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EXAMINING FEEDBACK IN AN INSTRUCTIONAL VIDEO GAME USING PROCESS DATA AND ERROR ANALYSIS

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Abstract

Appropriately designed technology-based learning environments such as video games can be used to give immediate and individualized feedback to students. However, little is known about the design and use of feedback in instructional video games. This study investigated how feedback used in a mathematics video game about fractions impacted student actions in the game. Results indicated the type of feedback did not significantly affect student actions. Process data were also analyzed to identify specific student errors as well as opportunities to provide feedback for future versions of the game. Results of this study suggest that process data are a unique feature of technology-based learning environments that can be used to analyze errors and create targeted feedback for students.

Introduction

Objective

The purpose of this exploratory study was to examine the impact of feedback on student success in a video game for learning, and to determine how process data can be used to enhance feedback.

Theoretical Framework

Feedback is information given to students with the goal of improving learning through changing a student behavior or how a student thinks about a problem. A recent review of the literature suggests that effective feedback must include both verification feedback (i.e., indicates whether the answer is correct or incorrect) and elaboration feedback (i.e., addresses specifics about student performance, such as particular errors students made, gives guidance, or provides examples) (Shute, 2008).

In a classroom, feedback given by the teacher requires the teacher to evaluate and analyze individual student artifacts. The analysis of each student's work requires valuable time that teachers may not be able to spare. In addition, there is evidence that teachers have difficulty evaluating student artifacts to determine instructional steps (Heritage, Kim, Vendlinski, & Herman, 2008; Herman, Osmundson, & Silver, 2010). However, technology-based tools, if

designed appropriately, can provide a unique environment where feedback and instruction can occur automatically and can be targeted to student misunderstandings or common errors.

Instructional video games are one type of technology in which feedback and instruction can be naturally incorporated. Level success feedback is inherent to video games. Students automatically know if they successfully solved the level because they either move forward in the game or must re-attempt the level. Additionally, elaborative feedback can be included in the game to explain why students succeeded or failed at the level and give guidance on the correct solution. Nonetheless, the research literature on feedback in instructional video games is limited, and process data are rarely used to analyze student errors and determine appropriate feedback. Therefore, this study explores the following research questions:

1. Does type of feedback impact student actions in the video game?
2. How can process data be used to improve feedback?

Method

One hundred and eighty-seven middle school students were asked to play a mathematics video game aimed at teaching key topics of rational numbers including identification of unit size, the numerator, the denominator, and addition of fractions (Chung, 2010). In each level of the game, students were asked to determine the fraction needed to jump a certain distance from the pink block to the blue "X" block (see Figure 1).

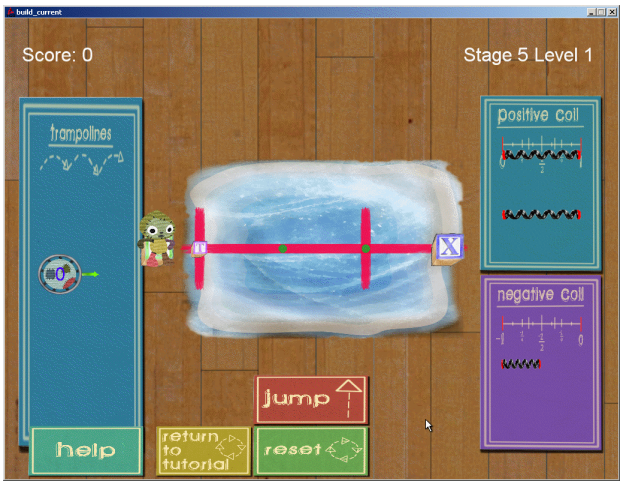

Figure 1. Screen shot of example game level.

Students were randomly assigned to receive either (a) both level success feedback and individualized elaborative feedback or (b) only level success feedback. Level success feedback was given in both conditions at the end of each level, and verified if the solution was correct or incorrect. If a solution was correct, the student was passed to the next level. If a solution was

incorrect, the character died at the point of the mistake. Individualized elaborative feedback was triggered by specific actions taken by students and resulted in feedback that addressed specific mistakes students were making (e.g., "The fraction denominators don't match!"), highlighted certain features to pay attention to (e.g., "Did you notice …"), and provided guidance to successfully complete that particular level (e.g., "Remember: ¼ + ¼ = 1/8").

Data Sources

Process data for three consecutive levels were collected as students played the game and logged student actions. This type of data can be used to determine the types, frequencies, and timing of student errors (Romero & Ventura, 2007). Process data in this study were used to (1) identify the types of errors and solutions for each analyzed level and (2) determine how many times students attempted a level. Types of errors were identified through cluster analysis (Kerr, Chung, & Iseli, 2010).

To answer research question 1 and determine if there were significant differences between conditions for the number of attempts students made or the types of errors students made on that level, an independent *t* test was conducted. To answer research question 2 and determine how process data could be used to improve feedback, the types of errors and number of students making each type of error by attempt were analyzed and graphed. For similar levels, the types of errors were compared.

Results and Conclusions

Research question 1: Does the type of feedback impact student actions in the videogame?

Results of the independent samples *t* test indicated that on Levels A and B, no significant differences were found between conditions on the number of attempts or the number of specific errors made in each level. On Level C, those who received both types of feedback attempted the level significantly fewer times ($M = 3.39$, $SD = 2.37$) than those who received only level success feedback ($M = 3.93$, $SD = 2.87$), $t(594) = 2.50$, $p = .02$, $d = .21$. No differences were found between conditions on the types of errors made.

Research question 2: How can process data be used to improve feedback?

The results indicate that of the 156 students who attempted Level A (see Figure 2), only about 6% solved the level on the first attempt (see Table 1). Error analysis of the first attempt indicates that approximately 30% of students attempted to solve the level using a mixed number, approximately 15% were using whole units only, and approximately 3% were ignoring the unit bars and using a denominator of thirds. An additional 46% of errors made in the first attempt were unidentifiable. Results also indicate that the number of errors drops off over time, and after

approximately the fourth attempt, most students have successfully completed the level (see Figure 3).

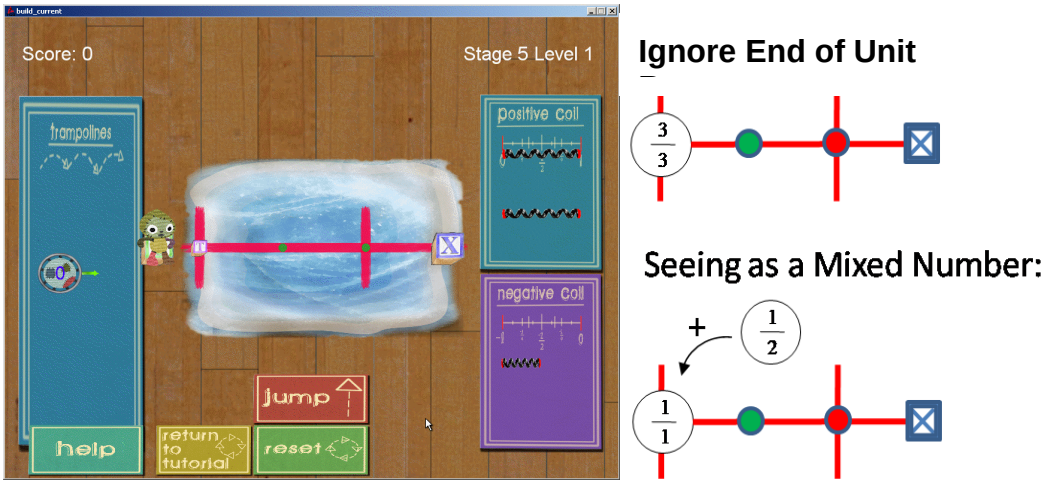

Figure 2. Screen shot of Level A and error pattern explanations.

Table 1

Percent Solutions and Errors for the First Attempt of Each Level

Type of solution or error	First attempt at solving level		
	Level A (n = 156)	Level B (n = 146)	Level C (n = 138)
Correct solution	6%	15%	18%
Ignoring unit bars	3%		
Using whole units only	15%	23%	4%
Using alternative form of correct solution	30%	---	---
Smaller denominator than needed	---	50%	25%
Larger denominator than needed	---	---	4%
Reset correct solution	---	---	7%
Unknown errors	46%	14%	42%

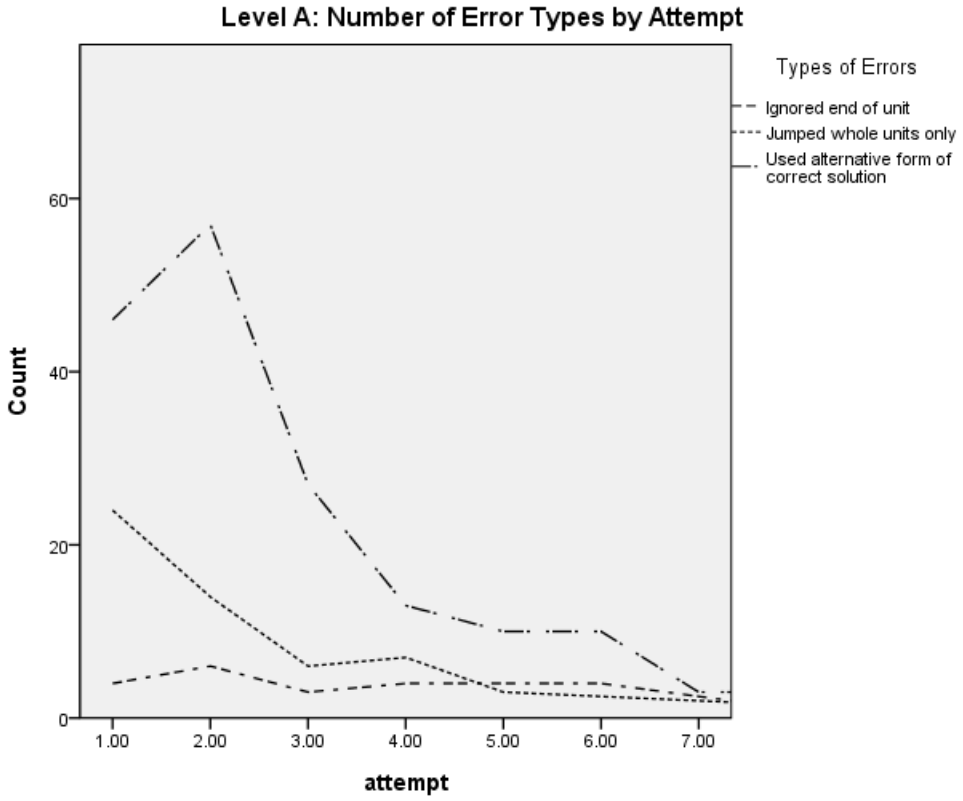

Figure 3. Number of students making errors by attempt.

In this game, improper fractions must be used instead of mixed numbers to solve the level. Therefore, results indicate that these students knew the answer to the level, but that most were unable to use the appropriate form until after several attempts. Feedback to these students should highlight alternative forms of correct solutions. These results also indicate that only a few students ignored the whole unit bar which is an error students typically make. In addition, many students only used whole numbers to solve the level. This indicates a significant misunderstanding at this level of the game, and reveals that major feedback relating to identification of the units, numerators, and denominators is necessary for these students. Since approximately half of the errors were unidentifiable into any one error or solution type, many errors were not evaluated in this analysis. Further work must be completed to identify these errors.

Results of the analysis of errors for Level B (see Figure 4) indicate that of the 146 students who attempted this level, approximately 15% solved it correctly on the first attempt (see Table 1). Error analysis of the first attempt indicated that approximately 50% used a denominator of halves, an additional 23% used only whole units, and 14% of the errors were unidentifiable.

Results also indicate that the number of errors drops off over time, and after approximately the fourth attempt, most students have successfully completed the level (see Figure 5).

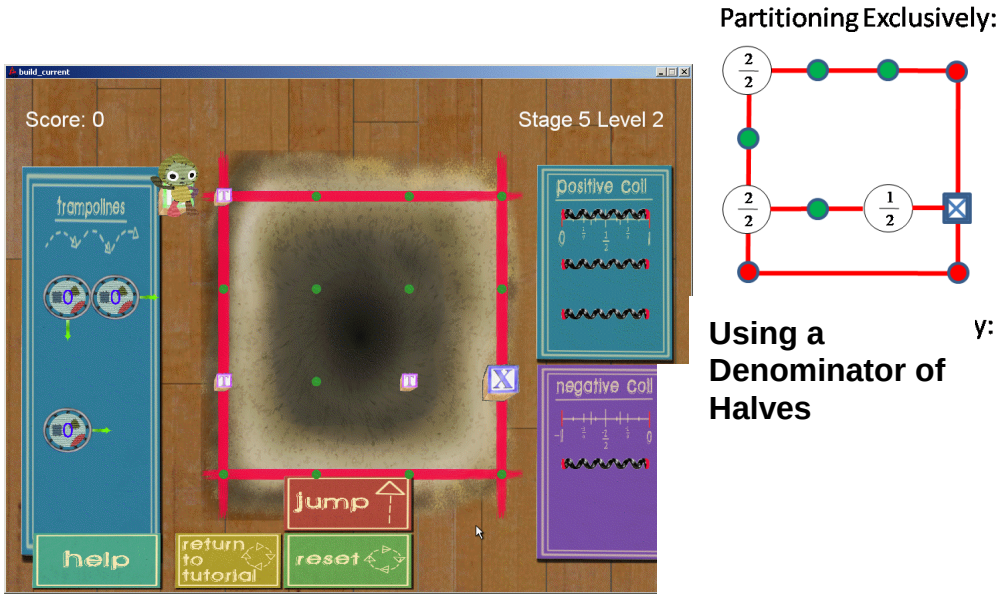

Figure 4. Screen shot of Level B and error pattern explanation.

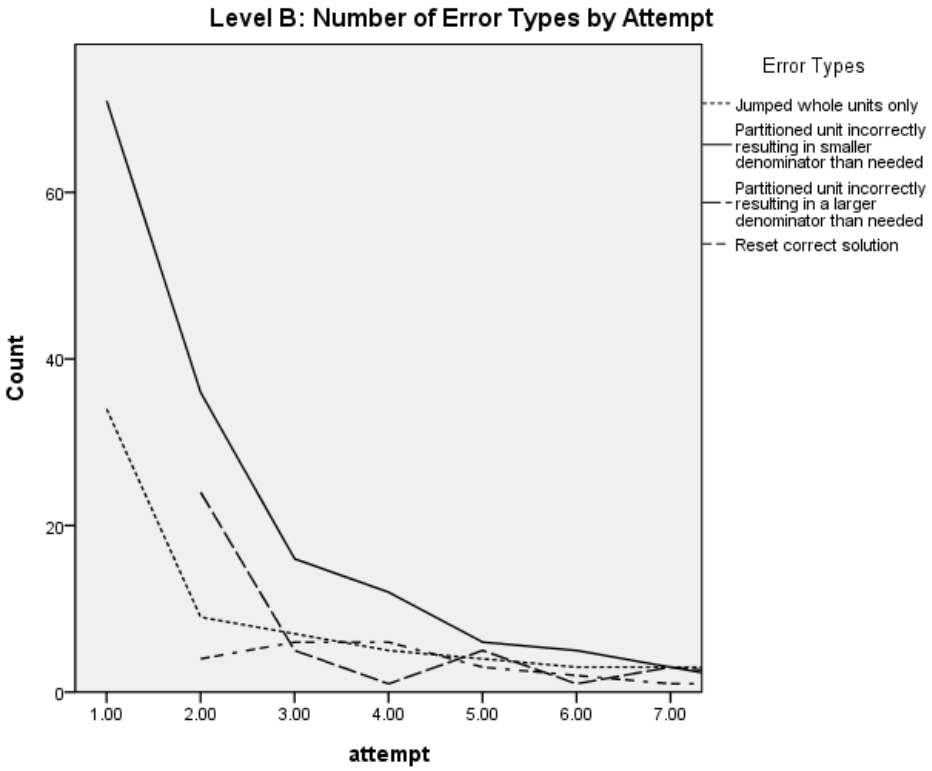

Figure 5. Number of students making errors by attempt.

These results indicate that many students made a common error and incorrectly identified the denominator as halves. Feedback for this common math error should highlight where the unit bar starts and ends, and how to determine the denominator. A higher percentage of students on Level B used only whole numbers to solve the problem than on Level A. This indicates that the feedback given in Level A was not sufficient to remediate this error. This evidence also indicates these students did not fully understand how to identify the unit and the denominator. The feedback to these students should be substantial. Fewer errors in this level were unidentifiable as compared to Level A.

Level C (see Figure 6) was very similar to Level B. Therefore, results between the two levels are compared in this analysis. Results of the analysis of errors for Level C indicate that of the 138 students who attempted this level, approximately 18% solved it correctly on the first attempt (see Table 1). Error analysis of the first attempt indicated that approximately 25% used thirds as the denominator, 4% used fifths as the denominator, 4% used whole units exclusively, and 7% reset a correct solution before completing the level during the first attempt. Forty-two percent of the errors were unidentifiable. Results also indicate that the number of errors drops off, and after approximately the fourth attempt, most students have successfully completed the level (see Figure 7)

These results indicate that half the number of students as on the previous level were incorrectly identifying the denominator as smaller than necessary, and provide evidence that students may be learning from Level B to Level C. Additionally, fewer than 5% as compared to 23% in Level B are using whole units only. This provides additional evidence that students may be learning from one level to the next. Using a larger denominator than needed emerged as a new error in this level. However, only 4% of students completed this action indicating that they were not identifying the denominator correctly. These students need feedback that helps them determine how to correctly identify the unit and denominator.

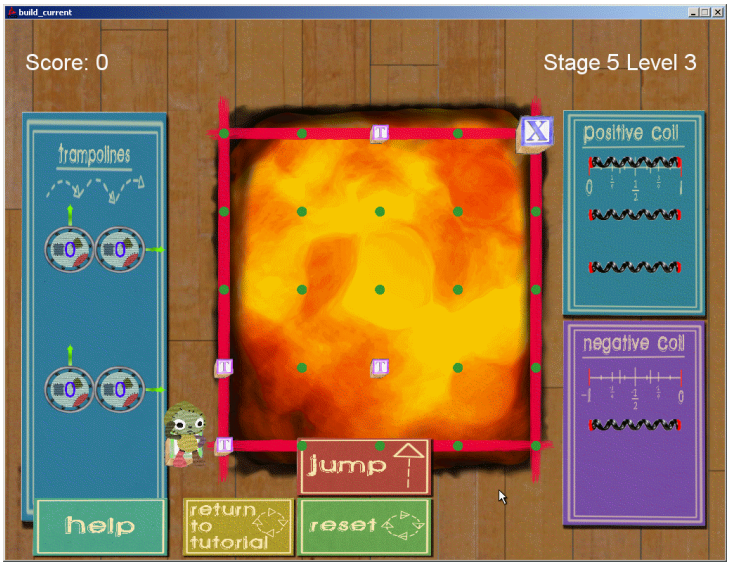

Figure 6. Screen shot of Level C.

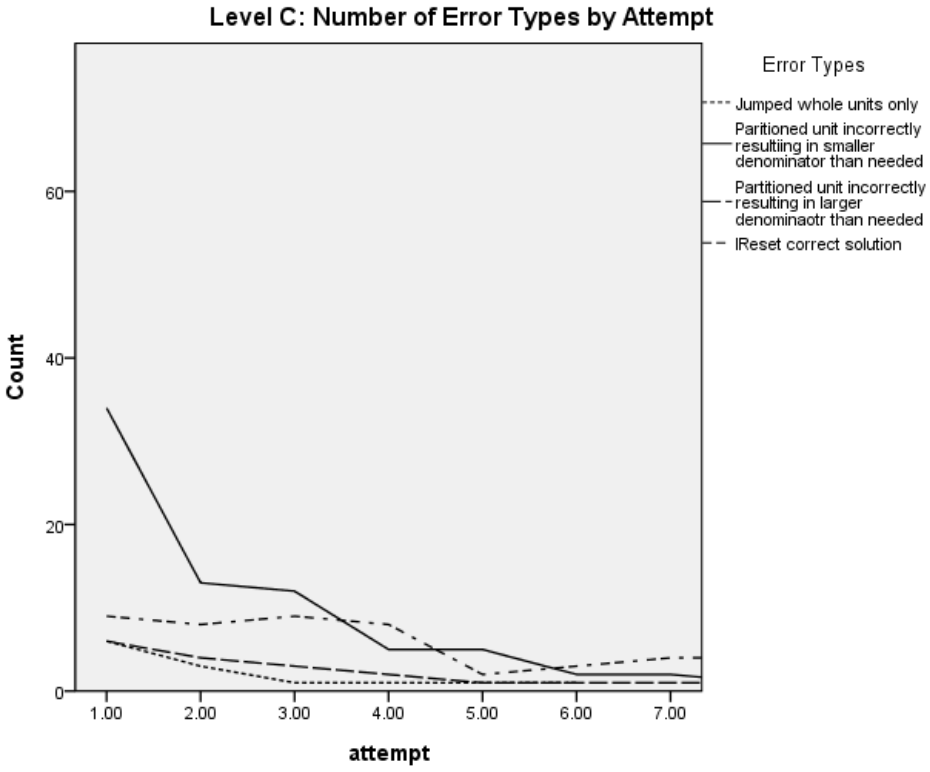

Figure 7. Number of students making errors by attempt.

Scholarly Significance

First, this study analyzed the impact of different types of feedback on student performance. Results indicated that in most cases, the combination of elaborative and level success feedback as initially designed did not lead to significantly different student actions than only providing level success feedback. Because no differences were found between conditions, process data were used to analyze error rates and determine if feedback should be modified. Analyzing process data gave insight into the types of errors being committed and the number of attempts being made at each level. This information can be used to create more targeted feedback based on the data. This analysis also indicates that process data should be explored as an indicator of learning from level to level. Research such as this is important because it highlights how process data can be used to determine the types of errors made by students, and how feedback can be improved to target student understanding. Further analysis of all levels of the game is necessary to determine the full effect of the feedback on the number of attempts needed to solve each level and on the types of errors being made in each level.

References

Chung, G. K. W. K., Baker, E. L., Vendlinski, T. P., Buschang, R. E., Delacruz, G. C., Michiuye, J. K., & Bittick, S. J. (2010, April). Testing instructional design variations in a prototype math game. In R. Atkinson (Chair), *Current perspectives from three national R&D centers focused on game-based learning: Issues in learning, instruction, assessment, and game design*. Structured poster session at the annual meeting of the American Educational Research Association, Denver, CO.

Heritage, M., Kim, J., Vendlinski, T., & Herman, J. (2009). From evidence to action: A seamless process in formative assessment? *Educational Measurement: Issues and Practice*, *28*(3), 24–31.

Herman, J., Osmundson, E., & Silver, D. (2010). *Capturing quality in formative assessment practice: Measurement challenges* (CRESST Report No. 770). Los Angeles: University of California, National Center for Research on Evaluation, Standards, and Student Testing.

Kerr, D., Chung, G. K. W. K., & Iseli, M. R. (2011). *The feasibility of using cluster analysis to examine log data from educational video games* (CRESST Report No. 790). Los Angeles: University of California, National Center for Research on Evaluation, Standards and Student Testing (CRESST).

Romero, C., & Ventura, S. (2007). Educational data mining: A survey from 1995 to 2005. *Expert Systems with Applications, 35,* 135–146.

Shute, V. (2008). Focus on formative feedback. *Review of Educational Research, 78,* 153-188.