USING EXIT TICKETS TO LEARN FROM MISTAKES AND DEVELOPING GROWTH MINDSET IN AN ALGEBRA CLASS

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This study was designed to examine the use of mistakes to promote students' performance in undergraduate Algebra classes by developing a growth mindset. Participants were seventy-four students from three Algebra classes and received one of the three interventions along with regular instruction: (a) growth mindset feedback on mistakes (growth-feedback, n=27), (b) regular feedback on mistakes (feedback-only, n=23), and (c) watching video presentation (control, n=24). Participants from the growth-feedback and the feedback-only groups performed significantly better than the control group in the exams conducted after the intervention. Also, the growth-feedback participants outperformed the other two classes. Findings highlight the importance of valuing mistakes, providing feedback and fostering a growth mindset in developing students' math skills and promoting their academic achievement.

Keywords: Algebra, Growth-mindset, Constructive feedback.

Growth mindset is the belief that an individual's most basic abilities can be developed through dedication and hard work—brains and talent are just the starting point (Dweck, 2008). A growth mindset identifies a direct correlation between one's efforts and increased knowledge. Mistakes are inevitable in math and are also a source of frustration for both educators and students, as they reflect on potential misunderstandings and lack of learning (Lischka, et al., 2018; Mueller & Dweck, 1998). Growth mindset unleashes the potential of viewing mistakes as opportunities and using them as constructive tools for learning (Boaler, 2016; Mueller & Dweck, 1998; Sun, 2015). Growth mindset promotes individuals to engage with materials and skills with an understanding that failures and setbacks can ultimately bring success.

Although researchers (Eggleton, & Moldavan, 2001; Kaur, 2008) emphasize on the importance of instructional approach based on providing constructive feedback on students' mistakes, there are studies (Moldavan, 1986) that did not find this approach effective in promoting students' learning. This study examines the efficacy of constructive immediate feedback using growth mindset messages about mistakes in developing math skills and maximizing the academic achievement of students.

Growth Mindset and Mistakes

In teaching mathematics, instructors and students often come across mistakes that are a part of the learning process. Mistakes provide the first step in learning by highlighting an opportunity to construct new knowledge or work on misconceptions. An understanding of mistakes can facilitate both instructors and students in the strengthening of their knowledge. Instructors can use mistakes to incorporate teaching strategies that can facilitate students' deepening their learning by providing them opportunities to discover and construct knowledge. Students—using constructive feedback on mistakes—can use the learning opportunity from their mistakes to develop the knowledge that is lacking.

Importance of Constructive Formative Feedback

Instructors need to have a thorough understanding of the concepts that students are lacking and collecting timely feedback from students can help in getting acquainted with students' mistakes and in providing instructors insight to students' understanding (Doabler & Fien, 2013; TÜRKDOĞAN & Adnan, 2021). While it is imperative that instructors provide feedback on students' understanding, the quality and time of feedback plays a crucial role in fostering students' learning.

Using Growth Mindset View of Mistakes as a Learning Tool

A growth mindset is known to foster a notable change in students' attitude towards seeing mistakes as opportunities to learn and improve (Dweck, 2008; Boaler, 2016, 2022; Moser et al., 2011), and the results support the findings that the individuals with a growth mindset had superior accuracy after getting acquainted with mistakes compared to individuals with fixed mindset (Fixed mindset beliefs are assumptions that the brain cannot grow; individuals are either smart or not, and there is nothing that can change their innate ability). Learning from the examination of mistakes allows the brain to form productive pathways for new concepts while focusing on learning concepts that lead to mistakes/misunderstandings (Boaler, 2016; Borasi, 1996). Moreover, instructional experiences based on focusing on mistakes are recommended by the Standards for Mathematical Practice (Common Core State Standards Initiative, 2011): make sense of problems and persevere in solving them (SMP 1) and reason abstractly and quantitatively (SMP 2). Mistakes can help students in recognizing their own strengths and weaknesses and allow a window for instructors into students' thinking.

Available research (An & Wu, 2012; Kingsdorf & Krawec, 2014; Schnepper & McCoy, 2013) supports using mistakes to address students' misconceptions and learning process and using them to design curriculum. The use of mistakes that go beyond diagnostic tools and as a medium to combat misconceptions and promote learning has not been explored in the available research. It is also not clear how to effectively address mistakes in an instructional approach. In other words, following research questions are not explored by the available research: Can mistakes be used as a pedagogical tool to promote students' learning? Does the effectiveness of feedback on mistakes depend on the messages that they deliver?

Present Study

Present study was designed to understand the role of formative feedback on mistakes and developing a growth mindset towards mistakes in students' academic success in a mathematics classroom. Present study had two goals: (a) investigating the efficacy of capitalizing on mistakes for promoting students' academic success by integrating them in the instruction; (b) effectively engaging students in the instruction to take charge of their own learning by developing a growth mindset towards mistakes. The first step in addressing whether building on mistakes facilitates learning mathematics is to evaluate all participants' performance before the intervention (exam 1). The three classes: control group (class 1), feedback-only (class 2), and growth-feedback (class 3) received identical instructional material. To evaluate the efficacy of building knowledge on mistakes, the feedback-only and the growth-feedback classes received formative feedback on mistakes using exit tickets. Growth-feedback class received growth mindset intervention about mistakes in addition to the feedback on the exit tickets. Follow up exams (exam 2 and exam 3) evaluated the impact of the intervention on promoting learning.

Hypotheses

The study addressed following hypotheses to examine the efficacy of an intervention designed to investigate the use mistakes for promoting student success in mathematics classrooms:

H1. Does focusing on mistakes promote students' performance? Participants' performance between the experimental groups (the feedback-only and growth-feedback groups) and the control group were compared on the exams conducted before and after the intervention. If focusing on mistakes facilitates students' performance, then feedback-only and growth-feedback groups should perform significantly better than control group on exam 2 and exam 3, but there should be no difference in their performances in exam 1.

H2. Does the growth mindset intervention facilitate students' academic success? Performance of the participants in control group, feedback-only, and growth-feedback classes was compared in the exams conducted before and after the intervention. If growth mindset intervention is successful, then participants in growth-feedback group should outperform participants from control group and feedback-only on exams 2 and exam 3. There should be no difference in their performances in exam 1.

Method

Participants

Participants were seventy-four students from three sections of algebra class: class 1: control group (n=24), class 2: feedback-only (n=23), and class 3: growth-feedback (n=27). Participation was voluntary, and all participants signed a consent form before the intervention. Design The study had an experimental design where participants from the three classes were compared on their performances in exams conducted before and after the intervention. All classes received identical instructional material in the classrooms. Students from feedback-only and growth-feedback groups received formative feedback on mistakes and students from growth feedback group received growth mindset intervention on learning from mistakes (see Table 1 for the project timeline).

Table 1: Project Timeline

Activities conducted	Control Group	Experimental Group: Feedback-only	Experimental Group: Growth-feedback
Week 1-15: Regular classroom instruction	Yes	Yes	Yes
Week 5: Exam 1	Yes	Yes	Yes
Week 6-15: working on exit tickets after each class and receiving feedback	No	Yes	Yes
Week 6-15: watching and working on problems from the video presentation on the topics covered	Yes	No	No
Week 6-15: growth-mindset based feedback on exit tickets after each class	No	No	Yes
Week 10: Exam 2	Yes	Yes	Yes
Week 15: Exam 3	Yes	Yes	Yes

Intervention

The three classes met two times a week for 75 minutes and received identical instructional material in the class for 45 minutes. Last 30 minutes of each class were devoted to the problems based on concepts covered that day and approach to solving those problems was different in each class based on the intervention: control group watched a video presentation on solving some problems on concepts discussed in the class that day, feedback-only and growth-feedback worked on exit tickets and received feedback on their performances.

Formative Feedback. Feedback-only and growth-feedback groups worked on exit tickets that were based on problems covered in the class that day. It was mandatory for each student to work on the exit ticket and receive feedback from the instructor before exiting the classroom. Exit tickets were used to identify students' misconceptions and lack of knowledge and were used as a tool to improve/modify instruction. Exit tickets were used in two ways: providing immediate feedback to students and analyzing mistakes to restructure instruction in the upcoming classes for both groups.

Instructor provided feedback to each student by grading their exit tickets that included classifying their responses as correct or still needing work, detailing mistakes that lead to a wrong answer, and asking students (if time permits) to correct them before leaving the classroom. Instructor used mistakes to diagnose error patterns and adjusting instruction for next classes in feedback-only and growth-feedback groups by incorporating instructional techniques involving working on correcting possible mistakes on the new topics that were introduced in the class. This involved: revisiting the mistakes based on the analysis of students mistakes from the exit tickets, engaging students in collaborative work for identifying the source of wrong solutions and working on a strategy to correct them, and re-phrasing steps involved in computations by providing algebraic justification and connecting them with students' existing knowledge.

Growth Mindset Feedback. Participants from the growth-feedback group also received intervention after exam 1 on growth mindset and on the importance of mistakes in learning. Intervention involved providing students from growth-feedback literature about the importance of mistakes (Boaler, 2022) in mathematics and discussions in the classroom focused on these questions: What are mistakes? How do mistakes help the brain in strengthening existing connections? What role do mistakes play in learning? In addition to this, growth-feedback students received feedback on the exit tickets that included messages about learning from the mistakes in their work on exit tickets and using them to develop conceptual understanding of the concepts covered. Students were asked to rework on the problems from exit tickets (if time permits) by identifying their own mistakes (by comparing with the solution) and devising a strategy to remediate them. Instructor, then, provided feedback on exit tickets detailing how a particular mistake can be corrected by developing conceptual understanding of a particular concept. Both feedback-only and growth-feedback groups received immediate feedback on their work on the exit tickets, but only the growth-feedback students were prompted using the growth mindset approach. Students from growth-feedback were facilitated to take charge of their own learning and work on the mistakes by using their existing knowledge.

Measures

Exams

Participants' performance in the three groups were compared in the three exams, exam 1 was conducted before the intervention, and exam 2 and exam 3 were conducted after the intervention. The three exams covered different topics from the syllabus (exam 1-functions, inequalities, linear functions, equations; exam 2-polynomials and rational functions, and exam 3exponential and logarithmic functions, systems of equations and inequalities). An exam was scheduled every fifth week of the semester. Research has shown that mathematical concepts are interrelated (Batanero, & Díaz, 2007; Bourbaki, 1950) and build on the understanding of previous concepts (for example, addition and subtraction are interrelated and a thorough understanding of addition facilitate in understanding subtraction 8−3=? can be solved by knowing 3+?=8. It is crucial for students to have a thorough understanding of topics they learn as a new concept builds on the knowledge of the previous one. Therefore, an instructional approach based on using students' mistakes on everyday topics covered in the class as a learning tool was a step in the right direction.

Results

Students' performance (H1)

Students' average score in the three exams was compared between the three classes using ANOVA and Tukey HSD. Students' performances in the three exams (exam 1, exam 2, and exam 3 were conducted in week 5, 10 and 15 respectively) are detailed below (also see figure 1).

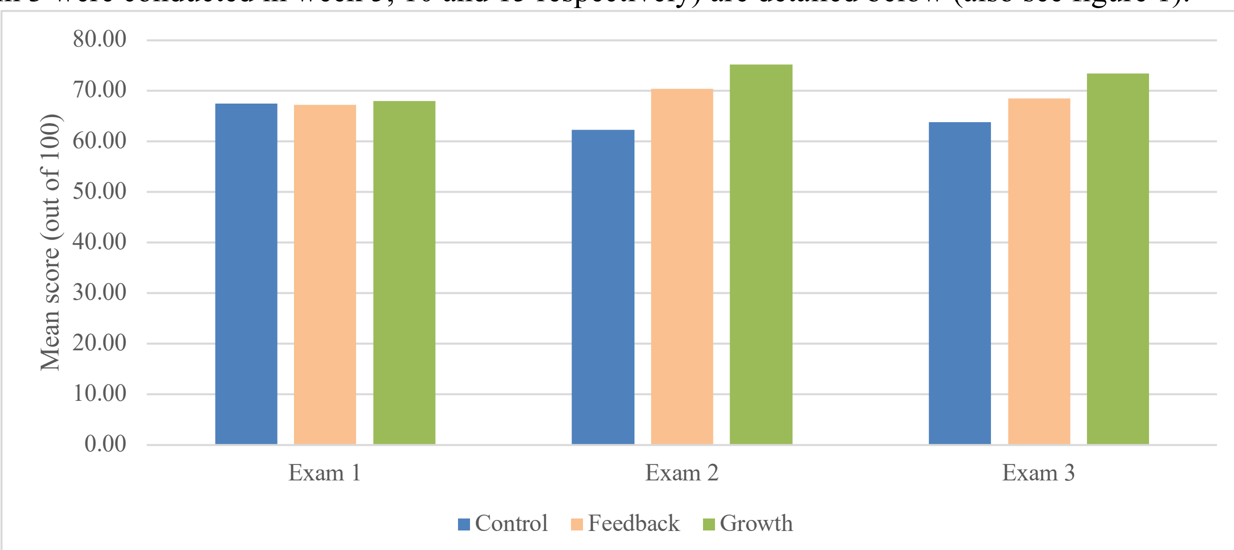

Figure 1: Comparison of participants' mean scores in the three exams

Exam 1. One way ANOVA revealed that there was no significant difference between the performances of participants in the three groups with $F(2,71)=0.06$, $p=0.93$. A post hoc Tukey HSD showed that there was no significant difference in the performances of participants in the control group (M=67.5, SD=6.3), the feedback-only group (M=67.3, SD= 5.8) and the growth feedback group (M=68, SD=7.0) with $p>0.05$ in all three cases.

Exam 2. One way ANOVA revealed that there was significant difference between the three groups with $F(2,71)=23.3$, $p<0.01$. A post hoc Tukey HSD showed that participants from the feedback-only (M=70.35, SD=6.1) and the growth-feedback (M=75.19, SD=7.4) groups performed significantly and substantively better than participants from the control group (M=62.29, SD=6.4) with $p<0.01$; the growth-feedback group performed significantly better ($p<0.03$) than the feedback-only group.

Exam 3. One way ANOVA revealed that there was significant difference between the three groups with $F(2,71)=14.9$, $p<0.01$. A post hoc Tukey HSD showed that participants from the feedback-only (M=68.56, SD=6.4) and the growth-feedback (M=73.51, SD=6.0) groups performed significantly and substantively better than participants from the control group (M=63.87, SD=6.5) with $p<0.03$ and $p<0.01$ respectively; the growth-feedback group performed significantly better ($p<0.02$) than the feedback-only group.

Significance

The results of this study highlight the importance of constructive formative feedback in promoting students' academic achievement. Only feedback-only and growth-feedback groups received immediate feedback on their work on the exit tickets and results revealed that these two groups outperformed the control group that received only usual instruction and watched video on the topics covered. All three classes were taught by the same instructor so the difference in students' performance in the three groups can be exclusively attributed to the intervention they received. Students in the experimental groups were provided immediate feedback on their mistakes which could have resulted in promoting conceptual understanding of the concepts. A timely feedback puts both instructor and students in the same boat of learning where they work collaboratively towards academic success of students. The results further support the significance of active learning that was facilitated with the use of exit tickets in the classroom. Closed monitoring of students' progress in learning and detailed feedback on their work allows instructors to build on the mistakes and use them as an effective pedagogical tool.

The other significant contribution of this research comes from the better performance of growth-feedback group that received growth mindset intervention along with feedback on the mistakes—revealing that students' perception of mistakes makes a difference in their learning. When students develop a growth mindset attitude towards their mistakes and welcome these mistakes as learning opportunities rather than hindrance to their success, they initiate a process of self-assessment and work towards the knowledge that is required and is lacking. In this study, the instructor also noticed that the growth-mindset group was more inclined to ask questions when a concept is taught and requesting justification towards any misconceptions in their learning. Students with a growth mindset tend to make the most from their experiences. The research also pinpoints the instructors' messages on mistakes that have more impact on students' learning. The difference in growth-mindset and feedback-only group can be accounted for by the messages that instructor delivered to the students. Growth mindset messages to students that rely on not only resilience but also commitment to learning, develop an attitude of taking responsibility for their own learning. A study by Canning et al. (2022) also supported this finding by revealing that an instructor's fixed mindset has a negative impact on students. The study calls on all educators to make their growth mindset more evident to their students. These findings corroborate with the results that instructors can instill their growth mindset on their students to promote learning. Growth-mindset messages convey an instructor's positive outlook towards students' potential to succeed and enables students to change their perspective towards mistakes from lack of understanding to a learning experience that they can build on. The consistent better performance of the growth-mindset group in exam 2 and exam 3 indicate the long-term positive impact of developing a growth mindset in the classrooms.

References

An, S., & Wu, Z. (2012). Enhancing mathematics teachers' knowledge of students' thinking from assessing and analyzing misconceptions in homework. International Journal of Science and Mathematics Education, 10, 717-753.

Batanero, C., & Díaz, C. (2007). The meaning and understanding of mathematics. In Philosophical dimensions in mathematics education (pp. 107-127). Springer, Boston, MA.

Boaler, J. (2016). Mistakes grow your brain. Youcubed at Stanford University Graduate School of Education. Accessed April, 14, 2016.
Boaler, J. (2022). Mathematical mindsets: Unleashing students' potential through creative mathematics, inspiring messages and innovative teaching. John Wiley & Sons.
Borasi, R. (1996). Reconceiving mathematics instruction: A focus on errors. Greenwood Publishing Group.
Bourbaki, N. (1950). The architecture of mathematics. The American Mathematical Monthly, 57(4), 221-232.
Canning, E. A., Ozier, E., Williams, H. E., AlRasheed, R., & Murphy, M. C. (2022). Professors who signal a fixed mindset about ability undermine women's performance in STEM. Social Psychological and Personality Science, 13(5), 927-937.
Common Core State Standards Initiative, 2011
Doabler, C. T., & Fien, H. (2013). Explicit mathematics instruction: What teachers can do for teaching students with mathematics difficulties. Intervention in School and Clinic, 48(5), 276-285.
Dweck, C. S. (2008). Can personality be changed? The role of beliefs in personality and change. Current directions in psychological science, 17(6), 391-394.
Eggleton, P. J., & Moldavan, C. C. (2001). The value of mistakes. Mathematics Teaching in the Middle School, 7(1), 42-47.
Kaur, B. (2008). Teaching and learning of mathematics: What really matters to teachers and students?. ZDM, 40, 951-962.
Kingsdorf, S., & Krawec, J. (2014). Error analysis of mathematical word problem solving across students with and without learning disabilities. Learning Disabilities Research & Practice, 29(2), 66-74.
Lischka, A. E., Gerstenschlager, N. E., Stephens, D. C., Strayer, J. F., & Barlow, A. T. (2018). Making room for inspecting mistakes. The Mathematics Teacher, 111(6), 432-439.
Moldavan, C. C. (1986). The effect of warning intermediate algebra students about typical errors (Doctoral dissertation, University of Georgia).
Moser, J. S., Schroder, H. S., Heeter, C., Moran, T. P., & Lee, Y. H. (2011). Mind your errors: Evidence for a neural mechanism linking growth mind-set to adaptive posterror adjustments. Psychological science, 22(12), 1484-1489.
Mueller, C. M., & Dweck, C. S. (1998). Praise for intelligence can undermine children's motivation and performance. Journal of personality and social psychology, 75(1), 33.
National Governors Association. (2010). Common core state standards. Washington, DC.
Schnepper, L. C., & McCoy, L. P. (2013). Analysis of misconceptions in high school mathematics. Networks: An Online Journal for Teacher Research, 15(1), 625-625.
Stevenson, H. W., Chen, C., & Lee, S. Y. (1993). Mathematics achievement of Chinese, Japanese, and American children: Ten years later. Science, 259(5091), 53-58.
Sun, K. L. (2015). There's no limit: Mathematics teaching for a growth mindset. Stanford University.
Türkdoğan, A., & Adnan, B. A. K. İ. (2021). The Relationship between Mistakes and Feedbacks Encountered in Mathematics Course in the 7th Grade. Journal of Computer and Education Research, 9(17), 480-496.