULTS

Results

In this section I present four results that came from analyzing written feedback given to students and interviewing students about that feedback. The first result is the student mindset associated with each of the participants. The second result is how students used written feedback provided to them in their mathematics class. The third result is the interaction between how students used their written feedback and their mindsets towards learning mathematics. The fourth result is students' definitions of success in mathematics.

Student Mindset

Although student interviews were focused on students' use of their written feedback, student responses were also used to verify students' mindsets towards learning mathematics that were identified through the student mindset survey and teacher evaluation of mindset. I present evidence from the students' interviews to support the conclusions I made regarding student mindset.

From Autumn's interview, I determined that she tended towards a fixed mindset when learning mathematics. Autumn's student mindset survey score and her teacher evaluation of mindset both suggested that she tended towards a fixed mindset, which was confirmed through the interview. In her interview, Autumn described herself as "*so so bad at math.*" She continued, "*I just … don't understand it. Ever. Like you can explain it to me like five million times and… I can do it … in the moment… and then as soon as… I'm doing the homework or it's on the test… I can't remember.*" Autumn also said, "*I'm not good at math and so a lot of times… I'll make … tiny little mistakes…*". Thus for Autumn, mathematics is not something she has been or ever will be able to do. To her, being good at mathematics is remembering what she was taught and

reproducing it without making mistakes and she sees herself as incapable of being good at mathematics. Autumn also mentions that her "*test scores are not good*" again indicating that she values getting the right answer over understanding the process. Because of Autumn's conception that she cannot do math and her focus on the answer rather than the process I concluded that Autumn tended towards a fixed mindset when learning mathematics, which aligned with her student mindset survey and the teacher evaluation of mindset.

Through Maddie's interview, I determined that it was likely that she tended towards a fixed mindset when learning mathematics. Maddie's student mindset survey and teacher evaluation of mindset were in opposition to each other with Maddie's survey score suggesting she had a growth mindset and the teacher evaluation of mindset suggesting she had a fixed mindset. Although Maddie's student mindset survey score suggested she had a growth mindset, I suspected that she might have a fixed mindset since her student mindset survey score was above the average score for the selection pool. After interviewing Maddie, I confirmed my suspicions that she tended towards a fixed mindset. When asked if she was good at math, Maddie responded with "*I feel like people are either … a writing person or a math person. And I feel like I'm definitely more of… a writing kind of person. And so math has always been something that I've … struggled more with.*" To Maddie, a person was either good at math or good at writing and she is good at writing. She also said, "*I can be good at math… if I can get the concept right away…,*" suggesting that for Maddie, there was nothing she could do to learn concepts. She either understood the concept or she did not. When asked in her interview what it meant to work hard in the class, Maddie said "*drill[ing] it into your brain.*" Thus for Maddie, memorization was the key, suggesting that her focus was on the right answer and not understanding the process it took to get the right answer. Because Maddie saw her understanding of math as innate, and

because of the suggested focus on the right answer, I concluded that Maddie's mindset aligned more with the teacher evaluation of a fixed mindset when learning mathematics.

After Lizzy's interview, I determined that it was likely that she tended towards a growth mindset while learning mathematics. Lizzy's student mindset survey and teacher evaluation of mindset both suggested that she had a growth mindset, which was confirmed through her interview. When asked in her interview if she was good at math, Lizzy said, " *I like to think of math more as … I can learn math. Like maybe it's not the most natural thing to me.*" She also commented on how in math classes she usually is "*able to figure out what questions I need to ask to understand.*" Thus Lizzy did not claim to be innately good at math and explained her process she used to learn concepts she struggled to understand. Additionally, throughout her interview, Lizzy focused her comments around understanding processes rather than simply calculating the correct answer. Because Lizzy saw her mathematical understanding as something that could develop through work and because of her focus on the process rather than solely the correct answer, I concluded that Lizzy tended towards a growth mindset when learning mathematics, which aligned with her student mindset survey and teacher evaluation of mindset.

From Zach's interview, I could not determine his mindset towards learning mathematics. Zach's student mindset survey and teacher evaluation of mindset both identified him as having a growth mindset. When asked if he considered himself good at mathematics, Zach responded affirmatively. When asked if he has always been good at mathematics, Zach similarly responded affirmatively. Thus Zach seemed to suggest that he had an innate ability to do mathematics. Zach also described the College Algebra class as being "*... a lot lower than I thought it was going to be*" implying that because he was good at mathematics, the course was easier than he anticipated. Throughout his interview, like Lizzy, Zach focused on understanding the processes needed to

arrive at the correct answer. However, like Autumn, Zach also commented on the importance of getting a good grade and producing the correct answer the teacher wanted. Thus Zach focused both on the process and on the result. Because Zach seemed to imply that his mathematical abilities were innate and because of his focus on both the process and the result, I could not make a conclusion regarding his mindset towards learning mathematics. I did not have evidence to confirm the result of the student mindset survey or the teacher evaluation of mindset, but I also did not have evidence to refute those results.

Summary

In summary, using responses from the interviews, I sought evidence to support the student mindset survey scores and the teacher evaluation of mindset that were used for the participant selection process. In Table 5, I summarize student mindset according to the student mindset survey, teacher evaluation of mindset, and interview responses. From these three sources, I concluded that Autumn and Maddie tended towards a fixed mindset when learning mathematics and Lizzy tended towards a growth mindset when learning mathematics. Although I was not able to make conclusions about Zach's mindset from his interview, I considered Zach a student who tended towards a growth mindset for this study based on his student mindset survey score and teacher evaluation of mindset. Because mindset is a continuum, it is likely that Zach's mindset was a mixture of both a growth and fixed mindset, however because the student mindset survey and teacher evaluation of mindset both indicated Zach as having a growth mindset, I considered Zach to have a growth mindset for this study.

Table 5

Summary of Students' Mindsets

Student	Mindset Survey	Teacher Evaluation	Interview Conclusion
Maddie	Growth	Fixed	Fixed
Autumn	Fixed	Fixed	Fixed
Zach	Growth	Growth	Not Sure
Lizzy	Growth	Growth	Growth

Students' Interpretation and Use of Written Feedback

Students were prompted in the interview to discuss specific written feedback they received on their homework that I selected prior to the interviews. As a reminder to the reader, the students were interviewed on homework assignments during the exponential functions unit. The homework assignments were selected from the middle of the unit after students had learned about percentages, percent change, growth/decay factors, and compound interest. Students were asked in the interview to discuss the helpfulness of the feedback they received. In doing so, students provided insight into how they interpreted and used their feedback. I now present related interview responses along with their submitted work and the feedback they received to provide evidence for students' interpretation and use of their written feedback.

Maddie's Interpretation and Use of Feedback

Figures 7 and 8 provide the homework question and Maddie's mathematical work submitted that was given feedback and that was selected to discuss during the interview. This homework question has students make sense of the effect of compounding periods on money over a given time period. From this submission it is apparent that Maddie understood compound interest enough to correctly answer parts (a) and (b) about differing compounding periods and

Annual Percent Yield (APY). However, Maddie incorrectly calculated the amount of interest earned in part (c) by instead calculating the total value of the account. This work is highlighted in Figure 8.

Figure 7

Homework Problem #56 Taken from Carlson (2020, p. 156)

56. $18,000 is initially invested in an account with an APR of 5.1%.
    a. Does it make a bigger impact going from compounding interest annually to monthly or going from compounding interest daily to continuously?
    b. What is the annual percent change (APY) for each of the four compounding methods listed in (a)?
    c. If interest is compounded continuously, how much interest does the account earn over the first 10 years?

Figure 8

Maddie's Initial Submission (Highlight Added)

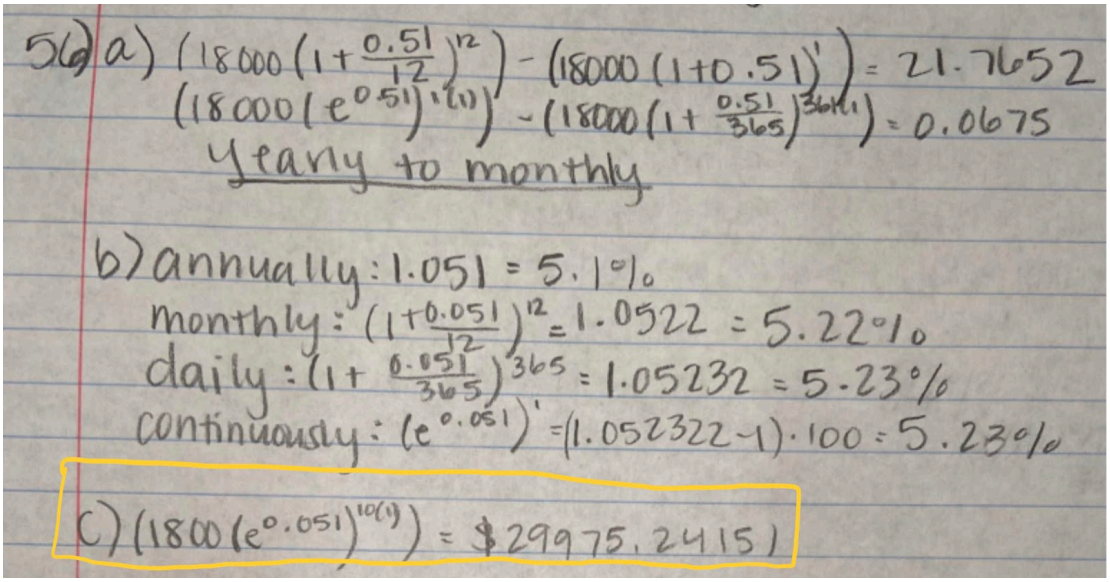


Figure 9 is the feedback that Maddie received on this question after her first submission. This feedback was considered student-centered feedback because it did not tell Maddie what to do to find the amount of interest in the account. Rather, the feedback contrasted Maddie's work

with what the question asked to get Maddie to put effort into learning the difference between her work and the work that was expected of her.

Figure 9

Feedback Given to Maddie

"What you found in part C is the total amount of money in the account after 10 years, but how much interest ($$$) did it earn over that time?"

From statements in her interview, I determined how Maddie interpreted the feedback she received. Maddie shared that due to the feedback provided, she knew her response was incorrect. She then said, *"this feedback isn't really giving me a step by step, it's just saying what I did wrong."* She continued by saying she would have preferred it if the feedback had explained *"how to find the interest instead of the way I did it, to kind of guide me in the right direction."* Maddie's comments suggest that she interpreted this feedback as an indication of the correctness of her work and nothing more. She explained that she wanted to receive feedback that gave her step-by-step directions of how to fix her work and that the feedback she was actually given was not helpful to her. Thus, it seems as though Maddie interpreted the student-centered feedback she received as if it were teacher-centered feedback because she saw it as only an evaluation of the correctness of her work.

Despite having not completed a resubmission of her work due to her busy schedule during that particular week, I determined how Maddie used her written feedback by using her interview responses. She explained how she normally took all her feedback on any written homework assignment to office hours in order to get her instructor or the TA's to *"explain it to*

[her]." Although Maddie did not get explicit directions in her feedback of how to fix her mistakes, she sought out opportunities to have someone elaborate on the feedback and provide more instruction on how to fix her mistakes. This suggests that if Maddie were to have done the resubmission for this particular assignment, she would have used any feedback she was given, written or verbal, as if it were teacher-centered feedback, intended to do the work of correcting her mistake for her. Thus Maddie was given student-centered feedback and both interpreted and used it as if it were teacher-centered feedback.

Autumn's Interpretation and Use of Feedback

Figures 10 and 11 provide the homework question and work Autumn submitted that was given feedback and was selected to be discussed during the interview. This homework question had students identify different unit decay factors given an exponential equation. From her submission, there is no evidence that Autumn understood what a decay factor is or how to find it in an exponential equation since she created a new and incorrect formula in parts (a) and (b). She then gave a final value by multiplying her incorrect decay factor by the given initial value instead of giving the decay factor.

Figure 10

Homework Problem #40 Taken from Carlson (2020, p. 153)

40. *Determine the specified growth factors for the following relationship. Write your answers in exponential and decimal form (round to the nearest thousandth).* The number of buffalo in a wildlife preserve at time t months after its initial measure is given by $f(t) = 49(0.97)^{2t}$.

    a. 1-month decay factor: b. ½-month decay factor:

    c. Circle the statement(s) below that describe(s) the behavior of the function above:

        i. An initial number of 49 buffalo decreases by 3% every ½-day.
        ii. An initial number of 49 buffalo decreases by 3% every 2-days.
        iii. An initial number of 49 buffalo decreases by 5.91% every 1-month.

Figure 12 is the feedback Autumn received on this particular submission for this problem. While the feedback Autumn received on this problem did not target her incorrect equation, it was considered student-centered feedback because it pointed Autumn in the direction of her mistake regarding decay factors, but did not correct it. The feedback suggested to Autumn the need to review decay factors and required that she put in some work to find what exactly she did wrong.

Figure 11

Autumn's Initial Submission

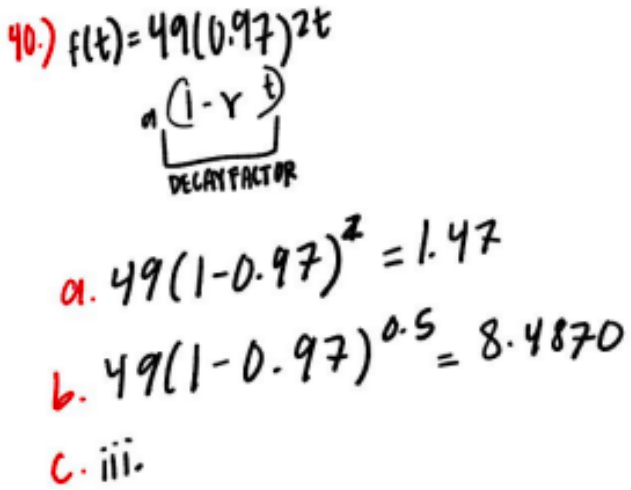


Figure 12

Feedback Given to Autumn

"… we want you to tell us what value is the decay factor and then write it in both decimal and exponential form. Which of the values of your equation represents the decay factor? …"

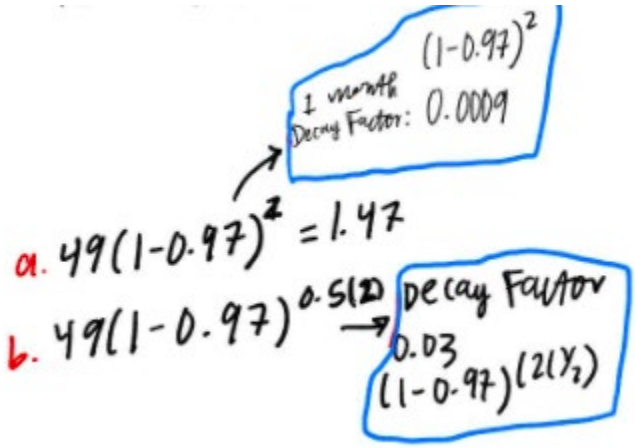
Using statements from her interview, I determined how Autumn interpreted the feedback she received on this particular question. In her interview, Autumn, referring to the feedback for this question, explained that this instance of feedback *"was helpful just because it was very… detailed."* Autumn continued by saying that, *"she [the grader] … told me … what to change."* However, the feedback Autumn was provided did not explicitly tell her what to change in her work. Rather the feedback asked Autumn a question to direct her attention to her mistake and implicitly encouraged her to take the time to learn more about decay factors in order to correctly answer the question. Based on her responses in the interview, it seems that for Autumn, the feedback she was given laid out a plan of exactly what she should fix in order to appease the grader. Thus, it appears as though Autumn interpreted the student-centered feedback she received as if it were teacher-centered feedback telling her exactly what to change.

Figure 13 shows Autumn's resubmission of the problem that I used to determine how Autumn used the written feedback she was provided. For her second submission, the only change in Autumn's work from her initial submission was an arrow that pointed to what Autumn considered to be her decay factor in the equations she created. Autumn did not reevaluate the correctness of her chosen decay factor or change her equation in any way, presumably because the feedback did not tell her to. The addition of the arrow to her work seemed to be Autumn's way of responding to the question posed in her feedback that asked which number the decay factor was. From her work, there was still no evidence that Autumn understood decay factors. It seemed as though Autumn did not put effort into learning more about decay factors and exponential functions before resubmitting her work. Thus Autumn used the feedback exactly how she interpreted it - as directions to follow. In other words, Autumn both used and interpreted

the student-centered feedback she received as if it had been teacher-centered feedback, similar to Maddie.

Figure 13

Autumn's Resubmission



Zach's Interpretation and Use of Feedback

Figures 14 and 15 provide the homework problem and Zach's work he submitted that were selected to be discussed during his interview. This homework question had students make sense of decay factors and percent changes given a context. From his work, it is evident that Zach understood growth factors and exponential functions. However, there was no evidence that he understood percent changes simply because he did not provide any percent changes in parts (a) and (b) or any possible work suggesting he was thinking about percent changes. Zach's work for these two parts is highlighted in Figure 15.

Figure 14

Homework Problem #30 Taken from Carlson (2020, p. 150)

30. An animal reserve in Arizona had 93 wild coyotes. Due to drought, there were only 61 coyotes after 3 months. Assume that the number of coyotes decreases (or decays) exponentially.
    a. Find the 3-month decay factor and percent change.
    b. Find the 1-month decay factor and percent change.
    c. Define a function that represents the number of coyotes in terms of the number of elapsed months.
    d. Re-write your function from part (c) so that it gives the number of coyotes in terms of the number of *years* that have elapsed.
    e. How long will it take for the number of coyotes to be one-half of the original number?

Figure 15

Zach's Initial Submission (Highlight Added)

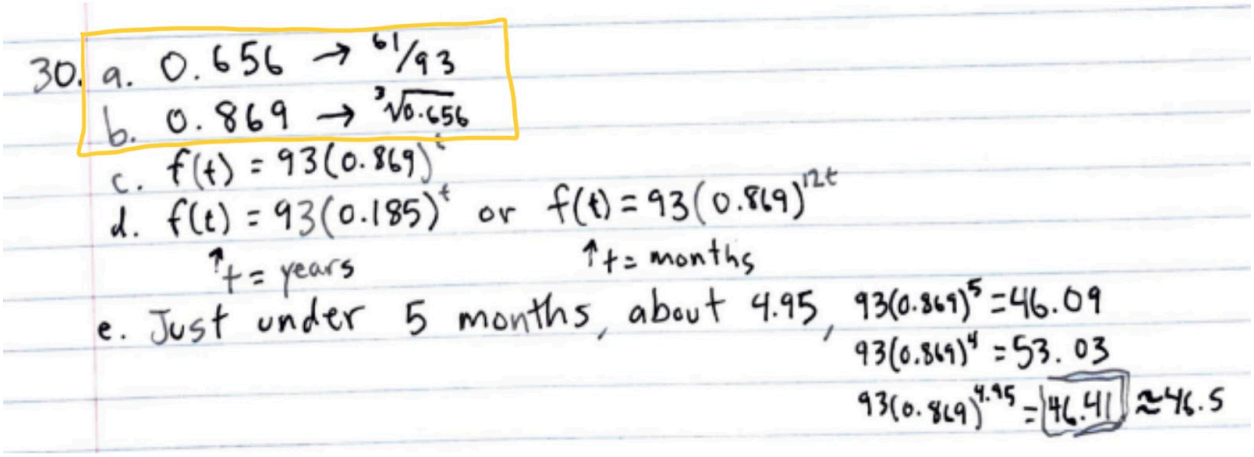
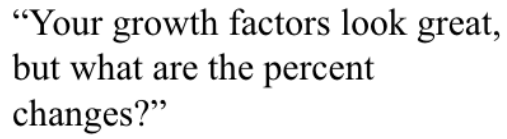


Figure 16 is the feedback Zach was provided on his work after his initial submission. This feedback was considered student-centered feedback because it reminded Zach that the question also asked for the percent changes, but did not tell him what the percent changes were or how to find them. The feedback pointed out what Zach did well and highlighted where he could improve to better answer the homework question.

Figure 16

Feedback Given to Zach



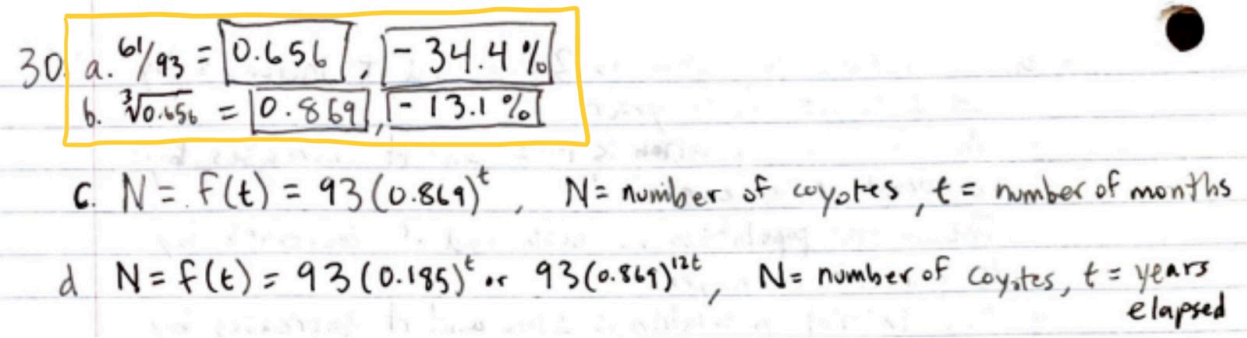
Using statements from his interview I determined how Zach interpreted the written feedback he was provided. When asked about the instance of feedback shown in Figure 16, Zach explained that he liked this feedback because *"That way you know exactly where you need to look and what you need to change, but they're not doing it for you so you actually have to do the work again."* Here, Zach explained the exact characteristic of the feedback that makes it student-centered. He noticed that the feedback directed his attention to his mistake, but did not give him the correct answer or even instructions on how to fix his mistake. Zach saw the feedback he was given and could read it and interpret it in a way that helped him see it as student-centered feedback with the purpose of making him do the work. Thus when given student-centered feedback, Zach interpreted it as was intended - as student-centered feedback.

Figure 17 provides Zach's resubmission of his work for the problem shown in Figure 14 that I used along with statements from his interview to determine how Zach used the feedback he received. In his resubmitted work, Zach correctly gave the percent changes requested of him. When asked if the feedback helped him learn more about percent changes, Zach explained that he *"understood the concept"* but forgot to actually answer the question fully. He further explained that *"it [the feedback] just helped me to remember … little pieces that I was forgetting to actually add… It was just forgetting to write everything down, I guess."* He concluded that there was no need for the feedback to encourage him to learn because he already understood

what was being asked. In short, Zach used the feedback provided to him as if it were teacher-centered feedback that evaluated the correctness of his work, rather than student-centered feedback that focused his attention on the concepts he needed to learn more about. Therefore, Zach interpreted his student-centered feedback as it was intended, but used it as if it were teacher-centered feedback.

Figure 17

Zach's Resubmission (Highlight Added)



Lizzy's Interpretation and Use of Feedback

Finally, Figure 7 from above and Figure 18 provide the homework problem and work Lizzy submitted to be graded that was selected to be discussed during her interview. As a reminder, the question in Figure 7 had students make sense of different compounding periods on an account over a given time period. Although her work is scattered, it is evident that Lizzy correctly answered the question posed in part (a) of this problem regarding the effect on an account of varying compounding periods. There is, however, no evidence that Lizzy understood APY or how to calculate the interest an account earns because she did not include any indication of an attempt on either parts (b) or (c) of the problem.

Figure 18

Lizzy's Initial Submission

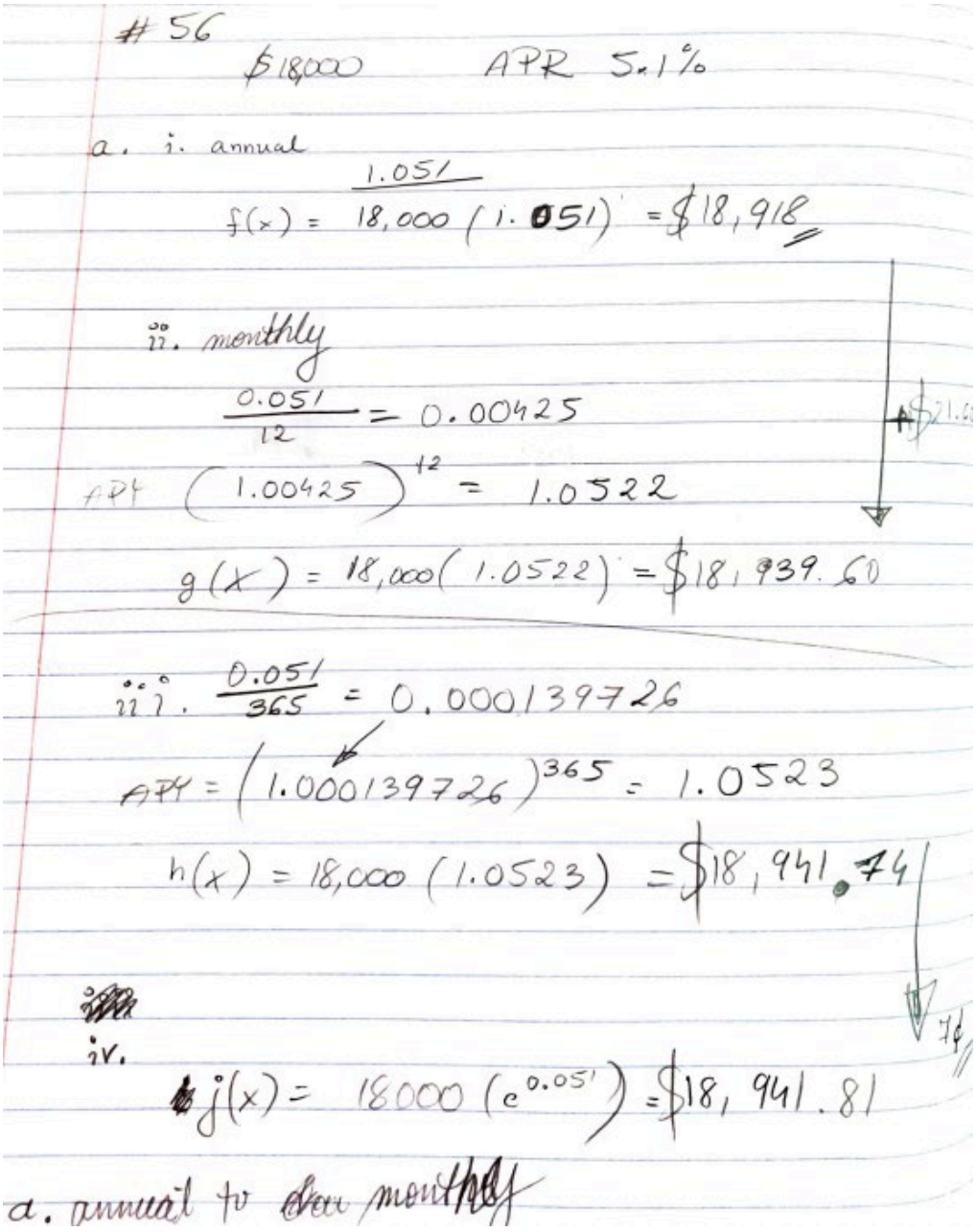


Figure 19 is the feedback Lizzy received on this homework problem. This instance of feedback highlighted what Lizzy did well and directed her attention to what was missing without doing the thinking for her. Thus this instance of feedback could be considered student-centered

feedback. However, it is important to note that the homework question Lizzy responded to did not ask students to calculate the amount of money in an account for a specific time period (see Figure 7). The problem only asked how accounts would compare if they had different compounding periods for the year. Lizzy did this by finding the amount of money in each account after one year, which is a valid solution path for this problem. Because the feedback was directed at a grader-imposed expectation, its focus was more on seeing the correct solution path on the page, rather than the correct understanding. Therefore, this instance of feedback was teacher-centered feedback disguised as student-centered feedback

Figure 19

Feedback Given to Lizzy

"Good job in part A, it looks great but remember to also calculate the amount of money for the time period that the problem is asking. How will this change your results in relation to each other? Will they even change? You are also missing part B and C"

Using statements from Lizzy's interview, I determined how Lizzy interpreted the feedback she received, despite it being teacher-centered feedback. In her interview, Lizzy explained, *"I like that she's not giving me … the specific answer … But she says 'How will it change your results in relation to each other? Will they even change?' and stuff like that. So kind of gives me a focus on what I should be doing with that."* In essence, Lizzy explained that what she liked about the feedback she recieved was the pieces that made it look student-centered despite the fact that this feedback was not related to the original problem she was asked to solve.

Similar to Zach, Lizzy was drawn to the feedback that encouraged her to think and learn more about the concept. She recognized that she was not given the answer and was instead asked to put in effort. Thus, as Lizzy read the teacher-centered feedback she received, she interpreted it as student-centered feedback.

Although Lizzy did not do a resubmission for this specific homework assignment, similar to Maddie, I determined how she used her feedback from her interview responses. Lizzy explained that with this type of feedback, or feedback that *"direct[ed] through questions"* she would *"try to apply what I know in that direction and usually figure it out."* Lizzy explained that her process for using the feedback provided to her an opportunity to utilize the understanding she already had to think through the problems differently and find ways to make sense of the problems. Based on Lizzy's description of her usual approach to the feedback she received on homework assignments, I concluded that she used the feedback to further her understanding of the concepts she had learned in class. Thus, Lizzy used the feedback she received, including this instance of teacher-centered feedback, to think through the problems and learn from her mistakes. In other words, Lizzy used the feedback as if it were student-centered feedback. Thus Lizzy both interpreted and used teacher-centered feedback as if it were student-centered feedback.

Summary

In summary, there are similarities and differences between how the four participants interpreted and used the written feedback they received. Three students (Maddie, Autumn, and Zach) received student-centered feedback on their homework and all three used the feedback they received as if it were teacher-centered feedback. However, Zach first interpreted his feedback as student-centered feedback before using it as teacher-centered feedback. Although

Lizzy received teacher-centered feedback on her homework, she interpreted her given feedback similar to Zach - as if it were student-centered feedback. Despite being the only participant to receive teacher-centered feedback, Lizzy was the only one of the four participants interviewed to use her feedback as if it were student-centered feedback. Table 6 presents the summary of how each student used the feedback they received. Thus, none of the four students interviewed used their feedback as it was initially intended to be used based on the type of feedback they were given.

Table 6

Summary of Students' Interpretation and Use of Written Feedback

Student	Feedback Given	Student Interpretation	Student Use
Maddie	Student-Centered	Teacher-Centered	Teacher-Centered
Autumn	Student-Centered	Teacher-Centered	Teacher-Centered
Zach	Student-Centered	Student-Centered	Teacher-Centered
Lizzy	Teacher-Centered	Student-Centered	Student-Centered

Students' Use of Written Feedback Relative to Their Mindset

From analyzing the four participants' interviews, written feedback, and submitted work, I concluded that the two students with fixed mindsets (Maddie and Autumn) used the written feedback they received similarly; whereas, the two students with growth mindsets (Zach and Lizzy) had few similarities in how they used the written feedback they received. Because of the variability in how the two growth mindset students used their written feedback, I cannot make any claims about the two growth mindset students' use of the feedback they received. Thus, I focus this section on how the two fixed mindset students used their feedback.

Based on interview responses from Maddie and Autumn, I concluded that for the participants in this study, students with a fixed mindset towards learning mathematics seemed to use written student-centered feedback as if it were teacher-centered feedback, did not see the feedback as useful in helping them learn, and may have used the feedback to start developing a growth mindset towards learning mathematics. I present evidence for each of these conclusions.

First, Maddie and Autumn both used student-centered feedback as if it were teacher-centered feedback. As displayed in Table 6, Autumn and Maddie were both given student-centered feedback, but through their responses to interview questions and their resubmitted work, I determined that both Autumn and Maddie interpreted and used their written feedback as if it were teacher-centered feedback. Thus both fixed mindset students tried to interpret and use feedback intended to help them learn the process as if it were feedback meant to evaluate and correct their answers. In other words, both fixed mindset students used the given student-centered feedback as if it were teacher-centered feedback.

Second, both Maddie and Autumn seemed unsure that the written feedback they received on their homework assignments helped them learn the concepts in the class better. During their interviews, both students were asked if they felt that the feedback they received on their written homework assignments helped them learn the concepts. Maddie's response was "*...probably not…*" and Autumn's response was "*...maybe a little bit.*" For both Maddie and Autumn, the purpose of the feedback was not to help them learn. As Autumn explained, the feedback told her "*what to change…*" not what to learn better. This was also supported by the fact that both Maddie and Autumn tried to use the student-centered feedback they received as if it were teacher-centered feedback. They did not see the feedback as something that could help them

understand the concept, but rather as something that could help them get the right answer. Thus for Maddie and Autumn, the written feedback was not useful in helping them learn.

Finally, there is evidence to suggest that Maddie and Autumn may have unknowingly used the written student-centered feedback to help them develop a growth mindset. All participants were asked questions directed at understanding their mindsets towards learning mathematics, understanding their thoughts about the feedback in general, and understanding their uses of specific instances of feedback. As Maddie and Autumn discussed their feedback, growth mindset wording began to present itself in their responses. For example, Autumn described being "*less frustrated* with her homework in this particular mathematics class because she knew that "*eventually I'll figure it out with the… feedback.*" This suggested that Autumn may have started to see herself as capable of understanding mathematics eventually regardless of the setbacks she faced initially. Similarly, Maddie explained that when she did the homework assignments, she would "*do it … the way I think I'm supposed to … and then if I get it wrong I can understand … why I got it wrong and redo it and … learn from that.*" Maddie's comment suggested that she was starting to see the value in learning from her mistakes in addition to understanding that eventually she could understand the concept regardless of initially getting an incorrect answer. Thus both Maddie and Autumn had instances of growth mindset phrases show up in their responses as they reflected on their experiences with the feedback they received.

It is important to note however, that the written feedback they received may not have been the only thing influencing Maddie and Autumn's development of a growth mindset. When Maddie and Autumn included instances of growth mindset phrasing in their interview responses, both referenced the opportunity they had to resubmit their work with corrections in addition to the written feedback they received. Thus, it seems that the low-stakes homework process unique

to their class that allowed them to attempt the problem, receive feedback without a numeric score, and then reattempt the problem may have also contributed to their development of a growth mindset. Therefore, I cannot definitively say that Maddie and Autumn used only their written feedback to further their development of a growth mindset.

Students' Definitions of Success in Mathematics

After analyzing student interviews and student mathematical work, I found it helpful to consider students' definitions of success in mathematics. In their interviews, each student was asked whether or not they felt successful in their College Algebra class and how they would define success in their mathematics class. From these two questions, I identified the four participants' definitions of success in their mathematics class. Table 7 lists students' statements from the interviews. I determined that three of the four students, Maddie, Autumn, and Zach, defined their success in their mathematics class on their letter grade for the class. Whereas, Lizzy defined her success on understanding and applying the concepts. Zach also included the need for understanding, but ultimately, he measured his success by exam scores.

Table 7

Students' Definitions of Success in Mathematics

Student	Definition of success in a mathematics class
Maddie	*"...just passing [the class]"*
Autumn	*"I feel like success is defined by… your test scores"*
Zach	*"...understanding the material well enough to score well on the exams and homeworks"*
Lizzy	*"Understanding the concept. Being able to use it and apply it to math problems."*

Students' definitions of success in mathematics became useful because for these four students, their definitions of success in mathematics aligned with how they interpreted and used their written feedback. Maddie, Autumn, and Zach all defined success in a mathematics class related to getting good grades. Additionally, Maddie, Autumn, and Zach all used their student-centered feedback as if it were teacher-centered feedback. Conversely, Lizzy defined success in a mathematics class as understanding the concepts and used her teacher-centered feedback as if it were student-centered feedback. Interestingly, Zach, who defined success as some understanding, but mostly good grades, first interpreted his feedback as student-centered, then used it as if it were teacher-centered. The other three students, who only had one definition of success, used their feedback how they interpreted it. Table 8 summarizes these results.

Table 8

Summary of Students' Definitions of Success and Use of Feedback

Student	Definition of Success	Interpretation of Feedback	Use of Feedback
Maddie	Good Grades	Teacher-Centered	Teacher-Centered
Autumn	Good Grades	Teacher-Centered	Teacher-Centered
Zach	Good Grades / Understanding	Student-Centered	Teacher-Centered
Lizzy	Understanding	Student-Centered	Student-Centered

Discussion

In this section, I discuss the findings from this study, and how the findings align with the existing research discussed in chapter 2. I first discuss findings related to evaluating student mindset. Then I discuss students' interpretation and use of written feedback relative to their mindsets towards learning mathematics. I then discuss students' interpretation and use of feedback relative to their definitions of success in mathematics. Finally, I discuss findings related

to the relationship among feedback, student mindset, and student definition of success in mathematics.

Evaluating Student Mindset

For this study, I assessed student mindset using a student mindset survey adapted from Sun's (2015) student mindset survey (see Table 4) and using questions in the student interview (see Appendix A). As shown in Table 5, my evaluation of student mindset through interview questions only aligned with the student mindset survey for two of the four participants, Autumn and Lizzy. Both Maddie and Zach's low student mindset survey scores suggested they tended towards a growth mindset. However, in their interviews, neither Maddie nor Zach consistently responded to the questions in a way that suggested a growth mindset. This suggests that the conclusions made from the student mindset survey may not be as reliable or complete as initially anticipated. Kunz (2020) notes that it could be the case that mindset is more complicated than Likert-scale questions can reveal. The findings in this study agree with Kunz's suspicion, suggesting the need to find a more reliable way to assess mindset.

Students' Interpretation and Use of Written Feedback Relative to Students' Mindsets

Based on the results of this study however, it does not seem as though I can definitively claim how students use written feedback relative to their mindsets towards learning mathematics. As noted previously, there was too much variability in how the two growth mindset students (Zach and Lizzy) interpreted and used their written feedback to make claims regarding how students with a growth mindset interpret and use written feedback. Although there was consistency with how the two fixed mindset students (Maddie and Autumn) interpreted and used their written feedback, the fact that I am not able to make any claims about the growth mindset students makes it difficult to generally state how student mindset influenced students'

interpretation and use of written feedback. Thus it does not seem that students' mindsets give the whole picture of how students use their written feedback.

Additionally, the type of feedback students received did not seem to influence how they interpreted and used their written feedback. For both fixed and growth mindset students, they interpreted and used their written feedback differently than was intended. The only exception was Zach who interpreted his student-centered feedback as student-centered feedback. However, Zach then used the student-centered feedback as if it were teacher-centered feedback. Thus, not only does mindset not give the whole picture, but the type of feedback students receive also does not seem to tell the whole story of how students interpret and use their written feedback.

Students' Interpretation and Use of Written Feedback Relative to Students' Definitions of Success in Mathematics

There did, however, seem to be a trend in how the four participants interpreted and used their written feedback they received that was not explicitly tied to their mindsets towards learning mathematics or the type of feedback they received. In this study, students interpreted and used their written feedback according to their definitions of success in mathematics. In other words, students interpreted and used their written feedback to help them achieve success, according to their personal definitions of success in mathematics (see Table 8). By definition, student-centered feedback focuses students' attention on the process and concepts of the problem and teacher-centered feedback focuses students' attention on whether the answer is correct or not and often corrects the students' mistakes for them. Autumn and Maddie defined success in mathematics as good grades and interpreted and used their written feedback as if it were teacher-centered feedback as a way to verify the correctness of their answers and to know exactly how to correct their mistakes. Thus, they used their feedback with the goal to improve their grades and

achieve success according to their definition of success in mathematics. Lizzy defined success in mathematics as understanding and interpreted and used her written feedback as student-centered feedback as a way to understand the process and concepts necessary to correctly answer the question. Thus, she interpreted and used her feedback to improve her understanding and achieve success that aligned with her definition of success. Zach defined success in mathematics as understanding but ultimately getting a good grade. Zach interpreted his feedback as student-centered feedback meant to help him understand the concepts and then used his feedback as teacher-centered feedback meant to help him get a good grade. Thus, just like the others, Zach both interpreted and used his written feedback in a way that aligned with his definition of success in mathematics.

As noted previously, the type of feedback students received did not seem to influence how they interpreted and used their written feedback. Regardless of whether they received teacher-centered or student-centered feedback, all four participants interpreted and used their written feedback to help them achieve success according to their definitions of success in mathematics regardless of the type of feedback they received (see Table 7). Lizzy received teacher-centered feedback on her homework assignment, yet interpreted and used her feedback as if it were student-centered feedback, which aligned with her definition of success. Maddie, Autumn, and Zach all received student-centered feedback on their homework assignment, yet they all used it as if it were teacher-centered feedback that aligned with their definitions of success. Thus, it seems that students' definitions of success in mathematics are a better indicator of how students use their written feedback than either student mindset or type of feedback they receive.

Relationship Among Mindset, Written Feedback, and Definition of Success in Mathematics

As explained in chapter 2, existing research suggests a possible relationship between students' mindsets towards learning mathematics and the written feedback they receive. Research has also shown that teachers aren't sure how to help their students develop a growth mindset (Kunz, 2020). Thus, prior to this study, I hypothesized that if we could understand how students used effective written feedback, and specifically how they used student-centered feedback relative to their mindsets towards learning mathematics, teachers could ultimately provide students with feedback that students could use to develop a growth mindset towards learning mathematics. However, based on the findings of this study, it does not seem as though there is as much of a relationship between student mindset and written feedback as was expected. As noted previously, students' definitions of success in mathematics were a better indicator for how students used their written feedback than were students' mindsets towards learning mathematics. This implies that if teachers want their students to improve their understanding of the concepts from the feedback they receive, teachers need students who define success in mathematics as understanding. Although there is still a possibility that mindset plays a role in how students use their feedback, there is a stronger relationship between students' definitions of success in mathematics and their feedback use than their mindsets and their feedback use.

It is also important to note that because mindset and definitions of success in mathematics are both part of a student's belief system, it would seem as though there is a relationship between students' mindsets and students' definitions of success in mathematics. Looking at mindset theory through the lens of definitions of success in mathematics, we see Boaler (2013) explains that if students frequently answer questions incorrectly, it can be hard for them to maintain a belief that they can achieve, which is a characteristic of a growth mindset (Boaler, 2015).

Further, if students only define success in mathematics as correct answers and good grades, incorrect answers may make it harder for students to develop a belief that they can achieve. Thus if students are unable to see themselves as successful, it may be difficult for them to develop and use a growth mindset while learning mathematics indicating that students' definitions of success in mathematics contribute to their mindsets towards learning mathematics.

Based on the findings from this study and this research, it seems as though if teachers want students to use their written feedback to help them increase their understanding of the mathematical concepts they learn and they want students to develop a growth mindset towards learning mathematics, helping students define success in mathematics as understanding may be key. If students define success in mathematics based on understanding, the findings of this study as presented in Table 8 suggest that they will use their written feedback to help them increase in understanding. If students use their written feedback to help them increase in understanding and they define success in mathematics as understanding the concepts, they will feel successful. If students feel successful, research suggests that it will be easier for students to both develop and use a growth mindset when learning mathematics.

The findings of this study also suggest that definitions of success in mathematics are easier for students to understand and interact with. Students were able to not only provide their definitions for success in mathematics, but also follow through with their definitions in how they responded to their written feedback. Conversely, there was a disconnect between students' self-assessed mindset and the mindset that was portrayed through their responses and actions as determined in the interview. Therefore, it seems that students may be able to define success easier than they can identify their mindset. This suggests that helping students change their

definitions of success in mathematics may be more productive than helping them change their mindsets.

CHAPTER FIVE: CONCLUSION

Many teachers want their students to have a growth mindset; however, research has only identified different words to use with students to prompt a growth mindset (e.g., you worked hard on that assignment versus you are so smart, Boaler, 2015). Despite their best efforts, teachers have not had success helping students develop a growth mindset (Kunz, 2020). This study investigated students' uses of written feedback relative to their mindsets towards learning mathematics with the hopes that by understanding how students used their feedback, we could tailor feedback to students' with a fixed mindset and help them use it like their growth mindset peers. From existing research I identified three groups of feedback commonly given to students; one of which (i.e. student-centered feedback) has characteristics that align with the characteristics of a growth mindset. I hypothesized a possible relationship between student mindset and student use of student-centered feedback. To investigate this relationship, I analyzed written feedback provided to students in a College Algebra class, their mindsets towards learning mathematics, and interviews conducted with them about their feedback. The results of this study suggest an alignment of students' definitions of success in mathematics and their feedback use rather than their mindsets and feedback use. Consequently, I concluded that students' definitions of success in mathematics influence their interpretation and use of their written feedback and may be a stepping stone in understanding student mindset.

Contributions

The results of this study provide at least three contributions to existing research on student mindset and written feedback. The first contribution is related to our understanding of mindset. Yeager and Dweck (2020) describe mindset as a continuum, however it is often talked about as being black or white, meaning that students have either a growth or fixed mindset.

Findings of this study support the need to think of mindset as a continuum that is dependent on the context the student is in. Students in this study were asked to self assess their mindset through a student mindset survey. However, because mindset is dependent on context and is more complicated than can be represented in a survey, students' interview responses did not always align with their self assessed mindset. This suggests that because mindset is complex, assessing mindset needs to be a more in-depth process rather than a quick survey.

The second contribution this study provides is our understanding of written feedback. Existing research has defined effective feedback that will help students increase in their understanding and elicit a positive response from students. However, the findings of this study suggest that even if teachers provide students with effective feedback (i.e. student-centered feedback) it is not guaranteed that students will interpret and use it as intended. This study found that regardless of whether students receive effective feedback or not, they will interpret and use that feedback in a way that aligns with their definitions of success in mathematics. Therefore, simply categorizing types of feedback as effective or ineffective is not enough to support teachers in improving students' learning through feedback. While the field understands how effective feedback may help students' understanding, how students interpret and use any of the feedback they receive may be more important in the learning process. Focusing more on how students interpret and use the feedback they are given will help the field better understand what makes feedback effective for students and what teachers can do to help students use their feedback to increase in understanding.

The third contribution this study provides is helping students use their feedback as it is intended to be used. In order for students to use their feedback as it is intended to be used, teachers need to attend to students' definitions of success in mathematics. If teachers want

students who use feedback to improve their understanding, they need to help students view success in mathematics as understanding rather than good grades. It seems then that the use of formative assessment may be beneficial. Formative assessment is defined as assessment that is directed towards promoting understanding and giving both the teacher and the student information on what steps need to be taken in the student's learning (Harlen & James, 1997). This is different from summative assessment, which is given when achievement needs to be reported and is often associated with a grade (Harlen & James, 1997). This implies that the frequent use of formative assessment may help students shift their focus from getting a grade to understanding a concept, which may influence how they interpret and use the feedback they receive on any formative or summative assessment.

Implications

The results of this study provide implications for both teachers and researchers. In this section I first discuss implications for teachers and how the findings from this study can influence their practice. Then I describe the implications for research and how the findings from this study can influence the research conducted on student mindset and written feedback.

Implications for Teaching

The first implication of this study is the importance of identifying students' definitions of success in mathematics and modifying them when necessary. Findings from this study show that students use their written feedback to help them achieve success according to their definitions of success in mathematics. Thus if teachers want students to use their feedback to learn, teachers need students who define success in mathematics as understanding the concepts. This implies that teachers should look for ways to identify their students' definitions of success in mathematics and work, if needed, to modify those definitions during the school year.

Additionally, findings from this study suggest that students' definitions of success in mathematics are easier to measure and less complicated than students' mindsets. Thus if teachers want to help their students work hard and understand mathematics, focusing on identifying and modifying their students' definitions of success rather than their mindsets would be a better use of time.

A second implication of this study is for teachers to consider their own definitions of success in mathematics, the definitions they want their students to have, and how their actions in the classroom support those definitions. If teachers define success in mathematics for their students based on the grades they earn, then their actions in the classroom will support that definition and students will have no reason to define success in mathematics differently. If teachers define success in mathematics for their students as understanding and they want their students to define success in mathematics that way, they need to provide students with opportunities to value understanding through their actions in the classroom. Boaler (2016) suggests that the education system and specifically the testing practices in schools have conditioned students to believe that mathematics is about performance and that success in mathematics is defined in terms of letter and number grades. Thus if teachers want their students to define success in mathematics based on understanding, they have to be conscious of the fact that their students are conditioned to define success in mathematics differently and that explicit changes may need to be made to their teaching practices to disrupt this definition of success.

One such change of practice and a third implication of this study is that teachers should implement more formative assessment in their instruction. The purpose of formative assessment is to direct students' attention away from grades and towards understanding; therefore, it is a valuable tool to help students change their definitions of success in mathematics to be based on

understanding. By using more formative assessment, teachers take the pressure away from getting a good grade and allow students the opportunity to seek out feedback on their work. This provides teachers with an opportunity to help students see the value in feedback and have more explicit discussions about defining success in mathematics. If students have the chance to focus less on grades or a score on an assignment and are given opportunities to discuss success in mathematics, it may be the case that they start to change how they define their success in mathematics, which in turn may help students use their feedback for understanding.

Another change of practice and a fourth implication of this study is that teachers should allow students to resubmit their work. Findings of this study suggest that by allowing for resubmissions, students may begin to develop a growth mindset because they do not feel the need to be perfect immediately and are given time to learn from their mistakes. This allows students to see the possibility that they can be good at math eventually because they can see their growth through the resubmission. Additionally, resubmissions emphasize to students that even if they do get a grade on an assignment, that grade is not the end. Similar to formative assessments, resubmissions remove the pressure from earning a perfect grade on the first attempt and allow for students to work to understand the material. Thus, resubmissions allow for students to value understanding over a good grade. By allowing for resubmissions, teachers send the message to their students that they want them to understand, which ultimately conveys the idea that success comes from understanding and the grade is only a byproduct of understanding.

Implications for Research

One implication of this study for research is that student mindset may be more complicated to measure and study than anticipated. Findings from this study show that simple surveys are not enough to make sense of student mindset and that mindset is more of a

continuum like Yeager and Dweck (2020) noted than two distinct categories. Additionally, findings from this study suggest that students' definitions of success in mathematics may be a piece of their mindsets towards learning mathematics. Thus it may be helpful to focus research on understanding students' definitions of success in mathematics as a way of understanding students' mindsets. It is also highly likely that students' definitions of success in mathematics are one of many pieces that define students' mindsets towards learning mathematics. Thus, research may benefit from unpacking students' mindsets to provide ideas such as definition of success in mathematics that are easier to measure to understand student mindset and provide teachers with more concrete steps in helping students develop a growth mindset. Additionally, because definitions of success in mathematics seem to be easier to measure, working with students' definitions of success in mathematics may be a more reliable way to assess mindset.

Limitations and Directions for Future Research

This study, like any other study, has its limitations that should be acknowledged. For this study, a major limitation is that only four students were interviewed and only one interview was conducted with each of the four students. Only interviewing four students is a limitation of this study because it is hard to make claims that all students will behave similarly to a sample size of four. Although there were consistencies among the four participants, I only have four examples of these consistencies, which again, makes it hard to generalize. Additionally, only one interview with each student is a limitation because there is no way to show extended consistency in individual students' interpretations and uses of their written feedback. Each students' interview consisted of questions about the feedback students received on a single homework assignment. Thus this study cannot say whether or not the students interpreted and used their feedback the same over an extended period of time.

These limitations suggest directions for future research. To address the limitation of only four participants, future research could include more students. Doing so would allow us to say that the trends found in this study are likely to be found with any student when it comes to how they use and interpret their feedback. To address the limitation of one interview about one homework assignment, future research could interview students over a longer time period and about multiple different homework assignments. Doing so would allow us to see consistency in individual students of how they interpret and use their written feedback as well as investigate how their definition of success in mathematics might change during a semester.

Another direction for future research is to select participants based on their definitions of success in mathematics rather than their mindsets towards learning mathematics. Since it seems to be the case that students interpret and use their written feedback according to their definitions of success in mathematics, future research could group students based on their definitions of success to confirm this trend. It would be beneficial to have equal groups of students who define success as understanding and students who define success as good grades to confirm the findings of this study. Doing so would ensure that interviews held with multiple students who have the same definition of success in mathematics would allow for generalization to all students with the same definitions of success in mathematics.

Conclusion

This study was conducted to understand the relationship between students' mindsets towards learning mathematics and students' uses of written feedback in a mathematics class. The intent was that by understanding how students used their written feedback, teachers could provide them with effective feedback that would support their development of a growth mindset towards learning mathematics. Thus this study investigated how students used their written

feedback and specifically how they used it relative to their mindsets towards learning mathematics. However, findings from this study could not say that student mindset was the driving force in how students used their written feedback. Rather, it seemed that their definitions of success in mathematics determined how students both interpreted and used their written feedback. These findings imply that helping students define success in mathematics as understanding would help them use their feedback to increase their understanding. These findings also suggest that students' definitions of success contribute to their mindsets towards learning mathematics. Thus if teachers want to support students in their development of a growth mindset towards learning mathematics, providing them with opportunities to change their definitions of success and with feedback focused on the mathematical concepts may be the best place to start.

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Appendix A

Sample Interview Protocol

Remind student that their instructor will not be told of their involvement in the study, so what they say will have no affect on their grade or what their teacher thinks of them. Also remind student that I'm just looking for how students honestly use the feedback they are given on homework. I am not judging their mathematical abilities

Introduction Questions:

- How is the semester going for you?
- How long have you been at BYU?
- What are you studying?
- What is your favorite class this semester?
- What is your end goal with your program?
- Why are you taking Math 110 (College Algebra)?
    - How is the class going for you?

Mindset Questions:

- Would you say in general, you like math? Why or why not?
- Are you good at math? Why or why not?
- Is this class what you expected it to be? Why or why not?
- Do you feel like you work hard in this class? Explain.
    - How would you define "working hard" for this class?
- Do you feel like you are successful in this class? Explain.
    - How would you define "success" in this class?

Feedback Questions:

- What have you thought about getting feedback on your homework?
    - Has this been a new experience for you, or have you had feedback like this before in a math class?
- What have you thought about being able to resubmit your work?
- Do you feel like the feedback has been helpful to you? Why or why not?
    - Can you think of particularly helpful feedback/ non helpful feedback you have gotten so far this semester?
- What would make the feedback more helpful to you?

Specific Questions about Homework and Feedback:

- You got feedback on this recent homework assignment (pull up homework and feedback for student to see). Looking at this feedback, was any of it helpful to you? (Ask about specific problems given student-centered feedback.) What made this feedback helpful or not helpful?
- Did you use any of this feedback to help you rework the problem/ understand the concept better? How and Why/why not?
- Can you think of any feedback you received this semester that was particularly helpful with reworking the problem or learning the concept?
- If you were the grader for this assignment, what feedback would you have given to help someone learn the concept better?
- Do you feel like when you do resubmissions of your work that you learn more about the concept between your first and second submission?
    - What contributes to that?

- Does knowing you will get feedback like what you have been getting help you feel more confident in your ability to do math? Why or why not?
- Does knowing you will get feedback like what you have been getting help you feel more confident when doing your homework problems? Why or why not?
- Is there anything else you would like me to know about your thoughts on the feedback you have been getting?
- Is there anything else you would like me to know about how you use the feedback you have been getting?

Final Reminders

- Remind student they will get a $15 Amazon gift card for their time. Explain it will be emailed out to them by next Friday and if they don't get it by then to email me and let me know so I can look into it.
- Is it ok if I think of any other questions or need clarification on your answers that I reach out to you through email?