ENACTMENT AND PERCEPTIONS OF GAME-BASED FRACTION INSTRUCTION BY SIX FOURTH GRADE TEACHERS

Curriculum materials that allow students to engage, represent, and express their thinking through multiple means can address systemic issues of access and promote interest in Science, Technology, Engineering, and Mathematics. We employed a sequential mixed methods design to understand how teachers perceived of and used game-enhanced fraction intervention in 4th and 5th grade mathematics classrooms. Results reveal different levels of curriculum integrity linked to different strategies teachers used to address perceived phenomena in implementation that impacted student outcomes.

INTRODUCTION

Game-based mathematics curricula are one way to create access and opportunity in mathematics. Meta analyses of research on gaming illustrates the potential of games to improve content accessibility through sandbox play and problem-solving, opportunities to build self-regulation, and explore content in ways previously inconceivable (Gao et al., 2020). However, elementary teachers' propensity to embrace and use game-enhanced instructional approaches with integrity in mathematics is not well understood. While much research exists on middle and high school teachers' use of game-enhanced programs in mathematics, there is little research that focuses on elementary school (Kirriemuir & McFarlane, 2003). Therefore, it is necessary to understand how elementary school teachers use game-enhanced curriculums with their students, what their successes and challenges are in implementation, and the extent to which students' outcomes change as a result of different teacher implementations.

The purpose of this paper is to explore how elementary school teachers perceive and implement a game-enhanced supplemental curriculum for fractions called Model Mathematics Education (ModelME). ModelME is a 36-lesson supplemental curriculum with a game built into it. The program is designed to increase student engagement, fraction knowledge and STEM/ICT career interest and is designed using the Universal Design for Learning (UDL) framework, an efficacious design framework for accessible and equitable instructional materials (CAST, 2023). A sequential mixed methods design is employed to investigate the feasibility of the curriculum in elementary classrooms, including how teachers implemented the curriculum, their perspectives and experiences as they used it, and their students' resulting fraction learning and STEM interest. The research questions are: To what extent do elementary teachers implement a game-enhanced supplemental fraction curriculum with integrity? , What are elementary teachers' experiences and perspectives after implementing the game-enhanced fraction intervention in their classrooms?, and To what extent did students' fraction schemes and STEM interest change after participating in a game-enhanced intervention?

THEORETICAL FRAMEWORK

Teachers' Beliefs and Use of Game-Enhanced Interventions

Each individual has their own set of beliefs which strongly direct their perceptions within their particular contexts (Pajares, 1992). Beliefs surrounding educational topics can influence teacher actions within their classroom. Because teacher beliefs impact the structure and climate of the classroom that students are a part of, teacher beliefs also impact students' learning (Cheung, 2012). With respect to digital games, the varied beliefs and attitudes teachers hold towards play a role in if the games are used in the elementary classroom, and how. Yeo et al. (2022) showed there was a direct relationship between teachers' attitudes surrounding games use to the likelihood of the games actually being implemented as intended in the classroom. The relationship was also mediated by teachers' perceptions how well it fit into the curriculum. Time is also listed as a major obstacle in effectively utilizing games in the classroom when digital games do not align with teachers' pedagogical perspectives (Kirriemuir & McFarlane, 2003). Even with positive beliefs towards digital games, teachers could hesitate to implement them due to cost or a focus on increasing scores on standardized tests (VeraQuest, 2012). So, while beliefs held by the teacher about using digital games in math could indicate the likelihood of implementing them, it is not always the case.

METHODS

Participants and Research Design

Six fourth and fifth grade teachers and their students (*n* = 133) in two different schools in the southeast United States participated in the study. Each school was located in a rural setting and included students with intersecting identities in terms of race, language, and disability. The supplemental curriculum was administered by the teachers in their core mathematics classrooms, which included approximately 15-25 students with each teacher. The program took place over nine weeks, which is considered best practice in terms of time period for technology-based interventions (Gersten & Edyburn, 2007). Prior to the study, informed consent and assent were gathered from teacher and student participants using Institutional Review Board (IRB) approved documents. Demographic information for the six participating teachers and their students will be shared in session.

Game-Enhanced Supplemental Fraction Program and Teacher Support

The game-enhanced curriculum investigated in this study is a supplemental program with four core components (Author) : *Multiple means of expression (MME), representation (MMR), and engagement (MME), carefully selected task based challenges*, *cognitive prompts*, and *social mediation of learning*. Teachers followed the curriculum guide to teach the supplemental program for nine consecutive weeks, 35 minutes a day, three days a week. Each lesson contained a five-minute preview, 10-15 minutes of student gameplay, and a 15-20 minute after game task (i.e., a number string, a worked example, or a game replay). Previews were supported by videos and were often presented with questions for students to discuss. Gamplay presents fraction challenges along a learning trajectory that spans five game worlds using sandbox, puzzle-like play. Students play the role of "Bunny," a character whose appearance they can change according to their preferences. After gameplay, students engage in the selected after game task for that day's lesson. These tasks generally follow a think pair share structure and ask students to re-create, evaluate, or extend their gameplay strategies.

Teachers received support on curriculum delivery. Day one of four professional development days opened with the study's purpose, the target population, and the theory of change and logic model for the overall project. For the next two days, teachers studied student gameplay to deepen their understanding of how the core program components are used to bolster student learning and played the game themselves as learners. Researchers gave teachers a curriculum guide on the final day to drive small group practice opportunities, where teachers delivered the curriculum using the curriculum guide as a resource through role playing, rotating between teaching roles and student roles. For each role, the groups also engaged in the after-game tasks, discourse, and talk moves to facilitate a sample student conversation. Finally, researchers prepared the teachers to administer the study's measures.

Data Sources

Four data sources were used in the study. First, to understand the extent to which teachers implemented the program with integrity, we observed approximately 35% of all teachers' lesson enactments. A checklist was generated to aid in researcher observations. Second, to gauge teacher perspectives on and overall experiences implementing the game-enhanced curriculum, teacher focus groups were held at the conclusion of the study. Two separate focus groups were held virtually using semi-structured questions and lasted anywhere from 45 to 60 minutes. Third, to gauge changes in students' fraction knowledge, the 12-item Fraction Schemes Test (Wilkins et al., 2013) was used. Internal consistency reliability for the paper test was reported as 0.70; criterion-related validity was reported as 0.58 ($p < 0.01$). Finally, to gauge changes in students' STEM interest, the Upper Elementary School (4-5) Student Attitudes Toward STEM (S-STEM) survey was used (Friday Institute for Educational Innovation, 2012). Cronbach's α of the S-STEM survey ranged from 0.84 to 0.86.

Analysis

To understand teachers' perspectives, researchers analyzed the focus-group data using concurrent rounds of open coding for each teacher for a within-case analysis (Yin, 2018). Next, a cross-case analysis was conducted to identify the shared experiences of teachers who implemented the game-based curriculum (Yin, 2018). To understand the teachers' adherence to the curriculum, researchers examined the fidelity checklists used to observe each teacher to calculate adherence and dosage percentages. For each area of the curriculum, researchers counted how many items teachers enacted. They then divided that total by the total number of possible items, generating a percentage for each lesson component within each lesson as well as an overall adherence score for the lesson holistically. To generate final percentages, researchers averaged all lesson adherence scores to obtain an average level of adherence for each teacher. Finally, to understand the extent to which students' fraction schemes and STEM interest change after participating in a game-enhanced intervention, researchers calculated normalized learning gains, which is used as an assessment of student knowledge of fractions and their STEM interest. NLGs and one sample t-tests were also used to evaluate responses to the S-STEM before and after the intervention. Univariate ANOVAs were also run to determine if differential program effects could be found across teachers, adherence levels, or dosage levels.

RESULTS

The highest adherence was observed in T2 and T5, with mid-level adherence observed in T1, T3, and T6. T4 had the lowest observed adherence. For dosage, three teachers (T3, T5, and T6) fell within 35-40 minutes of instruction, on average, per session. T2 had an observed average of 30-35 minutes per session. T1 was observed as having the highest dosage at an average of over 45 minutes. T4 was observed at the least average dosage per session of 25-30 minutes. A one-way ANOVA showed a statistically significant difference in adherence ($F(5) = 9001.64$, $p < 0.001$) but not dosage. Teachers 2 and 5 had significantly higher adherence than teachers 1, 3, 4, and 6. Results also reveal three categories of teacher preceptions: (a) *Time*, (b) *Too Different*, and (c) *Too Difficult*. For *Time,* teachers spoke of the phenomenon of the program running longer than expected. Strategies teachers named to deal with the phenomenon were skipping or deleting parts of the curriculum. Conversely, in the *Too Different* category, the phenomenon perceived misalignment from curricula teachers and students were already using in their core curriculum. Strategies included continuing to use the norms and teaching styles pushed by the core curriculum or making equity oriented additions, such as stating expectations. For the category of *Too Difficult*, the phenomenon was teachers' perception that the tasks were too hard for the students. Strategies differed across teachers - teachers either gave more time, additional means, or additional modalities for students to share their thinking about the tasks, or, conversely, told students what to think about the tasks. Finally, NLGs for teachers also differed for students' fraction knowledge and STEM Interest. For fraction knowledge, teachers 2, 4, 5, and 6 had positive NLG (0.31, 0.09, 0.16, and 0.05, respectively), while T1 and T3 had negligible positive (0.01) and negative (-0.01) gains. For STEM Interest, 2, 3, 4, and 5 had positive NLG (0.54, 0.12, and 0.31, respectively), while T1, T6, and T8 had small negative (-0.06, -0.03, and -0.02, respectively) gains.

MERGING AND INTERPRETATION

In response to the phenomena of *time*, *too different*, and *too difficult*, teachers 1 and 3 used predominantly "delete," "use core," and "tell" strategies. Conversely, teachers 2 and 5 had predominantly "skip," "make additions," and "give more time or multiple means" strategies in response to the experienced phenomena. Teacher 4 displayed predominantly "delete," "make additions," and "tell" strategies, while teacher 6 predominantly utilized "delete," "use core," and "give more time or multiple means" strategies. Teachers who made additions or provided more time and multiple means of accessing the program had higher adherence and greater increases in student learning and interest in STEM compared to teachers who used other strategies to address perceived issues of time, difficulty, or alignment of the game-enhanced program with core instruction. Teachers who chose to remove opportunities for student thinking (i.e., "tell"), revert to core instruction (i.e., "use core"), or both in response to issues of time, program difficulty, or alignment with core instruction saw lower or even no changes in students' fraction thinking and STEM interest. Therefore, we conclude that teachers' integrity to the curriculum approach, alongside asset-oriented additions, contributed to improvement in students' fraction knowledge and STEM interest.

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