Using Errors to Promote Learning in High School Mathematics Courses

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During my first year as a high school geometry teacher, I taught students who did not understand how to solve various problems I assigned, so they asked me for help. Students also made errors or had misconceptions. In order to help students overcome these challenges, I used the strategy of solving the problems on the board while trying to engage students and remediate any misconceptions. Afterwards, I assessed their understanding of the skill or knowledge needed to solve this type of problem. I came to the frightening realization that students did not overcome their misconceptions when I used this instructional approach.

After learning that my approach was not effective, I tried another strategy. I asked students to step up to the board and solve the problems with which they struggled or answered incorrectly. Therefore, a student who missed a problem or asked me for help would come up to the board in front of all of his or her peers and solve the problem with guidance from me, their teacher, as well as other students. Asking students to take this action was a bold and risky move because students often do not want to present at the board for several reasons. For instance, students do not want to seem incompetent or unintelligent in front of their peers. They may also be afraid of how other students respond. The experience can be extremely unpleasant in a classroom that has not fostered a safe learning environment.

I shared the approach with my colleagues. Some of them explained that they would never have a student come up to the board who did not know how to solve a problem correctly. This experience and my colleague’s responses prompted me to explore other opportunities for students to identify and correct misconceptions. If this is not an effective method of helping students, what are other instructional approaches teachers can use to support students in remediating their misconceptions? I also realized that teachers must create a classroom
environment in which students are comfortable making and learning from their mistakes. How can teachers create a classroom atmosphere in which students feel comfortable to publically learn from their errors?

These personal experiences and reflections have led to the development of the present study. This study has two main objectives. The first goal is to examine how teachers are implementing student-made errors as springboards for learning in their classrooms. The second purpose is to investigate how teachers are creating a safe learning environment so that students feel comfortable taking risks and making errors. Interviews with high school mathematics teachers will focus on the two objectives.

**Theoretical Framework**

Vygotsky’s (1978) sociocultural theory serves as the overarching theoretical framework for the present research. Vygotsky’s theory emphasizes the impact of the social environment on student learning. He wrote, “the child’s intellectual growth is contingent on his mastering the social meaning of thought, that is, learning” (Vygotsky, 1962, p. 51). In particular, students learn through the interaction between the consciousness of the student and the consciousness of others.

Vygotsky viewed higher mental functions as social because learning depends on the sociocultural environment in which learning lives. He goes on to say, “what the child can do in cooperation today he can do alone tomorrow” (Vygotsky, 1962, p. 188). The cooperation happens in a social setting.

Vygotsky’s (1978) theory is also important as the overarching theoretical framework because it highlights the importance of the zone of proximal development and interacting with a more accomplished individual. Vygotsky describes the zone of proximal development as the difference between what a student can do alone and the potential developmental level with the
help of a more accomplished individual or capable peers. The zone of proximal development supports the idea that students can participate in activities above their current level of accomplishment in collaboration with a more accomplished individual.

Vygotsky (1978) makes the argument that socialized speech turns into inward speech, which is important for problem solving and learning. Socialized speech is the communication that occurs in a social setting with others. Inward speech refers to the dialogue between a person and himself. As students identify and correct their errors in a social setting, they engage in socialized speech, which according to Vygotsky turns into inward speech. Inward speech is important because it can lead to internalization of metacognitive skills.

Vygotsky also argued that society decides what is important for students to learn. The older generation dictates what the younger generation learns including the cognitive tools to learn the culturally important knowledge. Different cultures emphasize different sets of skills and tools sometimes indirectly and directly. Vygotsky’s sociocultural theory explains how and what students learned.

According to Vygotsky (1978), internalization is a result of social interaction and the individual thinking process. In fact, he wrote, “learning awakens a variety of internal developmental processes that are able to operate only when the child is interacting with people in his environment and in cooperation with his peers” (Vygotsky, 1978, p. 90). Errors happen in the learning process and in a social environment. Students can realize that they have made an error with the help of a more accomplished individual or capable peers. Internalization is a crucial step in this process, because students are able to do on their own what they could not do before. Moreover, students develop the ability to identify and work through their errors.
While Vygotsky’s sociocultural theory is the overarching framework for this study, Piaget’s (1936) ideas also inform this work. There are differences between Vygotsky and Piaget’s respective theories of how students learn. Piaget’s theory of cognitive development emphasizes the students’ individual learning process while Vygotsky emphasizes how students learn in a social context. Piaget also mentions the idea of disequilibrium when a new idea does not fit into a student’s current schemes. Disequilibrium is an opportunity for students to interact socially with others.

The cognitive development of high school students is a factor that could impact their view of errors. According to Piaget’s (1936) theory of cognitive development, high school students could most likely be at the highest level of their cognitive development, which is formal operations. At the highest level of cognitive development, students are aware of others’ thinking and think about other’s thinking.

As Berger (2011) explains, brain maturation increases self-consciousness. In other words, adolescents think intensely about themselves and what others may think about them. For example, imaginary audience is an attribute of the highest cognitive level of development. The imaginary audience is a group of imaginary people that watch an individual and his or her every move. This is applicable to making an error or the thought of making an error in front of another classmate. According to Berger (2011), the imaginary audience causes students in this age group to believe that they are at center stage and to imagine how others will react to their appearance or behavior.

**Literature Review**

Students’ perceptions of errors reflect the established norms of a classroom. Yackel and Cobb (1996) define norms as “regularities in patterns of social interaction” (p. 460). Classroom
norms with respect to speaking, responding, and interacting with others are developed both explicitly and implicitly. For example, a teacher may explicitly tell students that they should not “talk over” the teacher when the teacher is talking. On the other hand, students may learn not to answer questions unless the students are sure that they are correct because previously the teacher chastised and/or ignored students who made errors. Whether intentionally or unintentionally established, cultural norms influence the social interaction and practices in a classroom.

Yackel and Cobb (1996) examined second and third grade classrooms in which teachers led discussions consisting of students explaining and justifying their solutions. Yackel and Cobb’s data included video recordings, interviews, field notes, and student-written work. Yackel and Cobb analyzed the data and developed sociomathematical norms by studying the teacher and student interactions.

In addition to general classroom norms, Yackel and Cobb (1996) identified sociomathematical norms, which are specific to the learning of mathematics and establish habits and patterns that promote mathematical understanding and individual autonomy. Yackel and Cobb explain that social norms, applicable to English, science, and mathematics classes, include students challenging each other’s thinking and justifying their own interpretations. However, they clarify that sociomathematical norms are “normative understandings of what counts as mathematically different, mathematically sophisticated, mathematically efficient, and mathematically elegant” (p. 461). For example, student explanation is present across various content areas other than mathematics. In contrast, the sociomathematical norm relates to whether a student explanation is accepted in mathematics.

Sociomathematical norms focus on establishing mathematical explanations, defining the process of student contribution, and describing the mathematical basis for explanations. The
sociomathematical norm of establishing mathematical explanations focuses on how a student should justify his or her mathematical reasoning. Yackel and Cobb’s (1996) findings highlight the importance of the teacher’s role in establishing the norms in the classroom. According to Yackel and Cobb, teachers’ viewpoints and beliefs about mathematics influence the sociomathematical norms established in the classroom. For example, Yackel and Cobb describe instances when the teacher demonstrates that he or she values the student response by praising or correcting it.

**Norms around Errors**

Norms related to making mistakes can be opportunities to learn from errors. Many students are apprehensive about sharing their mistakes and have a negative perspective about errors. For example, students believe the very nature of learning mathematics is making correct computations based on the procedures taught in class. Therefore, students do not want to make mistakes. Some students view errors as embarrassing especially if they happen in front of their peers. For instance, some students view errors as a sign of failure and incompetence. For errors to promote learning, teachers have to change students’ attitude toward them (Eggleton & Moldavan, 2001). Hattie and Timperley (2007) describe how "personal risk is involved" when learning (p. 100). However, if students are not comfortable making mistakes, they will not take the personal risk and minimize the opportunity to learn from their errors.

Teachers can help students become fearless learners who take risks when solving problems in mathematics classrooms. However, this task is difficult because of certain norms with respect to errors. Many students believe that errors are a result of incompetence, carelessness, and failure. In addition, many students have learned test-taking strategies, algorithms, and procedures with the sole purpose of obtaining a correct answer. Students who
make many errors earn lower grades. Further, Izen (1999) examined literature to argue that students have learned that making fewer errors is an indication of success. Hattie and Timperley’s (2007) review of literature revealed the difficulty in creating a new view of errors as springboards for learning, noting the student approach to learning from errors as "rarely welcomed" (p. 101). If students do not appreciate how errors can lead to learning, then a barrier exists when teachers attempt to use errors to promote learning.

Schleppenbach (2007) claims that a safe environment is critical for students to learn from their mistakes. Teachers need to create an environment in which students feel comfortable sharing their ideas even when they may not feel confident in their solution. In addition to feeling comfortable making mistakes, students need to have the skills to respond appropriately to another student’s incorrect solution (Schleppenbach, 2007). Further, the classroom norms with respect to errors must be changed.

**Benefits of Errors**

Ashlock (2009), Bryant and Rivera (1997), and Carraher (1985) advocate for teachers to use student errors to gain insight into students’ progress and to better design instruction. Teachers can examine student errors to understand why students made those mistakes in the first place. In fact, Ashlock (2009) mentions how teachers can categorize mistakes as a *slip* or a *bug* depending on the nature of the error. A slip is a computational error while a bug is an illustration of a misunderstanding. Evaluating errors can help teachers move beyond knowing if students understand or not to the degree to which students understand.

Exploring student errors can impact a teacher’s assessment of student learning and plans for future instruction. In her research on children in Brazil, Carraher (1985) found that formal and informal assessments did not portray student learning in the same manner. Students were
able to use different strategies like regrouping and decomposing effectively on the informal assessment in an informal setting. However, on the formal test in a formal setting, students did not use the same strategies but instead unsuccessfully attempted to use the procedures taught in school. In this case, the errors on the formal test would not have provided the teacher with a true perspective of the student’s knowledge. The teacher could then use the errors to promote further learning.

Other research supports the positive effects of using errors to promote learning (Ashlock, 2010; Borasi, 1994; Izen, 1999; Martinez, 1998). The research findings highlight how using errors can help students develop a new perspective about errors, engage students in learning, help students reflect on their own thinking, and improve students’ abilities to problem solve. Others, like Martinez (1998) and Izen (1999), use errors to change the way students think about errors.

Research findings suggest incorporating errors in classroom lessons can help students develop effective learning behaviors and attitudes. Eggleton and Moldaven’s (2001) article in a practitioner journal used a case study of a middle school mathematics classroom. They observed a classroom lesson in which students participated in an activity comparing different values represented as fractions, decimals, and percentages. As students made mistakes related to converting, understanding decimals, and comparing ratios, the teacher would ask the class questions. The teacher used the errors made for a class discussion that prompted students to confront errors and misconceptions. Eggleton and Moldaven analyzed their observations and described how the errors were the focus of the class discussions and helped students correct their misconceptions. Eggleton and Moldavan noticed how students’ attitudes about learning changed after using errors to promote learning and reflection. Eggleton and Moldavan describe a particular interaction between two students who explore their errors with a challenging problem.
The students felt confident in correcting their solution after slowing down and using reasoning to check their work.

Eggleton and Moldavan (2001) found that when students view errors as a learning opportunity their attitude about learning is more optimistic when approaching a challenge. Martinez (1998), in a resource for teachers, supports the idea that incorporating errors can help students develop optimistic views of learning. He states that students could improve their problem solving skills by replacing the fear of making errors with a perspective of viewing errors as part of the learning process. Izen (1999) emphasized that errors inevitably happen and contribute to the learning process. This positive perspective provides students with an opportunity to feel empowered to learn mathematics without the fear of making mistakes.

If students do not have a negative or apprehensive attitude toward errors, students are more willing to take risks and accept challenges. Izen (1999) emphasized the importance of students being fearless learners in order to be successful in mathematics. He describes fearless learners as students willing to make errors and learn from their errors. As mentioned previously, when teachers examine errors they can gain a deep understanding of student learning. However, Izen stresses that students must be willing to make errors. Izen illustrates a common scenario in mathematics classrooms in which students “would rather not try than do something incorrectly” (p. 756). When students have a positive attitude toward learning from errors, they are more willing to attempt problem-solving and challenging tasks.

Another aspect to consider that could possibly influence the way students view errors is Carol Dweck’s (2006) idea of mindsets. The two mindsets describe how people view their potential in different endeavors like academics or sports. One of the mindsets is growth and the other is fixed. According to Dweck, people with growth mindset believe that intelligence can
grow and improve. People with this particular mindset believe that they can learn from mistakes. According to Dweck, people with growth mindset are able to cope with failure.

On the other hand, people with fixed mindset believe that fate and personal attributes determine achievements. Dweck (2006) explains that people with fixed mindset would rather attribute their failure to lack of ability. People with fixed mindset believe accomplishments are associated with the person instead of a person’s effort. In contrast, people with growth mindset place an emphasis on effort. Teachers can expect students with fixed mindset to struggle using errors as opportunities for growth because of their view of errors damaging their sense of who they are.

Dweck’s (2013) research on parental praise as a predictor of children’s motivation supports and extends her previous work on mindsets. In the study, the conversations between, parents and their children were recorded. The recordings were transcribed, and the research team coded the transcriptions by categorizing the instances of praise into three different categories including process praise which focuses on praising students on how they did something, person praise which reflects a person’s qualities, and other praise. Dweck concludes that the process praise children hear influences their motivation.

Boaler’s (2016) book, which is a resource for teachers, embraces the idea of developing growth mindset and how it applies to mathematics. Boaler specifically writes about the power and value of mistakes as opportunities for learning. Boaler explains how students feel discouraged making mistakes because they think it means they are not a “math person.” Boaler further describes how students do not feel smart after making mistakes. However, Moser’s (2011) research findings indicate the opposite. When students make a mistake, regardless of whether they know they have made a mistake, their brain reacts with higher brain activity
measured by event related potential (ERN) and positivity component (Pe) responses. Boaler describes how surprised teachers are to hear this but explains that mistakes are usually a result of students attempting challenging work.

Further research supports the idea of errors promoting learning by enabling students to confront their misconceptions. For instance, Eggleton and Moldavan (2001) suggested that students should wrestle with their erroneous thinking. Their findings demonstrated how the mistakes became “catalysts for the learning” in the classrooms examined (Eggleton & Moldavan, 2001, p. 45). In fact, the errors provoked thoughtful and engaging classroom discussions. Students needed to explain, justify, and think about the errors they made and the errors made by their peers. Some students had to confront their misconceptions and evaluate their thinking. Eggleton and Moldavan’s research demonstrates how teachers can use errors to begin insightful and innovative learning opportunities.

Hetland (2013) draws on research to argue that the use of errors promotes creative thinking, problem solving, and ultimately positive changes in student thinking. When used productively, errors foster creative thinking because they highlight what went wrong and provide a catalyst to find a better approach and develop new exciting ideas. In other words, mistakes cultivate creative thinking and creative thinking is crucial for problem solving. Hetland demonstrates how errors can change student thinking, which leads to implementing errors as opportunities for learning. Empirical studies support Hetland’s ideas (e.g., Borasi, 1994).

Borasi (1994) investigated the use of errors as a method to promote learning, possible benefits for student learning, and the opportunities teachers can create using activities that stem from errors. In particular, the purpose of her study was to examine several aspects of the activities including the nature of the error, context, source, levels of student participation,
education goals, and lastly the results (Borasi, 1994). Borasi did her research with two struggling students engaged in an eight-lesson instructional unit involving inquiry. Having two students participate in the study allowed the researchers to monitor their thinking, errors, interactions, and progress with more accuracy. In the study, students were involved in activities that stemmed from an error they had made in the previous lesson (Borasi, 1994).

Borasi (1994) describes the benefits of incorporating errors in the various lessons. The activities in the study focused on errors and allowed students to engage in unique learning opportunities. Students were able to generate and explore their own questions from the errors they made by engaging in problem solving, logical reasoning, and mathematical reasoning. Borasi describes the students as motivated and interested in the problems initiated by errors. She also mentions that students learned the value of mistakes. According to Borasi’s observations, the benefits of incorporating errors include an increase in student motivation and the quality of the learning of mathematics.

Borasi (1994) also explored the changes in student behavior as time progressed. In one particular lesson, the teacher began by focusing on one student error. Borasi noticed that the students were more cautious about errors afterwards. In another lesson, students were engaged in a problem, which they thought was a mathematical contradiction. Students had to think critically and justify their responses. Students did not give up on the challenge but instead thought creatively about the problem. As a result of their discussion, students were able to understand the nature of mathematics as an evolving and developing field of ideas.

The outcomes of learning from errors were numerous in Borasi’s (1994) study. For example, students were able to learn problem-solving skills. They also learned to monitor their thinking, communicate their ideas, and justify their thoughts in a logical manner. According to
Borasi, students were able to initiate problems and take ownership of their learning. The researchers were surprised to see how the students had a new appreciation for learning mathematics. As the study progressed, the students’ ability to explore mathematics on their own grew. In fact, they were more eager to engage in mathematical thinking. The opportunity to engage with errors allowed students to view mathematics with a positive and optimistic perspective corroborating Izen’s (1994) findings. Borasi’s study demonstrates how a challenging task is worthwhile because incorporating errors into classroom activities helps students learn mathematics.

However, Borasi’s (1994) study involved only two students engaging in the error activities. As mentioned previously, personal risk is involved when making mistakes and some students face anxiety. This anxiety increases when teachers ask students to share their mistakes in front of their peers in a classroom setting. This is a challenge for teachers to help students as they use errors as a strategy in the classroom because of the sociocultural barriers built by students and teachers. Borasi’s work demonstrates how this challenging task is worthwhile because incorporating errors into classroom activities helps students learn mathematics.

Challenges

Along with students, teachers must have the necessary skills to promote errors as springboards. Yackel and Cobb (1996) examine different aspects of sociomathematical norms including teacher responses. Their research findings focus on investigating common norms in mathematics classrooms and exploring the effects on student learning. The type of feedback given from teachers differs and has an effect on the outcome of student progress. One of the highlights of Schleppenbach’s (2007) study is how the Chinese teachers deliberately plan for students to make errors and then use the errors for learning. According to Ding (2007), teachers
in her research were not able to use student’s errors to promote student thinking. Teachers must have competent skills to incorporate and use errors as catalysts for learning.

Schleppenbach’s (2007) research analyzes and compares American and Chinese teachers’ responses to student errors. Students made errors in both American and Chinese classrooms. Schleppenbach’s method included videotaping lessons, transcribing the lessons, and interviewing the teachers about the lesson. Schleppenbach coded the mistakes and teacher responses. She computed the amount of time for each lesson and compared it to the types of mistakes and teacher responses. According to Schleppenbach’s research, the Chinese teachers used an error as an instructional strategy more often than the American teachers. Eggleton and Moldavan’s (2001) findings agree with those of Schleppenbach’s in that there is a certain attitude toward errors in classrooms among American teachers. According to her findings, teachers in American classrooms were hesitant to explore students’ errors.

Teacher responses to a student’s error play an important role in student learning. Yackel and Cobb (1996) argue that students interpret teachers’ responses as an indicator of what is valued mathematically. In addition, teacher responses give students insight into the accuracy of their solution. According to Yackel and Cobb, the teacher can “legitimize certain aspects of the children’s mathematical activity and implicitly sanction others” (p. 466). The manner in which teachers provide feedback to an error is very important if the intention is to use an error as a springboard for learning. A key component of teacher responses, according to Shute (2008), is an element of elaboration, which involves describing the error, providing practice examples, and offering some guidance. Shute, and Yackel and Cobb mention the potential influence of teacher responses to student errors.
A teacher’s theoretical framework may also create a barrier to using errors to promote learning. Theoretical frameworks have changed significantly in this century with different movements to improve education. Educators have not always viewed errors as opportunities to promote learning, and, for some educators, this is still the case. From a behaviorist standpoint, mistakes are not reinforced or encouraged for learning. In fact, behaviorists encourage and praise students for correct behaviors, which demonstrate learning (Borasi, 1994). Therefore, the teacher’s viewpoint of learning and the role of errors in learning indicate how the errors are used in the classroom. When a teacher views learning mathematics as a factory of production that only values correct responses, errors are not acceptable in the classroom (Eggleton & Moldavan, 2001).

Creating an optimal environment where errors are productively used to promote learning is not an easy task for teachers. Hattie and Timperley (2007) gathered an immense amount of research on feedback in order to analyze the effectiveness of feedback and the factors that make feedback the most effective. With this analysis, Hattie and Timperley wanted to create a model that explains how feedback can promote learning and teaching. Hattie and Timperley described a typical student approach in which students "respond only when they are fairly sure they can respond correctly" (p. 101). Students did not want to make mistakes because they were afraid to be wrong. Martinez (1998) mentions how even adults do not want to make mistakes. In order for errors to promote learning, students must be comfortable with making mistakes.

Lannin et al. (2006) closely examined student-thinking processes as they made an error and resolved an error. The study focused on two participants and did not involve teachers. Lannin et al. developed an error analysis cycle, which describes how students recognize, explain and reconcile an error. Lannin et al. described the three situations in which students recognize
that they have made an error and the reflection process students used to resolve their error. The three situations are discovering two different answers, social influence, and unreasonable results. However, Lannin et al. did not specify how a teacher could support the error analysis process.

Student errors provide teachers with an understanding of student learning and serve as an opportunity to further student learning. Using errors as catalysts to promote learning is realistic, but teachers must establish a positive and safe learning environment in which students feel comfortable taking risks (Borasi, 1994). In fact, Borasi explains how errors can be used as bridges to problem-solving skills, mathematical thinking, metacognition, and justification. Her research demonstrates the benefits of using this strategy with only two students. Based on research on classroom norms and students’ apprehensiveness toward errors, the task of incorporating errors to enhance learning is difficult. Borasi’s study was conducted with only two students, which possibly removes the challenge students face when making mistakes in a classroom full of students. Would researchers find the same results as those in Borasi’s study in a classroom of students engaging with errors? Will students develop the same optimistic and positive perspective if they make errors in front of their peers? Should teachers or students point out the error? Should teachers allow students to present errors to their peers? Would students who made the error learn better by having another student present the solution correctly?

The purpose of the present study is to examine how secondary mathematics teachers are using errors to promote deeper understanding and fearless learning while cultivating a classroom atmosphere that allows students to take risks and make mistakes. Specifically, the following research questions will be addressed:

1. How do teachers use student mathematical errors to develop fearless learners, who are willing to learn from their mistakes and to take risks?
2. How do teachers develop a safe classroom environment in which students feel comfortable to make mistakes and correct mistakes in front of their peers?

Methods

Study Design

The researcher conducted a qualitative research study using interviews as the primary source of data (Avy, Jacobs, & Razavieh, 2002). According a review of research by Avy et al., interview response rates are very high and can provide valuable information. The researcher used the general interview guide approach (Turner, 2010). According to Gall et al.’s (2003) resource for researchers, the general interview guide approach is more structured than an informal conversational interview with some areas of flexibility. The researcher examined and analyzed 11 teacher questionnaires and interview responses. From this data, the researcher produced a summary of how the participating teachers use mistakes to promote fearless learning and help students feel comfortable using errors.

Participants

The participants include 11 secondary mathematics teachers from a metropolitan area in the Southwest United States (Table 1). The participating teachers all have an interest in the use of errors to promote understanding and confront mistakes. The teachers have a range of teaching experience from first year teachers to twelve years of teaching. More than half of the teachers have taught less than five years. Seven of the 11 teachers received their certification through an alternative program. Teachers have taught a variety of subjects in mathematics from algebra to senior level classes.
### Table 1

**Study Participants**

<table>
<thead>
<tr>
<th>Participant</th>
<th>Years Teaching</th>
<th>Teacher Certification</th>
<th>Initial Area of Certification</th>
<th>Courses Taught</th>
<th>Mathematics Course(s) Currently Teaching</th>
</tr>
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<tbody>
<tr>
<td>Bremby</td>
<td>1</td>
<td>Alternative Certification</td>
<td>Mathematics (8-12)</td>
<td>Algebra 1, Algebra II, Pre-Calculus</td>
<td>Pre-AP Algebra 2, Pre-Calculus</td>
</tr>
<tr>
<td>Cassey</td>
<td>0</td>
<td>Traditional</td>
<td>Mathematics (8-12)</td>
<td>Pre-Calculus</td>
<td>Pre-Calculus</td>
</tr>
<tr>
<td>Collins</td>
<td>6</td>
<td>Traditional</td>
<td>Mathematics (8-12)</td>
<td>Algebra I, Geometry, Math Models with Applications, Algebra II, Pre-Calculus, and STAAR Test Review</td>
<td>Algebra I, Geometry, Math Models with Applications, Algebra II, Pre-Calculus, and STAAR test review</td>
</tr>
<tr>
<td>Gone</td>
<td>3</td>
<td>Traditional</td>
<td>Math/Science Grades (4-8) Mathematics Grades (8-12)</td>
<td>Algebra I, Pre-Calculus, and Physics</td>
<td>Algebra I</td>
</tr>
<tr>
<td>Lincoln</td>
<td>10</td>
<td>Alternative Certification</td>
<td>Mathematics (8-12)</td>
<td>Not Identified</td>
<td>Geometry</td>
</tr>
<tr>
<td>Moxley</td>
<td>1</td>
<td>Alternative Certification</td>
<td>Mathematics (8-12)</td>
<td>Algebra I</td>
<td>Algebra 1</td>
</tr>
<tr>
<td>Pallenta</td>
<td>3</td>
<td>Alternative Certification</td>
<td>Chemical Engineering</td>
<td>Organic Chemistry, English as a Foreign Language, Geometry, and Pre-Calculus</td>
<td>Geometry and Pre-Calculus</td>
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<td>Tamez</td>
<td>12</td>
<td>Alternative Certification</td>
<td>Mathematics (8-12)</td>
<td>Ordinary, supplementary, and advanced levels of IGCSE program, Geometry</td>
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<td>Trend</td>
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<td>Alternative Certification</td>
<td>Mathematics (8-12)</td>
<td>8th Grade Math, Algebra I, Geometry, and Algebra II</td>
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<td>Geometry and Math Models</td>
<td>Honors Geometry and Math Models</td>
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<tr>
<td>Yanel</td>
<td>3</td>
<td>Traditional</td>
<td>Mathematics (8-12)</td>
<td>TAKS Re-testers and Algebra I</td>
<td>Algebra I</td>
</tr>
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</table>
Procedure

After the researcher received IRB approval (Appendix A), all potential participants were introduced to the study through informal conversations with the researcher or through an email inviting teachers to participate in the study. The researcher used purposeful sampling (Avy et al., 2002). All potential participants of the study completed a five-item questionnaire (Appendix B).

Prior to inviting teachers to participate, the researcher conducted a pilot questionnaire. The purpose behind the pilot questionnaire was to examine the questionnaire items. Once the researcher received responses, she changed some of the questions in order to reduce redundancy and increase clarity. For example, the pilot questionnaire included “How can teachers use student made errors to promote deeper understanding?” and “How do YOU use student made mathematical errors to promote deeper understanding in your classroom?” The researcher found that the teacher responses were not very different and decided to eliminate the second question.

The questionnaire had two main purposes. First, the questionnaire helped identify the teachers who have a genuine interest in using errors as learning opportunities. The information provided by the teachers gave the researcher an idea of their perspectives about mistakes. If it was evident that a teacher completing the questionnaire did not see the value of students learning from their mistakes, then the researcher did not select the teacher as an interview participant. Secondly, the completion of the questionnaire helped maximize the interview time. By using the participants’ responses to the questionnaire items, the researcher was able to use the interview time more effectively.

After the researcher identified eleven teachers who used errors as learning opportunities, the researcher invited these teachers to participate in individual interviews at each participant’s school. Four who completed the questionnaire declined to participate in an individual interview.
Therefore, the only data for these four teachers are their responses from the questionnaire. Seven teachers agreed to participate in an individual interview.

The interviews were semi-structured; that is, some questions were prepared ahead of time while others resulted from the conversation during the interview. There were some open-ended questions that the researcher asked all the participants (Appendix C). In addition, the researcher generated questions specific to each participant based on his or her responses on the questionnaire. The interview also included follow-up questions (Turner, 2010). The interview focused on how teachers use mistakes to engage students and further their learning. The researcher asked teachers to explain how they view mistakes as part of the learning process and use mistakes to catapult learning. Further, the teachers’ views and perspectives gave the researcher insight into how to help students confront their mistakes in a positive learning atmosphere. The interviews lasted between 30 and 60 minutes. The researcher recorded and then transcribed all of the interviews for data analysis.

Data Analysis

The two main sources of data were the questionnaire responses and the transcribed interviews. The researcher used the constant comparative method to analyze the data (Glasser & Strauss, 1967). The constant comparative method is appropriate for this study because the process allowed for the coding and synthesizing of data into a theory in a repetitive yet concise manner. The researcher reviewed her data searching for strategies, from those strategies she developed codes and with those codes she coded her data. The codes were condensed throughout the process to ensure that codes were not repetitive. The researcher constantly examined and revised her codes to appropriately represent the reported strategies. Ultimately, the codes were restructured in terms of the researcher’s synthesis and/or the participants’ own phrases.
Categories emerged from the development of the codes. The method allowed the researcher to code and analyze data simultaneously to develop concepts (Glaser & Strauss, 1967). The process repeated itself to examine the relationships between the categories, codes, and concepts.

**Findings**

Teachers provided a variety of instructional suggestions for using errors as opportunities for learning during the interviews. These instructional strategies allow teachers to use the errors students made to promote learning and develop skills. Teachers also provided ideas to help students feel comfortable making errors.

**Teachers’ Utilization of Errors**

From the information provided on the questionnaires and from the interviews, the researcher developed a list of twelve teacher practices within four domains. The four domains are teacher centered, student inquiry centered, social norm centered, and resource centered (Table 2). Table 2 also displays the number of teachers who suggested each strategy.

**Teacher centered.** Teacher centered instructional strategies focus on ways in which the teacher redirects and reteaches in response to an error. Furthermore, teachers provide clear direction by informing students that they made a mistake, what the mistake was, and/or how to correct the mistake. One of the strategies occurs when the teacher tells students if their solution is correct or incorrect. Another strategy is when the teacher reteaches the idea to correct the error and/or the misconception. The last strategy of this kind is when the teacher presents the student with a familiar example and reviews that example so students can develop a better understanding. This set of strategies is teacher directed because the teacher is identifying the error rather than having students figure out their mistake.
Table 2

*Instructional Practices to Promote Deeper Understanding by using Errors*

<table>
<thead>
<tr>
<th>Strategies</th>
<th>Number of Teachers (n=11)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teacher Centered</td>
<td></td>
</tr>
<tr>
<td>Teachers reteach</td>
<td>4</td>
</tr>
<tr>
<td>Teachers notify student if their answers are correct or not</td>
<td>9</td>
</tr>
<tr>
<td>Teachers give students a more familiar example or provide hint</td>
<td>8</td>
</tr>
<tr>
<td>Student Inquiry Centered</td>
<td></td>
</tr>
<tr>
<td>Teachers can ask students questions</td>
<td>11</td>
</tr>
<tr>
<td>Teachers present a student error</td>
<td>4</td>
</tr>
<tr>
<td>Teachers ask students to compare two solutions</td>
<td>5</td>
</tr>
<tr>
<td>Teachers have students think back, rework, and analyze</td>
<td>6</td>
</tr>
<tr>
<td>Social Norm Centered</td>
<td></td>
</tr>
<tr>
<td>Teachers provide positive feedback or encouraging words</td>
<td>7</td>
</tr>
<tr>
<td>Teachers make mistakes in front of their students</td>
<td>2</td>
</tr>
<tr>
<td>Resource Centered</td>
<td></td>
</tr>
<tr>
<td>Teachers involves a second student to assist</td>
<td>10</td>
</tr>
<tr>
<td>Teachers can have students use resources</td>
<td>4</td>
</tr>
</tbody>
</table>

Four teachers recommended reteaching the concept. The teacher provides a new lesson to help students fix their mistakes, correct their misconceptions, or realign their thinking. Teachers could reteach the concept to the entire class or a small group. Ms. Trend explains that reteaching is:

really contextual, so I guess it depends on the example and depends on what we were doing. If I think it would benefit the whole class, I might go deeper into a little mini teaching lesson. Or if it's really just something that that particular student alone is struggling with, something they're still not getting, then I would try to hit them individually at some point. I think that's what I would do. (Interview, February 21, 2016)

According to Ms. Trend, reteaching is a strategy to use when students make mistakes.

One of the strategies is for teachers to notify students whether the solution is correct or not in order for the students to be able to focus their energy on more critical skills like analyzing
their mistake. In other words, if a mistake is made, the teacher proceeds to tell the student that their solution is incorrect. Ms. Trend believes that students will feel less pressured after knowing whether they are correct or not. According to Ms. Trend, identifying the student error “is freeing, and it allows them to do more critical thinking” (Interview, February 21, 2016).

Another strategy is for teachers to give students an additional example when they make a mistake. Ms. Pallenta explains, “I might model a similar problem, so different numbers so I'm not doing the problem for them, but a similar one to model” (Interview, February 12, 2016). A similar example can help students relate and understand the main concept at hand. Ms. Trend mentions, “[I] refer to other examples we’ve done, ‘Well, what did you do here?’ and ‘How does that look in this problem?’” (Interview, February 21, 2016). Teachers may also provide students with an example with which they would be more familiar when they make a mistake. Ms. Trend commented, “If they still can’t get it, I'll do one of two things. Either I will give them a little hint to fix their own answer or sometimes I will have another student practice - I guess giving them a hint’” (Interview, February 21, 2016). When students make mistakes, teachers may provide students with a hint or a similar example as Ms. Pallenta and Ms. Trend have suggested.

**Student inquiry-centered.** Student inquiry-centered instructional strategies occur when teachers create opportunities for students to identify their error and correct it on their own with limited guidance from the teacher. The participating teachers suggested four instructional strategies in this category, namely the teacher asking questions, requesting that students compare two solutions, presenting students with a mistake, and prompting students to reflect. Each strategy has the intention of promoting students’ thinking about the error and self-correcting their solution. Students are using inquiry to think through their errors.
All of the study participants recommended asking students questions when students made errors. Teacher questions can take many forms, and participants suggested several different types of questions that the teacher could ask. Mr. Lincoln explained that asking students questions could help them realize their own mistakes. He mentioned, “I usually ask them questions when I'm walking around and checking work or when I'm checking their warm-up - first thoughts. I'll look at them and say, ‘Why did you do this?’ or, ‘How did you get this?’ or, ‘Are you sure about this?’” (Interview, February 25, 2016). Mr. Lincoln asks students questions as a form of promoting student inquiry about student errors. Ms. Pallenta added that she asks questions when students are correct or incorrect. She admits that she “question[s] maybe at times too much, but anything kids do, if they show me work, why did you get that, how did you know how to put that number there. So my kids are pretty used to me asking follow-up questions” (Interview, February 12, 2016). This is student inquiry centered because the teacher is not directly telling the student what the error is, why it is wrong, and how to fix it.

Participants also suggested asking students to compare two solutions as part of the student inquiry category. In other words, teachers present two solutions, one solution that is correct and the other incorrect. A variation of this strategy is for teachers to have students present solutions to each other. For example, Mr. Lincoln has students sit in groups of three and compare their solutions from their graded tests. He adds, “They compare their tests. ‘Let me see your test,’ and let them compare their tests. ‘How'd you get that right and I got that wrong? What did you do?’ and those kinds of things” (Interview, February 25, 2016). Mr. Lincoln intends for the students to share their reasoning and help each other correct mistakes. He does this by “allowing groups to help correct and teach can better increase understanding” (Questionnaire, February 7, 2016). Ms. Willow also has students compare and contrast their solutions. She adds, “They could
compare and contrast like, 'Oh, I worked it out this way, but you worked it out this way,’ and then it would be - if it's a compare/contrast situation, then they should be able to identify where their mistake was” (Interview, February 23, 2016).

Another strategy is for teachers to present students with a mistake. Participants mentioned different ways to present errors in their classes. For example, Ms. Cassey presents the most commonly made errors anonymously to her class. She has students compare and explain the difference between the correct and incorrect answer. Ms. Cassey explains that her students, will be like, ‘I made the same mistake.’ And then people are like, ‘Yeah. Me too.’ And I'm like, ‘Okay.’ That's when we have a class discussion of why they thought it was their answer and how it's not, or we compare and learn. (Interview, February 24, 2016)

Mr. Tamez describes:

A couple of times what I did was at the end of the class I'd give them index cards to answer a quick question or two. Then I collect them, pick the ones that have interesting mistakes or common mistakes - the most common ones then put them under the document camera, and ask the students, what do they see wrong in that answer, or to comment on the answer. What needs to be fixed or something like that. (Interview, February 16, 2016)

For this strategy, teachers are presenting students with the opportunity to develop their reasoning skills, articulate their thoughts, and go through the process of identifying errors with the help of their peers.

Six of the 11 research participants suggested the strategy of asking students to reflect on and analyze their work. For example, Ms. Pallenta has students “‘pause, rewind. Try again.’ Meaning I want the kids, I'm excited that they want to give an answer, but I want them to pause,
go back a little bit, and start again. It's worked in class” (Interview, February 24, 2016). Other teachers also used this strategy when discussing students’ solutions. Mr. Tamez elaborated by saying, “I ask them to go back and rethink about the steps again” (Interview, February 16, 2016). Mr. Tamez and Ms. Pallenta highlighted the importance of asking students to think back, reflect, and analyze their mistakes.

**Social norm centered.** The third category addresses the social norms of the classroom. As previously mentioned, using errors to promote learning may not be the social norm in every classroom. However, the participating teachers recognized the importance of adapting errors as a tool for growth and learning. Teachers suggested providing encouraging feedback to students and modeling making a mistake.

One strategy of the social norm category is for teachers to provide students with positive feedback. Ms. Trend mentioned, “I'll first start with the positives. So if they wrote it in the correct format or maybe got the right coefficient or whatever it is, I'll say, ‘I'm really glad you got this right’ or just something positive. And I say, ’but this is not completely right’” (Interview, February 21, 2016). Teachers can recognize positive aspects of students’ work regardless of their errors. Teachers can also encourage students after they made a mistake with positive words. Ms. Trend says she “profusely” thanks students (Interview, February 21, 2016). Ms. Pallenta mentions how “when a student makes a mistake I thank them. I let them know that I saw other students make the same mistake so I'm happy that they were brave to volunteer their answer“ (Questionnaire, February 7, 2016). Another form this can take in a classroom is awarding students points for participation despite mistakes. In fact, Mrs. Gone mentioned, “I give students points for volunteering. When students do volunteer, or are called on, I give them a chance to fix
their mistakes” (Questionnaire, February 7, 2016). In this strategy, Mrs. Gone gives students positive feedback in the form of participation points.

Another instructional strategy is for teachers to provide a positive example of how to respond to a making a mistake in front of others. Ms. Trend recommends thanking students after they let her know that she made a mistake. She also said that she makes mistakes to encourage her students to take risks. She adds, “I say all the time in my class, ‘It’s okay to be wrong, it’s okay to make mistakes’ and when I make mistakes, I'm like, ‘Look guys, even I make mistakes. It happens’” (Interview, February 21, 2016). Teachers can set an example for students to follow in a similar situation. Ms. Cassey mentioned how she reacts to making a mistake in front of her students, “I put the wrong thing and they're like, ‘Didn't you say this?’ I was like, ‘Yes I did. Thank you.’ And then I start singing Hannah Montana, ’Everybody makes mistakes’” (Interview, February 24, 2016). Teachers said that modeling how to react after making an error was important for students to witness.

**Resource-centered.** Resource centered instructional strategies occur when the teacher provides or suggests resources to students who made errors. This category focuses on resources like notes, books, or peers. This is different from teacher-directed efforts because teachers are not the source of guidance or redirection. Students are using their resources to correct their errors.

Ten participating teachers suggested asking another student to help the student who made the mistake. Teachers can have another student explain a concept or how to fix a mistake. For instance, Ms. Pallenta asks, “If another student can help out. Then the student explains what they would do differently. I then go back to the original student and have them rework the problem and explain why they are doing it differently now” (Questionnaire, February 7, 2016). Ms.
Willow suggests this strategy because, “now it’s two to four kids working together to try and figure out versus one by themselves” (Interview, February 23, 2016).

Participants also suggested having students use resources like their notes, journals, books, and examples as a strategy to promote learning from errors. The participants spoke about their experiences in helping promote deeper understanding after students made a mistake by asking students to look at an example in their notes. Mr. Lincoln mentioned that he says to his students, “I’m telling them all the time, ’Look back. That word's in your composition book. Turn back a few pages. What did you write about that? Where's the example you wrote down?’ Constantly refer to the materials” (Interview, February 25, 2016). He believes that students can use all kinds of resources like their books, laptops, and the Internet. Ms. Willow shared how she responds when students make errors by saying, “Look over your work, go read the problem again, go look at notes” (Interview, February 23, 2016). With this strategy Mr. Lincoln and Ms. Willow help students help themselves correct their mistakes.

**Teacher Practices to Make Students Comfortable with Errors**

As the literature suggests, teachers need to develop an environment in which students feel comfortable making mistakes in classrooms. From the participant suggestions, three categories emerged to describe the types of teacher practices to make students more comfortable. The three realms relate to practices in areas of the teacher’s classroom set up, response in academic terms, and social interaction (Table 3).
Table 3

*Strategies for Making Students Comfortable with Errors*

<table>
<thead>
<tr>
<th>Teacher Practices to Make Students Comfortable</th>
<th>Number of Teachers (n=11)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teacher’s Classroom Design Realm</td>
<td></td>
</tr>
<tr>
<td>Teachers establish procedures and classroom norms</td>
<td>4</td>
</tr>
<tr>
<td>Teachers can create small cooperative groups</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Teacher’s Academic Realm</td>
<td></td>
</tr>
<tr>
<td>Teachers can notify students if they are correct and incorrect</td>
<td>1</td>
</tr>
<tr>
<td>Building the complexity</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Teacher’s Social Realm</td>
<td></td>
</tr>
<tr>
<td>Teachers provide positive feedback</td>
<td>3</td>
</tr>
<tr>
<td>Teachers make mistakes in front of their students</td>
<td>2</td>
</tr>
<tr>
<td>Teachers can be socially aware</td>
<td>3</td>
</tr>
<tr>
<td>Teachers can build relationships with students</td>
<td>2</td>
</tr>
<tr>
<td>Teachers’ viewpoint of using errors as opportunities for growth</td>
<td>3</td>
</tr>
</tbody>
</table>

**Teacher’s classroom design realm.** According to four of the teachers interviewed, the manner in which a teacher sets up her classroom can influence students’ comfort levels with respect to viewing and using errors. Another aspect is classroom procedures and norms, which give students structure and guidance in regard to how they should behave in class. For example, teachers mentioned how they could make students feel comfortable with strategic student grouping.

Establishing classroom procedures and expectations is an instructional practice that four participants suggested to encourage learning from student errors. Establishing classroom procedures helps students know how to interact with one another. In classrooms where there are norms and procedures designed to help students respect each other despite making errors, students are more comfortable making those errors. Ms. Pallenta mentioned how she establishes expectations in particular when it comes to student-to-student interaction. She says to her
students, “No, I don’t accept that language. That’s not okay. We’re not making fun of each other” (Interview, February 12, 2016). Her classroom procedures and expectations have the purpose of preventing students from being embarrassed.

Participants placed students in cooperative groups as a strategy to use errors to promote learning when students make mistakes. When students work in a cooperative group setting, they collaborate with and help each other when an error happens. Participants mentioned the benefits of having students in cooperative groups so that students can help each other. Ms. Collins stated, “I make them work together because we have tables, we don’t have desks. So, you’re forced to sit with people, and I just have to draw a really hard line at the beginning and be like, ‘We will not have negative talk. No negative conversation. No put downs’” (Interview, March 28, 2016).

**Teacher’s academic realm.** For the academic realm category, teachers build students’ comfort level through academic efforts. Participants suggested knowing students’ progress and increasing the complexity of the problems when applicable. The academic realm of the instructional strategies relates to teacher interactions that involve scaffolding and content.

One participant, Ms. Trend, also suggested notifying students if they had made a mistake so that students are aware of their solution. She said:

One of the things I do whether they be right or wrong, is right up front I'll tell them - after I maybe encourage them or whatever - I'll tell them, ‘You either got it right, or got it wrong’ before I do like a follow-up question, maybe in depth. I think that frees them up to be like, ‘Oh, I know the answer now. It's either right or it's wrong, and I'm going to do deeper, critical thinking’ like, ‘Oh, I got it right. Well, why did I get it right?’ (Interview, February 21, 2016).
In fact, she describes the strategy as “freeing, and it allows them to do more critical thinking” (Interview, February 21, 2016). According to Ms. Trend, this strategy allows students to focus on correcting their errors.

Another participant suggested that in order for students to be comfortable exploring their mistakes in front of others, teachers must build students up to it. In other words, teachers built the complexity of the problems in which students engaged. Teachers can have students explore mistakes with a problem of lower complexity and then give students more challenging problems. For example, Ms. Cassey mentioned how her students had to expand a trigonometric function but they struggled and made mistakes. In order to help her students, she described:

I gave my students an algebraic expression and they all knew to re-write it as two factors. When I presented the trig expression, some of them were able to see that we need to rewrite the expression as two factors. Other students, however, were not able to see why distributing the exponents was incorrect. We then expand the expression and when we arrive to the final result they were able to see that they were missing an entire term when they distributed the exponent. (Questionnaire, February 7, 2016)

This strategy helps students relate one problem to another more complex problem.

**Teacher’s social realm.** Teachers can influence students’ comfort level through their social interactions. Nearly all the participants recommended some type of strategy involving how teachers interact with students on a social level. The social aspect applies to both small-group and whole-class settings.

One instructional strategy in the social realm category is for teachers to make errors in front of their class. Teachers can make mistakes in front of their students so they can relate to their teachers. Ms. Trend recalls how she makes mistakes in front of her class. She tells her
students that, “It’s okay to be wrong” and “look guys, even I make mistakes, it happens” (Interview, February 21, 2016). The way she responds to making an error models for students how to respond after making a mistake. Ms. Cassey had a similar approach. She described making errors:

It's just a natural thing. It's going to happen. It's inevitable. I do. I even have a poster - I know it's so cheesy [chuckles] - on my wall that says, "Life is about learning mistakes and learning from them." It's not just okay to be like, "Oh yeah. I made a mistake.” But, "Hey what can I do to fix it?” or, "What can I do to learn from it?" (Interview, February 24, 2016)

Teachers can set an example of how errors are part of the learning process and as a result make students comfortable.

Three participants suggested that teachers should be aware of students’ social needs and tendencies. According to Ms. Willow, teachers should know how students react to finding out that they are wrong. For example, she mentioned:

I think if I know a kid- well, if I know that they have like no clue how to do it, I typically won't send them to the board. Just because I don't - I don't know, it can be such a vulnerable thing. Like if they already struggle with math, and I know for sure that they don't- I don't want to purposefully put them on the spot. But if it's someone who - I'd be more likely if the kid was supposed to have worked it out and I think that they're capable of solving it. (Interview, February 23, 2016)

Ms. Willow’s knowledge of students informs her decision to ask students to take a risk.

The relationship between the students and teacher impacts the classroom environment and ultimately students’ comfort levels sharing their mistakes. Ms. Trend mentioned:
It's all about do the relationships and the climate - if you have that kind of climate where it's okay to make mistakes, they see me making mistakes, they see other people making mistakes, and not having a big deal about it, then it's not a big deal to make mistakes. (Interview, February 21, 2016)

Ms. Trend believes the teacher’s relationship with students influences how they feel about making mistakes.

The teachers’ viewpoints can make a difference in how teachers use errors to promote deeper understanding. For example, Mr. Lindsey explained how a teacher could view errors as an accomplishment. In fact, he mentioned, “Wrong answers aren’t always wrong, there might be other possibilities” (Questionnaire, February 7, 2016). Teachers’ viewpoints can influence a teacher to build a classroom environment in which students feel safe to take risks and make mistakes. Mr. Tamez explained how he tells his students that, “if we don’t make mistakes, then we don’t learn” (Interview, February 21, 2016). A teacher’s viewpoint of errors can determine whether teachers believe errors promote learning and therefore lead to building a safe classroom environment for using errors.

**Discussion**

The present study addressed the following research questions:

1. How do teachers use student mathematical errors to develop fearless learners, who are willing to learn from their mistakes and to take risks?

2. How do teachers develop a safe classroom environment in which students feel comfortable to make mistakes and correct mistakes in front of their peers?

The researcher collected responses from 11 secondary mathematics teachers from completed questionnaires and follow-up individual interviews. The researcher was able to organize the
teacher responses into a list of strategies to use errors to promote learning and a list of strategies to help students be more comfortable making errors.

**Use of Errors to Promote Learning**

The reported strategies fell into four categories including teacher centered, student centered, social norm centered, and resource centered. The purpose of each strategy was for teachers to use errors to deepen understanding. Each category fulfills the purpose through a different entry point. For instance, in the teacher centered category, teachers are the source of knowledge and guidance in comparison to the strategies in the resource centered category.

With the responses from the questionnaire and interviews, the researcher developed a list of strategies to guide teachers on how to respond to errors in a way that will help students learn. Borasi’s (1994) work shows how errors can be used to promote learning, develop problem-solving skills, and engage students in mathematics. While Borasi’s study advocated for the use of errors to deepen understanding, her findings were derived from working with only two students. The teacher strategies explained in the present research come from teachers with class sizes greater than two students.

Borasi (1994) developed a list of nine learning opportunities offered by error activities. The list includes “recognize the more humanistic aspects of mathematics, experience ownership, and reflect on the nature of mathematics” (pp. 185-186). Borasi’s list of learning opportunities differ from the list of instructional strategies that promote learning suggested by teachers because the list of instructional practices are strategies teachers can use. In contrast, Borasi’s list emphasizes the positive learning outcomes.

According to Shute’s review of literature (2008), teacher feedback should have an element of elaboration, which involves describing the error, providing practice examples,
offering some guidance. Some of the suggested strategies align with Shute’s findings. For instance, one of the strategies in the teacher centered category is for teachers to give students a more familiar example or provide hints. Another strategy that aligns with Shute’s findings is for teachers to have students use their resources like when Mr. Lincoln and Ms. Willow ask students to review examples in their notes.

Ashlock (2009) mentions the difference between a slip and a bug in his resource book for teachers. More than one teacher also talked about the distinction between types of errors in their explanations. Mrs. Gone described a student making an error by describing the error as “small” (Questionnaire, February 7, 2016). Mr. Lincoln elaborated by stating, “small mistakes don’t necessarily mean that they’re all wrong – that they don’t know what they’re doing … They still know what to do. They just need to fix the small mistake” (Interview, February 25, 2016). These teachers did not use the same terminology as Ashlock; however, the teachers alluded to the idea of different types of errors.

Yackel and Cobb (1996) describe sociomathematical norms as norms that indicate what is valued in mathematical reasoning and justifications. Hattie and Timperley (2007), Izen (1999), and Boaler (2012) suggest that student errors in mathematics are not always welcomed. The use of errors challenges the traditional current sociomathematical norms. One specific strategy, that emerged in the present study, that challenges the traditional sociomathematical norms, is for teachers to make mistakes in front of their students.

While there are four categories of instructional strategies, teachers may use a strategy from one category followed by a strategy in a different category. For example, a teacher may tell students that their answer is wrong but follow up with the strategy of asking the student questions. Another example is Mr. Tamez’s combination of strategies: “I ask them to go back
and rethink about the steps, or let's go over the steps again” (Interview, February 16, 2016). In this example, he has students think back but also asks questions, a different strategy.

**Making Students Comfortable**

The findings from the present research also address the concerns of the current literature on the social aspect of using errors. Izen (1999) and Boaler (2012) mention how students do not always view errors in a positive way. The strategies in Table 3 are teacher recommend practices on how to make students more comfortable using errors in a classroom setting.

Martinez (1998), Borasi (1994), and Izen (1999) argue that errors can productively change how students think. Their conclusions align with some of the reported strategies, in particular Ms. Trend’s and Ms. Palladino’s strategy of giving students positive feedback after making errors. The positive feedback could help students think of errors differently.

Piaget’s (1936) idea of the imaginary audience is addressed in one particular strategy. The imaginary audience refers to a group of imaginary people that critically observes the student. The imaginary audience can cause the student to experience some uneasiness when performing problems in a setting in which they believe will bring judgment from others. The study participants recommended that teachers establish classroom norms and procedures to help students interact with the imaginary audience. For example, Ms. Pallenta’s reported strategy is for teachers to not allow students to tease each other. Her strategy strives to create a safe and bully-free atmosphere in which students can take risks.

Vygotsky’s (1978) ideas are prominent in the strategies to make students more comfortable. Vygotsky’s work focuses on how learning happens in a social setting. For instance, the strategy of creating cooperative groups in which students can work together with more
accomplished or equally capable peers reflects Vygotsky’s ideas. In cooperative groups, students could grow from their errors with the help of peers in their group.

Schleppenbach (2007) advocates for teachers to create a safe learning environment in which students are comfortable making errors. The list of strategies aligns well with Schleppenbach’s findings because the purpose of the strategies is to create a safe learning environment for students to feel comfortable making mistakes. Further, this study produced a second list of strategies so students can use errors to promote learning.

Dweck’s (2006) idea of mindset is evident in one particular strategy. Three participants argued that the teacher’s viewpoint could influence students’ comfort level in using errors. While the teachers do not apply the same terminology found in Dweck’s work, the participants shared the same sentiment regarding teacher’s viewpoint effecting students’ comfort levels. Additionally, Ms. Moxley describes her viewpoint by stating, “I always make sure my students know that the only time their brain grows is when they make a mistake” (Questionnaire, January 14, 2016). Her positive viewpoint of errors reflects a growth mindset and growth mindsets emphasize that errors are not an indication of failure.

There are similarities between some of the instructional strategies for using errors to promote learning and for making students comfortable. The strategy of teachers telling students if they are incorrect or not is included in both categories of strategies. Teachers recommended one strategy but used the strategy for different purposes. For example, Ms. Trend uses the strategy to make students more comfortable because it is “freeing” for her students. In contrast, Ms. Bremby said, “I tend to let the student know how far into the problem everything was correct” (Questionnaire, February 7, 2016). In other words, one instructional strategy may have
the potential to productively affect students in using errors to promote learning and make them comfortable.

**Implications**

Three pedagogical implications result from this study. The first is the idea that teachers can welcome errors. Boaler (2012) suggests that errors are actually an indication of challenging work, and the list of strategies help teachers use errors. Second, there is a progression in the strategies from heavily teacher supported to less teacher support. Lastly, the strategies reported from the participants in the study have multiple purposes and are used in multiple ways.

Moser’s (2006) research indicates that there is more brain activity when students make mistakes. Boaler (2012) uses Mosser’s research to conclude that students are more likely to make mistakes when engaging in challenging work. The findings from this study encourage teachers to provide students with opportunities to make errors as a result of engaging in challenging tasks while simultaneously providing strategies for using errors to promote deep understanding.

Hetland (2013) states that errors signify that students are engaged in problem solving and creative thought. Hetland explains that when students attempt to correct their mistake, they develop novel ideas with creativity. Hetland’s findings also point to the idea that students can be positively influenced by participating in tasks that create opportunities for errors to happen. Moser’s (2011) and Hetland’s (2013) work have pedagogical implications for teachers because their work makes a case for teachers to provide students with opportunities to make errors. If students do not make errors, then they do not have the opportunity to think creatively or increase their brain activity.

The four categories of strategies for teachers to use errors to promote learning range from teacher centered strategies for which the teacher provides the student with direction to student
inquiry centered strategies for which the teacher prompts student thinking to guide students. There is a progression in the strategies to support the development of student autonomy. Borasi (1994) found that the use of errors could positively affect students by improving their problem-solving skills.

Teachers can use the strategies in Tables 1 and 2 in multiple ways for multiple purposes. For example, all of the participants suggested that teachers could present errors when students make mistakes. However, teachers asked questions for different purposes such as identifying an error. Ms. Yanell presents student errors to the class by asking them to think about other “common mistakes” students made on the assignment (Questionnaire, February 7, 2016).

Providing students with encouragement was a strategy that participants suggested. Both Ms. Moxley and Ms. Trend encouraged their students. In Ms. Moxley’s and Ms. Trend’s examples, they responded to student errors with positive verbal feedback. In contrast, Ms. Yanell who had the same purpose, implemented the strategy differently. Ms. Yanell gave her students participation points for their grade.

**Future Research**

The sample size for this study is small which is an area that has the potential for exploration in future research. These data were collected from 11 high school mathematics teachers. With 11 teachers, generalizations cannot be applied to a large group of teachers. Future research could potentially collect data from a larger group of teachers to generate generalizable ideas about how teachers use errors for learning.

Schleppenbach (2007) found that American teachers responded less to errors than Chinese teachers. As Table 2 shows, there is varied frequency of how many teachers suggested each strategy. While this research study did not compare American and Chinese classrooms, all
11 teachers were able to reflect and describe an instructional strategy that they used to capitalize on errors. There is an opportunity for future research to investigate the frequency of the use of the instructional strategies in each lesson suggested by the participating teachers.

Lastly, the researcher did not observe the strategies that the teachers provided to evaluate their effectiveness in a classroom. Teachers made recommendations and talked about the strategies that work for them, but the researcher did not observe the teachers implementing the strategies. There is room for future research to reflect on the effectiveness of the strategies that the participants mentioned.

**Conclusion**

The researcher used responses from 11 high school mathematics teachers to create a list of strategies for using errors to promote deeper understanding and making students more comfortable. The lists provide teachers with practices to promote learning despite the stigma against errors (Boaler, 2012). The lists along with other research (Hetland, 2013; Borasi, 1994; Boaler, 2012) make a case for building new sociomathematical norms for using errors.

The findings from this research study have pedagogical implications for teachers such as strategies that enable many benefits for using errors such as promoting problem-solving skills, creative thinking, and increased brain activity for students with growth mindset. A closer analysis of the strategies also indicates a progression between the strategies. Further, strategies can be used for different purposes with different manners of execution according to the reported teacher responses. The study also has the potential to provide a foundation for future research studies based on the findings presented herein.
References


Appendix A:

IRB

TCU INSTITUTIONAL REVIEW BOARD
Review Cover Sheet

Date: September 10, 2015

Principal Investigator: Dr. Sarah Quebec Fuentes, Associate Professor, College of Education

Project Title: How Are Teachers Using Errors to Promote Learning in High School Mathematics Classrooms?

Multi-Year Project: Yes ☐ No ☒

Proposed Participants:
☐ TCU students, faculty, or staff
☒ Non-TCU Participants
☐ Special populations (e.g. children)—specify

If requesting an exemption or expedition, please state reason: The study involves minimal risk, and the interviews will be recorded. Therefore, I am requesting an expedited review.
The TCU Institutional Review Board (IRB) is responsible for protecting the welfare and rights of the individuals who are participants of any research conducted by faculty, staff, or students at TCU. Approval by the IRB must be obtained prior to initiation of a project, whether conducted on-campus or off-campus. While student research is encouraged at both the undergraduate and graduate level, only TCU faculty or staff may serve as Principal Investigator and submit a protocol for review.

Please submit this protocol to the appropriate Departmental Review Board for recommendation and submission to the IRB. DRBs will submit to the IRB electronically at IRB.StudentSubmit (pdf preferred). Include the Protocol Approval Form as a word document with highlighted sections filled in. Also submit a consent document, HIPAA form if applicable, Protecting Human Research Participants Training certificates, recruitment materials, and any questionnaires or other documents to be utilized in data collection. A template for the consent document and HIPAA form, instructions on how to complete the consent, and a web link for the Protecting Human Research Participants Training are available on the TCU IRB webpage at www.research.tcu.edu. Submission deadline for protocols is the 15th of the month prior to the IRB Committee meeting.

1. **Date:** April 13, 2015

2. **Study Title:** How Are Teachers Using Errors to Promote Learning in High School Mathematics Courses?

3. **Principal Investigator (must be a TCU faculty or staff):** Sarah Quebec Fuentes, Associate Professor, College of Education

4. **Department:** College of Education

5. **Other Investigators:** List all faculty, staff, and students conducting the study including those not affiliated with TCU.
   Ana Castañeda, Graduate student

6. **Project Period:** October 1, 2015 – September 30, 2016

7. **If you have external funding for this project –**
   **Funding Agency:** N/A   **Project #:**  **Date for Funding:**
8. **If you intend to seek/are seeking external funding for this project –**

**Funding Agency:** N/A  **Amount Requested From Funding Agency:** N/A  **Due Date for Funding Proposal:** N/A

9. **Purpose:** Describe the objectives and hypotheses of the study and what you expect to learn or demonstrate:

The purpose of this study is to examine how secondary mathematics teachers are using errors to promote deeper understanding of mathematics and fearless learning while cultivating a classroom atmosphere that allows students to take risks and learn from their mistakes. Specifically, the researcher will address the following research questions:

1. How do teachers use student-made mathematical errors to develop deeper understanding of mathematics?
2. How do teachers use student-made mathematical errors to develop students as fearless learners, who are willing to learn from their mistakes and take risks?
3. How do teachers develop a classroom environment that makes students comfortable enough to make and correct mistakes in front of their peers?

10. **Background:** Describe the theory or data supporting the objectives of the study and include a bibliography of key references as applicable.

Student errors occur in classrooms regularly. However, the focus of many studies is not on how teachers can use errors to promote learning. However, according to Izen (1999), errors are part of the learning process; not all students view errors through this perspective. Some students and even teachers believe that students should eliminate errors. Izen (1999) also describes the benefits of students having a positive approach to errors as fearless learning. Researchers such as Borasi (1994), Hattie and Timperley (2007), Schleppenbach (2007), and Shute (2008) have suggested the possibility of errors being catalysts for learning and described how students took ownership of their learning. Borasi’s (1994) research explains the possible outcomes of using errors to promote learning. Borasi viewed errors as springboards for inquiry and in his research found that students learned the mathematics that stemmed from their errors. However, Borasi only had three students in his study and did not have to establish a classroom comfort level similar to one needed with a full class of students. Researchers suggest that building the classroom environment is a factor in how students view mistakes. Schleppenbach (2007) claims that a safe environment is critical component in order for students can learn from mistakes. This study will address the result of combining the Izen’s (1999) idea of “fearless learning” and Schleppenbach’s (2007) idea of a safe learning environment.

References


11. **Subject Population:** Describe the characteristics of the participant population including the inclusion and exclusion criteria and the number of participants you plan to recruit:

The participants will include secondary mathematics teachers from Fort Worth Independent School District. The participating teachers will all have an interest in the use of errors to promote understanding and confront mistakes. The teachers will believe that errors can be opportunities for enriching understanding.

12. **Recruitment Procedure:** Describe your recruitment strategies including how the potential participants will be approached and precautions that will be taken to minimize the possibility of undue influence or coercion. Include copies of the recruitment letters, leaflets, etc. in your submission.

The researcher will recruit participants by two methods: informal conversations or a recruitment email. The researcher, a high school mathematics teacher, will have informal conversations with her colleagues to identify other mathematics teachers who have an interest using student errors to promote deep understanding and correction of misconceptions. The researcher will invite these teachers to complete a questionnaire (Appendix A) based on informal conversations. The researcher will send an email (Appendix B) asking for high school math teachers if they are willing to participate in the study. Any interested high school math teachers will email the researcher their completed questionnaire.

The researcher will select a subset of participants to participate in a follow-up interview based upon their responses to the questionnaire (Appendix A). Specifically, since the study focuses on how teachers use errors to promote learning the participants selected for the follow-up interview will all be teachers that believe in using errors.

13. **Consenting Procedure:** Describe the consenting procedure, whether participation is completely voluntary, whether the participants can withdraw at any time without penalty, the procedures for withdrawing, and whether an incentive (describe it) will be offered for participation. If students are used as participants, indicate an alternative in lieu of participation if course credit is provided for participation. If a vulnerable population is recruited, describe the measures that will be taken to obtain surrogate consent (e.g., cognitively impaired participants) or assent from minors and permission from parents of minors.
All participants in the study will complete an initial questionnaire electronically. An introductory paragraph to the survey will indicate that by completing and submitting the questionnaire, the teachers are providing consent. The subset of teachers, selected to participate in the follow-up interview, will sign a consent form (Appendix C). The researcher will explain the content of the consent form with the subset of teachers agreeing to participate in the follow-up interview and teachers will confirm their agreement to participate by signing the consent form. Participation in the study is voluntary. Participants can withdraw at their own discretion at any time of the study. If participants wish to withdraw, they may notify the researcher in person, by phone, or via email. There will be an incentive for participants who are interviewed. The district mathematics coordinator has agreed that the amount of hours spent for the interview may contribute to the teacher’s professional development hours (Appendix D). The incentive for teachers to participate in the study is the opportunity for professional development. They have the opportunity to share their practices and ideas with other colleagues.

14. Study Procedures: Provide a chronological description of the procedures, tests, and interventions that will be implemented during the course of the study. Indicate the number of visits, length of each visit, and the time it would take to undergo the various tests, procedures, and interventions. If blood or tissue is to be collected, indicate exactly how much in simple terms. Flow diagrams may be used to clarify complex projects. Potential participants will be introduced to the study through informal conversations with the researcher or through an email inviting teachers to participate in the study. All participants in the study will complete a questionnaire delivered through electronic means using Socrative (Appendix A). The researcher will give the participant teachers a code to access the survey. Participant teachers will then complete a five-item questionnaire. The researchers will be the only people, who have access to all responses. A subset of the teachers, who completed the questionnaire, will participate in a semi-structured interview. The researcher will conduct interviews individually at each participant’s school. The interview protocol is in Appendix C. The interviews will last between 30 to 60 minutes. The researcher will audio record and transcribe all of the interviews for the data analysis. During the interviews, the researcher will take notes. As a form of validation, the researcher will use member checking system. In other words, the researcher will present findings to the participants and allow their input before finalizing the report.

15. Data Analyses: Describe how you will analyze your data to answer the study question. The two main sources of data will be the questionnaires and the interviews. The researcher will use the constant comparative method (Glaser & Strauss, 1967) to analyze the data. The constant comparative method is appropriate for this study because it will allow the researcher to code data to synthesize the data into a theory in a repetitive yet concise manner. It will allow the researcher to develop the concepts, relationships and themes from the data. The researcher will have a large
collection of data from the interviews. The researcher hopes to see common practices that the teachers vouch are effective ways to promote learning through errors.

References

16. **Potential Risks and Precautions to Reduce Risk:** Indicate any physical, psychological, social, or privacy risk which the subject may incur. Risk(s) must be specified. Also describe what measures have been or will be taken to prevent and minimize each of the risks identified. If any deception is to be used, describe it in detail and the plans for debriefing.

There are very few risks involved with this study. The risks for teachers in this study are not greater than those they encounter in their daily practice. Teachers may feel as if their practice is being evaluated when sharing their thoughts. In order to minimize this risk, confidentiality will be maintained with the participants and participants may withdraw from the study at any time.

17. **Procedures to Maintain Confidentiality:** Describe how the data will be collected, de-identified, stored, used, and disposed to protect confidentiality. If protected health information is to be re-identified at a later date, describe the procedure for doing so. All signed consents and hard data must be stored for a minimum of 3 years in a locked filing cabinet (and locked room) in the principal investigator’s office, lab, or storage closet at TCU. Your professional society may recommend keeping the materials for a longer period of time.

To maintain confidentiality, the researcher will use pseudonyms and exclude any identifiable information. The audio recordings will be kept locked electronically on the researcher’s device. The researcher will keep the hard copies of the responses to the questionnaire, audio recordings, interview notes, consent forms, and any other hard copies in a locked filing cabinet in the Principal Investigator’s office in the College of Education for a minimum of three years along with the USB device with the electronic data.

18. **Potential Benefits:** Describe the potential benefits of the research to the participants, to others with similar problems, and to society.

Teachers have the potential to grow professionally through reflecting on their practice when sharing their opinions and practices with the researcher. Current and future classroom teachers can benefit from the findings of this study because the study will share ways in which current high school mathematics teachers are using mathematics errors as springboards for learning.

19. **Training for Protecting Human Research Participants:** Submit training certificates for all the study investigators. The training link is available on the TCU IRB webpage at [www.research.tcu.edu](http://www.research.tcu.edu).
Certificate of Completion
The National Institutes of Health (NIH) Office of Extramural Research certifies that Ana Castaneda successfully completed the NIH Web-based training course “Protecting Human Research Participants”.
Date of completion: 06/24/2014
Certification Number: 1493615

Certificate of Completion
The National Institutes of Health (NIH) Office of Extramural Research certifies that Sarah Quebec Fuentes successfully completed the NIH Web-based training course “Protecting Human Research Participants”.
Date of completion: 11/28/2014
Certification Number: 1626782
20. **Check List for the Items That Need to be Submitted:** Please combine all the files into one pdf document before submitting the materials electronically to the IRB. To prevent any delay in the approval of your protocol, use the most recent template for the protocol, consent document, and HIPAA form by downloading them from [www.research.tcu.edu](http://www.research.tcu.edu) each time you prepare your materials.

   a. Protocol
   b. Consent document
   c. HIPAA form if applicable
   d. Protecting Human Research Participants Training certificate for each investigator
   e. Recruitment fliers, letters, ads, etc.
   f. Questionnaires or other documents utilized in screening and data collection
Appendix A
Teacher Questionnaire

Name: ________________________________________

1. I am seeking your ideas on how to use errors to promote deeper understanding. This survey should take about 15-20 minutes of your time. Your input is valuable to investigating common and helpful teaching practices. Your participation is voluntary and you may choose to not complete the questionnaire. By submitting this questionnaire, you are releasing consent. Although I am asking you for your name, I will use pseudonyms for reporting purposes. If you have any questions, please feel free to contact me through phone (817-913-2838) or email (a.k.castaneda@tcu.edu).

Thank you for taking the time to complete the questionnaire. Please be honest and detailed in your responses.

2. How can teachers use student made errors to promote deeper understanding?

3. How do YOU use student made mathematical errors to promote deeper understanding in your classroom?

4. How do you make students comfortable to take risks and make mistakes in your classroom?

5. If a student makes a mathematical mistake and it is clear that they have a misconception, how would you help them confront their misconception?

6. How would you handle the following situation:
A student volunteers to go to the board to solve a problem. You allow the student to go the board without looking over his or her work. When he or she is solving the problem, you realize that the student is solving the problem incorrectly.
7. Again by submitting this questionnaire electronically, you are releasing consent.

Figure 1. Opening page of Socrative questionnaire.
Greetings!

I would like to introduce myself. My name is Ana Castañeda. I am mathematics teacher at South Hills High School as well as a graduate student at TCU. I’m working on a study for my master’s program. The purpose of my study is to examine how current high school mathematics teachers are using errors to promote learning.

I am inviting you to participate in my study. If you are willing to participate, please complete the questionnaire. To complete the questionnaire:

1. Click on https://b.socrative.com/login/student
2. Use 9H2FU2KT to view the questionnaire.
3. Enter your first and last name.
4. Complete the questionnaire.
5. Submit your questionnaire.

By submitting the questionnaire, you are consenting to have your responses be used as data for the study. Your confidentiality will be maintained. Pseudonyms will be used and data will be kept in a locked file in the College of Education.

A subset of participants who complete the questionnaire will be asked to participate in an interview. The interviews will be scheduled around a time that is convenient for you and will not last longer than one hour. If you have more questions, I would be happy to answer them.

Thank you,
Ana Castañeda
817.913.2838
a.k.castaneda@tcu.edu
Appendix C
Sample Interview Surveys

Name: _____________________________________________

1. Elaborate on how you use student made mathematical errors to promote deeper understanding.

2. What do students gain from the experience of confronting their mistakes in front of their peers?

3. How do you make students comfortable to make mistakes in your classroom?

4. In the questionnaire, you wrote how you would help students confront their misconceptions. Elaborate more on … .

5. In the questionnaire, you wrote how you would handle a situation with a student answering a question at the board in front of their peers. Elaborate on what you said about …. 

6. In a hypothetical situation, if you had a student who you knew had made a mathematical error on a problem, would you ask him or her to solve the problem on the board in a class full of students? Why or why not?

7. In a hypothetical situation,
   A student is solving a problem on the board and makes an error. Another student in the class ridicules the student at the board.
   How would you respond?
Appendix D

Teacher Incentive

MEMO

Shannon Hernandez
Director of Secondary Mathematics
100 N. University Dr., Ste. 5E 423 Fort Worth, Texas 76107
Office 817.814.2540 Fax 817.814.2545
www.fwisd.org

2014-2015 Mathematics Professional Development Stipend
Prior Approval Request Form

Name: Ana Castaneda

NOTE: Attendance at Professional Development on contract days will not apply to the stipend.

Professional Development/Course Description: (Include location, sponsor, time, and date) Keep all paperwork from the professional development along with a copy of this form to include with your stipend form.

Subject teachers will be interviewed at their high school during the fall semester of 2015. The interviews will follow up a cycle template.

Number of stipend hours requested from event: 2

How will this professional development be utilized in your classroom?

I will use their ideas in my classroom to support the understanding, develop problem solving skills and help students view mistakes in a new way.

What TEKS are addressed in this professional development?

The process TEKS.

NOTE: This form must be submitted one week PRIOR to attendance at the professional development session. Attach a detailed agenda of the session.

Signature and Date

Administrator's Signature Required and Date

Email or Fax signed and completed form prior to event. Math Dept fax # 817-814-2545.

Math Department Only

Received:

Approved/Rejected

Director of Mathematics
Title of Research: How Are Teachers Using Errors to Promote Learning in High School Mathematics Classrooms?

Funding Agency/Sponsor: Not applicable

Study Investigators: Sarah Quebec Fuentes, Associate Professor, College of Education
Ana Castañeda, Graduate Student

What is the purpose of the research? The purpose of this study is to examine how secondary mathematics teachers are using errors to promote deeper understanding of mathematics and fearless learning while cultivating a classroom atmosphere that allows students to take risks and learn from their mistakes.

How many people will participate in this study? Ten to 15 teachers will complete the questionnaire, and the researcher will conduct a follow-up interview with six to 10 teachers, who also completed the questionnaire.

What is my involvement for participating in this study? You will answer a questionnaire and send it to the researcher. Based on your responses, the researcher will contact you to schedule a semi-structured interview. The researcher will interview you, audio record you and take notes. The researcher will use pseudonyms and present the findings to you before publishing the findings.

How long am I expected to be in this study for and how much of my time is required? The questionnaire should not take more than 15 minutes of your time. The interview following the questionnaire will last between 30 to 60 minutes.
What are the risks of participating in this study and how will they be minimized? You may feel uncomfortable sharing your thoughts and opinions because of fear of the researcher evaluating your practices. The researcher will assure you that your identities will be concealed. Pseudonyms will be used and data will be kept in a locked file in the College of Education.

What are the benefits for participating in this study? You have the potential to grow professionally through reflecting on your practice when sharing your opinions and practices with the researcher.

Will I be compensated for participating in this study? You may credit 2 hours of your time toward professional hours needed for the district mathematics stipend.

What is an alternate procedure(s) that I can choose instead of participating in this study? None.

How will my confidentiality be protected? The researcher will use pseudonyms. The researcher will present findings in a manner that will not easily identify you. The data will be kept in a secured locked file in Dr. Quebec Fuentes’ office in the College of Education.

Is my participation voluntary? Yes, your participation is voluntary.

Can I stop taking part in this research? Yes, you may withdraw at any time without penalty.

What are the procedures for withdrawal? The researcher asks you to notify her in an email (a.k.castaneda@tcu.edu) or via phone (817.913.2838).

Will I be given a copy of the consent document to keep? Yes.

Who should I contact if I have questions regarding the study? Ana Castaneda, TCU graduate student, a.k.castaneda@tcu.edu, 817.913.2838 Sarah Quebec Fuentes, s.quebec.fuentes@tcu.ed, 817.257.6026
Who should I contact if I have concerns regarding my rights as a study participant?
Dr. Anna Petursdottir, Chair, TCU Institutional Review Board, Phone 817 257-6436.
Dr. Tim Barth, Co-Chair Institutional Review Board, Telephone 817-257-6427.

Your signature below indicates that you have read or been read the information provided above, you have received answers to all of your questions and have been told who to call if you have any more questions, you have freely decided to participate in this research, and you understand that you are not giving up any of your legal rights.

Participant Name (please print): ____________________________________________

Participant Signature: ________________________________
Date: ______________

Investigator Name (please print): ________________________________Date: ______________

Investigator Signature: ________________________________
Date: ______________