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Using Explicit Instruction and Video Modeling to Teach Rational Number Skills to Students With Learning Disabilities

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The purpose of this study was to examine the effects of utilizing explicit instruction, point-of-view video modeling, and augmented reality technology to teach mathematics to students with disabilities. A multiple probe single-case research design was used. Three students with Learning Disabilities (LD) who were receiving special education services in mathematics participated in the study. The results were analyzed using visual analysis of trend, level, and variability and demonstrated a functional relation between the intervention and the students' performance on three rational number mathematics skills. Maintenance and generalization of the rational number skills were measured with variable findings. The intervention was determined to be socially valid by the participants and teachers.

Keywords: **explicit instruction, video modeling, augmented reality, rational numbers, computer assisted instruction**

Introduction

Barriers to Rational Number Mastery for Students with Learning Disabilities

In the United States (US) mathematics performance of students across student populations has been consistently low and often decreasing over the last few years (NAEP, 2019, 2022). The severity of these difficulties varies but has become more pronounced with time (Nelson & Powell, 2018; Wei et al., 2013). While this is not unique to individuals with disabilities, the most current data from the National Assessment of Educational Progress (NAEP) indicate that a mere 16% of students with disabilities meet the mathematics proficiency level in 4th grade and that percentage drops to 7% by 8th and 12th grade (NAEP, 2019, 2022).

Rational numbers (i.e., fractions, decimals, and percentages), is an area specifically vital for success in mathematics, specifically in algebra, and as such needs to be a focus in teaching and research (Booth et al., 2014; Hansen et al., 2017; McMullen & Van Hoof, 2020; Ni, 2001). However, rational numbers have proven to be a "major challenge" for students in pre-K to grade 8 (National Research Council, 2001, p. *x*). Because fraction knowledge in younger grades predicts algebra performance in high school (Cirino et al., 2019) and the foundation for mathematic understanding starts

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in the early grades, especially for rational numbers (often in 3rd grade), it is critical that students learn and understand rational numbers (Berch, 2017).

Students with learning disabilities (LD) in mathematics have particular difficulty with rational numbers, in comparison to their peers, and exhibit an "extra delay in their rational number understanding" (Jordan et al., 2017; Van Hoof et al., 2017, p. 181). Van Hoof and associates (2017) found that students with LD in mathematics were more affected by natural number bias, meaning they applied properties of natural numbers to tasks with rational numbers (Ni & Zhou, 2005), than the control groups which led to added difficulty in their understanding of rational numbers.

Multiple theories suggest reasons behind students' difficulty with rational numbers. Natural number or whole number bias posits that individuals generalize natural number properties to rational number tasks even when it is not appropriate (Ni & Zhou, 2005). The framework theory of conceptual change, examines students' difficulty with rational numbers through a cognitive developmental lens, suggesting that as students develop, a discrepancy materializes between rational number concepts and the principles that govern reasoning with natural numbers (Vosniadou & Skopeliti, 2014). The integrated theory of numerical development is a third theory that proposes that the development of numerical understanding includes learning about the various characteristics that that unite and differentiate all types of real numbers (Siegler et al., 2011). These authors suggest is that using a mental number line has been shown to be a valuable support for understanding fraction magnitude (Siegler et al., 2011; Tian & Siegler, 2016).

Instructional Methods for Teaching Mathematics to Students with Disabilities and Augmented Reality

Researchers recommend implementing intensive academic interventions along with effective mathematics instruction to improve student performance in mathematics (Fuchs et al., 2017; Nelson & Powell, 2018; Powel & Fuchs, 2015). Hwang and colleagues (2019) highlight the need for developing "interventions with specifically designed instruction to better address the conceptual and procedural knowledge of fractions" (p. 58). Multiple systematic reviews, meta-analyses, and research syntheses have identified several components that are effective in improving outcomes for students with disabilities. Gersten and colleagues (2009) noted that among various instructional approaches and curriculum designs—such as explicit instruction, heuristics, student verbalizations, visual representations, and the range and sequence of examples—explicit instruction was a key component that produced significant effects. Shin and Bryant (2015) found that concrete and visual representations, heuristic strategies, and explicit instruction are critical in teaching fractions to students struggling in mathematics. This study incorporates two practices that have shown positive effects or promise for teaching mathematics to individuals with LD: explicit instruction and video modeling, while incorporating augmented reality (AR) as a platform for delivering the instruction.

Explicit Instruction

Explicit instruction is a systematic, direct, and engaging approach to lesson design and content delivery, aimed at fostering student success (e.g., Archer &

Hughes, 2011; Hollingsworth & Ybarra, 2009). It involves structured instructional design procedures and delivery methods, often following a three-step process: modeling, prompting, and checking. This approach helps teachers maximize instructional time (Jitendra et al., 2018). Research supports explicit instruction as an effective method for both instructional design and delivery techniques (e.g., Hughes et al., 2017; Hughes et al., 2019), and it is considered a high-leverage practice for teaching students with disabilities (McLeskey et al., 2017). It is also a crucial element of mathematics instruction, particularly in teaching rational numbers (Gersten et al., 2009; Misquitta, 2011; Satsangi et al., 2019). Although there is a strong body of research indicating the effectiveness of explicit instruction for teaching mathematics to individuals with LD, a systematic review of video modeling interventions for students with LD found that there is still a need to expand the research base for this population (Boon et al., 2020).

Video Modeling

Video modeling is presenting a model in video and audio format that the participant imitates (Hughes & Yakubova, 2016). This process has benefits, including allowing for multiple stimulus and response opportunities and standardization of presentation. The video acts as a stimulus for learning or imitating new behaviors (Nikopoulos & Keenan, 2007) and is often utilized in concert with prompting, forward and backward chaining, utilization of reinforcement (Nikopoulos et al., 2009). Video modeling can be conducted in various ways, including: video self-modeling (Hughes & Yakubova, 2016; Prater et al., 2012), point-of-view modeling (POVM), video modeling, and video prompting (Hughes & Yakubova, 2016; Kellems & Edwards, 2015). When speaking about these interventions and methods in general, the term *video-based interventions* is often used. Video modeling is an intervention with empirical support, behavioral underpinnings, and a strong theoretical framework (Banda et al., 2011; Corbett & Abdullah, 2005; Hughes & Yakubova, 2019; Prater et al., 2012).

Evidence supports the effectiveness of video modeling for skill acquisition, maintenance, and generalization (Mason et al., 2013) and its efficacy for teaching mathematics to students with disabilities (Cihak & Bowlin, 2009; Kellems, et al., 2020, Morris et al., 2021; Satsangi, et al., 2019, 2020), particularly rational numbers (Yakubova et al., 2015). While research about video modeling indicate positive effects across disabilities to teach academic, functional, social, life skills, and behaviors (e.g., Aldi et al., 2016; Burton et al., 2013; Satsangi et al., 2022; Saunders et al., 2018; Yakubova et al., 2016) there is still a need for further research to strengthen the research base in teaching mathematics to students with LD (Boon et al., 2020).

Augmented Reality

Augmented reality (AR) has been utilized to support mathematics instruction (Bacca et al., 2014; Cihak et al., 2016) and can serve as a platform for delivering instructional interventions due to its customizable features, such as video content integration (Bacca et al., 2014). Additionally, AR combines real and virtual information through the use of images, videos, or audio to enhance the learning environment. It can also display shapes, objects, or images that a computer or mobile device converts into other content, such as pictures, information, or videos (Cakir & Korkmaz, 2019). Research on the application of AR in educational settings continues to expand (Akçayır & Akçayır, 2017; Bacca et al., 2014; Garzón & Acevedo, 2019).

This Study

Considering the evidence base for explicit instruction and video modeling in teaching mathematics, this study aims to expand research on digital applications of explicit instruction for mathematics instruction, using video modeling and incorporating augmented reality technology as a platform to teach rational number skills to students with learning disabilities (Ennis & Losinski, 2019; Hughes, 2019; Kiru et al., 2018). Combining explicit instruction and video modeling into a targeted, intensive intervention may help students with disabilities improve their mathematics proficiency. Additionally, using augmented reality as a platform to deliver explicit instruction video models in a self-directed manner could assist in automating parts of the instruction. Kiru et al. (2018) emphasized the need for more research on technology-mediated mathematics interventions, especially those incorporating key components of explicit instruction (e.g., overt demonstrations, guided and independent practice, and specific academic feedback). This study includes these elements of explicit instruction and also addresses multiple strands of proficiency identified by the National Research Council (2001) as important by enhancing students' understanding of concepts and strengthening procedural fluency.

Research Questions

The research questions include: What are the effects of an intervention featuring explicit instruction, point-of-view video modeling delivered using augmented reality on the participants' performance solving rational number problems? What are the effects of the intervention on participants' skill maintenance? What are the effects of the intervention on participants' ability to generalize their performance to applied word problems? To what degree is the intervention socially valid?

Method

Participants

An Internal Review Board and the school's administration approved this study. Teachers identified potential students who experienced difficulties in mathematics for possible inclusion in the study. Two assessments were administered to verify the need for intervention and identify target skills. The first was the i-Ready diagnostic assessment which provided an overview of the students' academic needs in mathematics. This was part of the curriculum being used in the class. The second was the aimswebPlus benchmark assessment. This assessment evaluated the students in five areas of mathematics: (a) geometry, (b) measurement and data, (c) base 10 number and operations, (d) number and operations related to fractions, and (e) operations and algebraic thinking. The fractions section of this assessment included subtraction word problems with common denominators, identifying equivalent fractions, identifying fractions on a number line, and comparing the magnitude of fractions by writing fractions with common denominators.

Three 4th-grade students were identified for inclusion in the study. Each participant was Caucasian, classified as having LD, and was receiving special education services in mathematics. Parental or guardian consent and student assent were obtained for each participant. The students were determined to need intensive mathematics instruction in rational numbers based on their performance on aimswebPlus progress monitoring benchmark assessments being at or below the 20th percentile and their i-ready diagnostic assessments performance being at or below the 25th percentile.

Musette

Musette (pseudonym), a Caucasian female student receiving special education services in mathematics, was classified as having LD. Her performance on the aimswebPlus benchmark placed her in the third percentile in relation to the national norm-referenced sample. Results from the i-Ready assessment suggested that Musette's mathematics performance was in the second percentile.

Jaren

Jaren (pseudonym), a Caucasian male student receiving special education services in mathematics, also had a LD classification. His performance on the aimswebPlus benchmark placed him in the tenth percentile in relation to the national norm-referenced sample. Moreover, Jaren scores on the i-Ready diagnostic assessment indicated that compared to a nationally normed sample, he was in the seventeenth percentile.

Alaric

Alaric (pseudonym), a Caucasian male student with a LD classification was also receiving special education services in mathematics. His performance on the aimswebPlus benchmark placed him in the tenth percentile in relation to the national norm-referenced sample. Alaric's scores on the i-Ready diagnostic assessment indicated that compared to a nationally normed sample he was in the twenty-first percentile.

Setting

The study was conducted in a public charter school serving kindergarten through eighth grade in the northeastern United States. The school had an enrollment of 420 students. 32% of the students were from low-income families. Roughly 52% female students and 48% male students. Thirty percent of the students identified as non-white, and roughly 5% of the students are thought to be children or youth of immigrants. Thirty-four full-time teachers work at the school; 32% have a master's degree, and 67% have a bachelor's degree. The school was a Title 1 Targeted Assistance School, meaning that additional services are provided to specific students who are identified as failing or a high risk of failing. The school was using the Ready Math Curriculum in general education setting. The intervention took place during a time in the early afternoon when the students were pulled out for intensive mathematics instruction.

Independent Variable

The independent variable included explicit mathematics instruction using point-of-view video modeling delivered from an augmented reality platform to teach rational number skills (no in-person instruction was used). An intervention packet and iPad incorporating augmented reality technology delivered the instructional videos.

Explicit Instruction and Video Modeling

The videos for each skill were created by the researchers and incorporated a prototypical explicit instruction lesson and various other explicit instruction delivery techniques (Archer & Hughes, 2011; Gersten et al., 2009). The video lessons were recorded from the point-of-view perspective where the camera was pointing at the instructor's hands (Hughes & Yakubova, 2016). The videos were recorded using the camera on an iPad.

Two videos were recorded for each skill. The first video included the lesson opening and teacher model of the skill. The lesson opening included: (a) an overview of the skill, (b) a description of the skill's relevance, (c) a conceptual explanation, and (d) a review of applicable prerequisite skills. The model demonstrated the skill and provided multiple examples including a "think aloud." The lengths of the instructional videos were as follows: 4 minutes 33 seconds for skill 1, adding and subtracting fractions with common denominators; 8 minutes 56 seconds for skill 2, completing equivalent fractions; and 5 minutes 58 seconds for skill 3, converting fractions to decimal notation and converting decimal notation to fractions.

The second video included a guided practice portion of the instruction, where the students practiced with the instruction and followed a pattern of systematic fading of prompts (Archer & Hughes, 2011; Hughes et al., 2017). A check stage followed, it evaluated the students' ability to perform the skill and practice without prompting. The length of the guided practice videos was as follows: 2 minutes 54 seconds for skill 1, adding common denominators; 3 minutes 18 seconds for skill 2, completing equivalent fractions; and 3 minutes 10 seconds for skill 3, converting fractions to decimal notation and converting decimal notation to fractions.

Intervention Packet and Augmented Reality

The researchers utilized a marker-based augmented reality as the platform for delivering the explicit instruction videos. The process was adapted from an *Augmented Reality Implementation Checklist* published by Kellems and colleagues (2019). Participants were provided a paper intervention packet to complete the intervention. Images were placed at locations throughout the intervention packet that were connected to the explicit instruction videos. A similar platform could be accomplished in most Learning Management Systems (LMS's; e.g., Canvas, Blackboard, Google Classroom, Nearpod, etc.), or by imbedding QR codes, instead of images, that were linked to instructional videos. Each participant used an Apple iPad to scan the images in the instructional packet to access the videos. The iPad case held it vertically in landscape orientation when opened comparable to the orientation of a laptop screen.

The packet led the participants through the various stages of the explicit instruction sequence. Each of the videos were reviewed by the interventionist, a PhD student, using a checklist to: (a) ensure that each of the key explicit instruction components were present, (b) to confirm that the correct video was attached to each marker image, and (c) that the settings worked properly. There were four pages in each intervention packet. The cover page contained instructions for the intervention that were read to participants at the beginning of each session. The next page contained brief instructions and a marker image that the students scanned to trigger the introduction and teacher model video to play. The third page contained brief instructions, a marker image, and five guided practice problems that the students completed alongside the video. The fourth page contained instructions directing the students to complete the check problems (without looking back at previous pages in the workbook) allowing the participant to demonstrate their ability to perform the skill without prompting. For each skill there were between two and four check problems. Students were prompted to raise their hand when they had completed the check problems. The interventionist then reviewed the check problems for accuracy. If the participants completed the check problems correctly, the intervention packet was taken, and the participant was provided with a one-page worksheet with five unique problems on it to complete independently.

Dependent Variable

The dependent variable was the permanent product mathematics measures collected from each participant on three rational number skills: (a) adding and subtracting fractions with common denominators, (b) completing equivalent fractions, and (c) converting fractions to decimal notation and converting decimal notation to fractions. These skills were selected in collaboration with the school mathematics specialist and were skills the students lacked. Student responses were scored for overall correctness. If the complete answer was provided, it was determined correct. Partial credit was not given for partially correct answers or correct answer sequences. Answer keys were created for grading of baseline, intervention, and maintenance worksheets.

Worksheets

Mathematics worksheets were created to evaluate the participants' ability to perform each of the rational number skills. Each worksheet had a place for the participant to write their name and the date. Seven to nine worksheets were made for each phase, baseline, intervention, and maintenance. The problems were randomized using the "generate sets" function in the worksheet creation software, Math Studio Pro (Schoolhouse Technologies). The interventionist and an outside rater, a former math teacher evaluated 100% of the problems and determined that they had no significant difference in problem difficulty.

Skill 1

The first skill included adding and subtracting fractions with common denominators. Every worksheet had three addition problems and two subtraction problems. The instructional prompt stated: "Find the sum or difference." The criteria for both addends, and the minuend and subtrahend, were that the denominators were either 2, 3, 4, 5, 6, 7, 8, 10, 12, or 100. Each fraction was aligned vertically, but the two fractions' relationship was horizontal (e.g., $^{3}/_{12} + ^{7}/_{12}$). Students were not asked to simplify the fractions.

Skill 2

The second skill selected was completing equivalent fractions. Each worksheet had five problems. The instructional prompt stated: "Complete the equivalent fractions." The problems were presented with a fraction in a vertical orientation (e.g., $^{3}/_{4}$) with an equal sign and then the given denominator of another fraction but a missing numerator, or vice versa, with the numerator missing from the first fraction and the second fraction complete (e.g., either $^{3}/_{4} = {}^{\square}/_{20}$ or $^{\square}/_{3} = {}^{7}/_{21}$). Denominators were 3, 4, 5, 6, 7, 8, or an equivalent multiple (up to 10 times) of one of those numbers.

Skill 3

The third skill included converting a fraction to decimal notation and converting decimal notation to a fraction. There were five total problems on each worksheet. The instructional prompt stated: "Convert fractions to decimal notation and convert decimals to a fraction." Denominators for the fractions were either 10 or 100. Examples of the two types of problems are as follows: $^{3}/_{10}$ =________________, or 0.29 = ____________________ .

Experimental Design

This study utilized the multiple probe across behaviors single-case research design replicated with three participants (Gast et al., 2018). The skills identified were determined to be functionally independent of each other, meaning that acquiring one skill should not lead to others' acquisition, and functionally similar meaning that each skill individually was likely to be impacted by the independent variable (Gast et al., 2018).

Procedures

Baseline

For baseline data collection, the interventionist presented the participants with a worksheet (for each of the three skills), two pencils, and a calculator (TI 30XA student scientific calculator). Each baseline page had five problems for the given skill. The participants were not provided any instruction or feedback about their performance during the baseline phase. Each of the participants began the baseline phase for all the skills at the same time. After that, baseline data were probed for the skills that were not immediately receiving intervention. Baseline sessions continued for the first skill until at least five intervention sessions achieved 80% or higher, with data showing stability. The intervention was then introduced for the next skill. Each remaining skill was probed until the participant had completed five intervention sessions with 80% accuracy or above.

Intervention

Prior to the first intervention session, students were oriented to an example intervention packet and directed to practice using the iPads to scan marker images. In this practice session all students demonstrated proficiency with using the iPads and the intervention packets. Before each session, the iPads were unlocked, and the augmented reality app was opened and set into search mode, looking for marker images. For the intervention sessions, students were given an intervention packet, an iPad, a pair of on-ear youth size headphones, two pencils, and a calculator (TI 30XA student scientific calculator). The interventionist read aloud the directions on the cover page to the participants and then directed them to begin working through the instructional packet. The participants turned to the second page in the packet and used their iPad to scan the marker image to start their first instructional video, the lesson opening and model. The teacher modeling the skills instructed the participants to keep their pencils down and watch and listen to the instruction. The lessons began by gaining the student's attention, stating the lesson's goal, and reviewing relevant prerequisite knowledge and provided conceptual information for the skill. The instructor in the video modeled the skill with three to five examples, by providing a visual and verbal demonstration, and cognitive modeling (i.e., the vocalization of internal dialogue or thought processes typically unspoken; Archer & Hughes, 2011).

The participants then turned the page of their intervention packet to the guided practice page. On the guided practice page, participants read the instructions (if applicable), scanned the marker image, and practiced the skill along with the video. The prompts and supports were systematically faded in the guided practice portion using a tell, ask, remind (TAR) procedure (Archer & Hughes, 2011). In this process, the instructor initially provided high scaffolding levels by "telling" the students how to perform each skill step. The instructor then faded the scaffolding by "asking" how to do each step of the skill while providing opportunities for students to respond. Finally, students were simply "reminded" to follow the steps or procedures. Fading the teacher prompting gradually placed more responsibility on and increased students' cognitive effort.

Following the guided practice portion, the participants raised their hands, and the instructional packet was exchanged for a page containing check problems. The lesson's check stage provided an opportunity for each student to independently, and without prompts, demonstrate their ability to perform the skill accurately and for the interventionist to provide feedback to the student. The check problems were on a separate page from the guided practice to ensure the students' ability to perform the skill without prompts. During the check, each student performed two to four iterations of the newly learned skill. The interventionist checked and provided feedback before the participant was able to continue. If the participant had an error in one or more check problems, the interventionist identified the area where the error occurred and helped the participant correct it. Then, depending on the nature of the error, the participant would either do an additional check page (for simple calculation errors) or, if necessary, was directed to begin the guided practice or model videos again (for multiple or more severe errors, i.e., process or conceptual errors). If the participant was directed to watch a video again, the participant completed an additional check page afterward. When the participant passed each of the check problems correctly, they would be directed to continue to the independent practice portion, which contained five practice opportunities.

If a participant answered the additional check problems incorrectly a second time, the interventionist would direct them to watch the "guided practice" video again, completing the guided practice problems again, before reattempting an additional unique page of check problems following the same procedure as before. The check procedure continued until the participant completed each of the check problems with 100% accuracy. Five to eight additional check pages were prepared for each skill.

Maintenance and Generalization

Collecting maintenance data provides valuable information about the continued intervention outcomes after it has concluded (Barton et al., 2018). Maintenance is defined as a durable change in behavior (Cooper et al., 2020), or the continued ability to perform a skill after the intervention is concluded. Maintenance probes were administered for each skill, 7 to 14 days post-intervention.

Generalization was conducted for each skill. Response generalization rather than stimulus generalization was collected by presenting word problems for each skill to evaluate the participants' ability to generalize the mathematics skills in applied situations. Generalization probes were collected in the baseline, intervention, and maintenance phases of the study to demonstrate increased rigor and allow for potential correlational conclusions about the participants' ability to generalize the skills (Ledford et al., 2018).

Interrater Reliability and Treatment Integrity

Interrater reliability was conducted on 100% of the dependent variable data. Scores that were obtained from each data collection session were scored by the interventionist and by a second rater, a Ph.D. candidate, who was trained to compare the students' answers to the mathematics problems with the answer keys. Interobserver agreement (IOA) was calculated on all permanent products produced by students. The agreement between the first and second rater was 100%.

Treatment integrity, was collected at each session across baseline, intervention, maintenance, and generalization phases. The intervention was implemented as described in the methods section 95% (mean) of the time (range 94-100%). Secondary raters observed 25% of the sessions across the baseline, intervention, maintenance, and generalization phases. All raters were provided a treatment integrity form ahead of observing the intervention and could ask questions and seek clarifications if needed. The form contained checkboxes for each component of the research session and intervention to insure it was implemented as outlined (the forms are available from the authors upon request). The agreement for the treatment integrity was 98%.

Social Validity

At the conclusion of the intervention each participant completed a social validity measure. Students responded to statements on a 6-point Likert-type scale that included emoji's about the intervention. Example questions included "Watching videos on an iPad helped me learn math;" "I enjoyed learning math from an iPad;" "I learn math easily on an iPad". Participants received paper copies of the social validity measure to be filled out with pencils. The statements and questions were read out loud to the students. The students were told not to write their name on the social validity questionnaire for anonymity.

Teachers of each participant, along with the school mathematics specialist, completed an anonymous social validity measure, administered in a paper-and-pencil format. Consisting of 11 statements, the measure required teachers to respond on a Likert-type scale ranging from 1 (strongly disagree) to 6 (strongly agree). The questionnaire also included statements such as, 'This was an acceptable intervention for the students' needs,' 'Most teachers would find this intervention appropriate for students with similar needs,' and 'I would recommend the use of this intervention to other teachers' (modified from Witt & Elliott, 1985) and concluded with four open-ended questions.

Data Analysis

The results were evaluated using visual analysis and descriptive analysis. These methods assist in determining if: (a) experimental control occurred, (b) there were intervention effects, and (c) a functional relation was demonstrated. Trend, level, variability, immediacy, overlap, and consistency are evaluated using visual analysis (Cooper et al., 2020). Trend evaluates whether the data is accelerating, decelerating, or continuing unchanged in each condition. Level assesses if there are visible gaps in the data, either up or down. Variability evaluates the stability or lack of stability in the data. Additional data patterns considered were the immediacy of the effect, overlap, and consistency of data patterns across similar phases (Kratochwill et al., 2010). This study evaluated the visual changes in level for each skill and participant.

In addition to visual analysis, the mean was used to determine level changes from baseline to intervention phases. The split-middle method evaluated the direction of the trend (White & Haring, 1980), and the stability envelope was calculated to determine the variability (i.e., range; Barton et al., 2018).

Results

Across the intervention, none of the participants produced any correct answers in the baseline phases. The overall average accuracy across participants and skills was 88.4% (range of 0-100) in the intervention phase. Visual analysis of the graphs for all the participants and skills determined that an immediate change in level occurred when the intervention was implemented on eight of the nine graphs. The intervention phase's data trend was determined to be level or increasing for seven of the nine intervention phases, using the split-middle method (White & Haring, 1980). Variability of the data in the intervention phase were deemed stable, with eight of the nine graphs having 80% of the data is within a 25% range of the median value (Barton et al., 2018).

Musette

Musette did not produce any correct answers in any of the baseline phases (see Figure 1). In the intervention phases, her overall average accuracy was 89.0% (range of 0-100). For adding and subtracting fractions with common denominators, her average accuracy was 96.6% (range of 80-100). Her average accuracy was 74.3% (range of 0-100) for the second skill and 96.0% (range of 80-100) for the third skill.

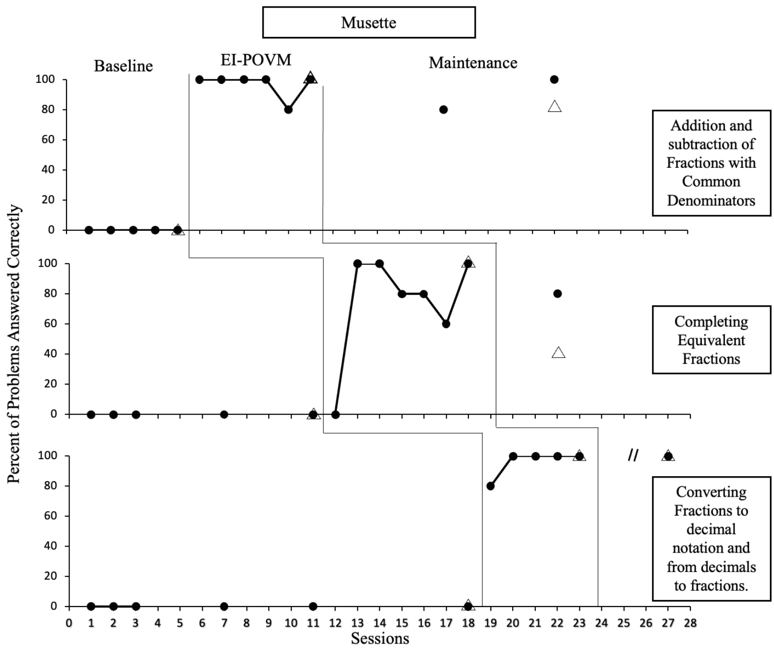

Figure 1. Percent of response accuracy for Musette across three rational number skills, including: addition and subtraction of fractions with like denominators, completing equivalent fractions, and converting fractions to decimal notation and converting decimal notation to fractions. Note: // = Sessions more than five days apart. Δ = Generalization data point. EI= Explicit instruction. POVM = Point-of-view video modeling.

Visual analysis of Musette's results are as follows. The level changed when the intervention was implemented, two of the three graphs had an immediate upward gap, and all data points except one were non-overlapping, meaning that each data point in the intervention was higher than in the baseline. Using the split middle method, the trend for the data in the intervention phase increases for skill one and skill three (White & Haring, 1980) and second skill using the semi-average trend estimation method. The variability of the intervention phase data was deemed to be stable for two of the three graphs (Skill 1 & Skill 3), the intervention phase data were deemed to be stable, with 80% of the data being within a 25% range of the median value (Barton et al., 2018). With the outlier excluded (the first data point in the intervention phase [0]), the data for that graph was also stable for the second skill. Musette had an average maintenance score of 90% accuracy across the three skills. She scored 100% on the generalization probe for all three skills. Her average generalization score in the maintenance phase was 73.3%.

Jaren

Jaren did not answer any problems correctly for all three baseline phases (see Figure 2). In the intervention phases, Jaren's overall average accuracy was 91.8% (range of 60-100). For the first skill, his average accuracy was 93.3% (range of 80-100). On average, his accuracy was 90.0% (range of 60-100) for the second skill and 92.0% (range of 80-100) for the third skill.

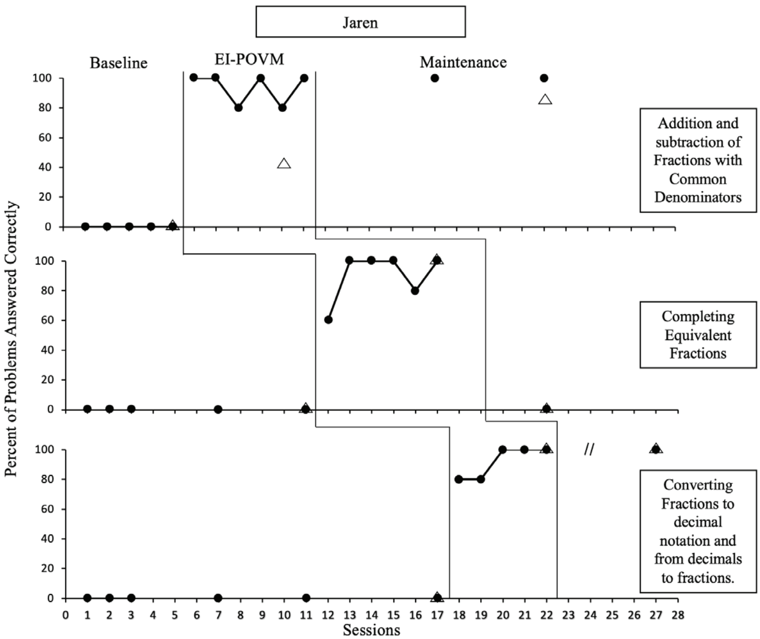

Figure 2. Percent of response accuracy for Jaren across three rational number skills, including: addition and subtraction of fractions with like denominators, completing equivalent fractions, and converting fractions to decimal notation and converting decimal notation to fractions. Note: // = Sessions more than 5 days apart. Δ = Generalization data point. EI= Explicit instruction. POVM = Point-of-view video modeling.

Visual analysis of Jaren's results was as follows. There was an immediate upward level change when the intervention was implemented for all three of the skills, with no overlapping data points from baseline to intervention phase, i.e., each data point in the intervention was higher than in the baseline. Using the split-middle method (White & Haring, 1980), the trend for the data in the intervention phase was increasing for all three intervention phases, skill one, adding and subtracting fractions, skill two, completing equivalent fractions, and skill three, converting fractions to decimal notation and converting decimal notation to fractions. The variability of the intervention phase data was deemed to be stable for all three graphs (skill 1, skill 2, and skill 3), the intervention phase data were deemed to be stable, with 80% of the data being within a 25% range of the median value (Barton et al., 2018). Jaren's overall average maintenance across the three skills was 75%. His average generalization score was 80% in the intervention phase and 60% in the maintenance phase.

Alaric

Alaric did not produce any correct answers in any baseline phases and probes across the three skills (see Figure 3). In the intervention phase, Alaric's overall average accuracy was 84.4% (range of 0-100). His average accuracy for the first skill was 86.7% (range of 60-100), 76.6% for the second skill (range of 40-100), and 90.0% for the third skill (range of 60-100).

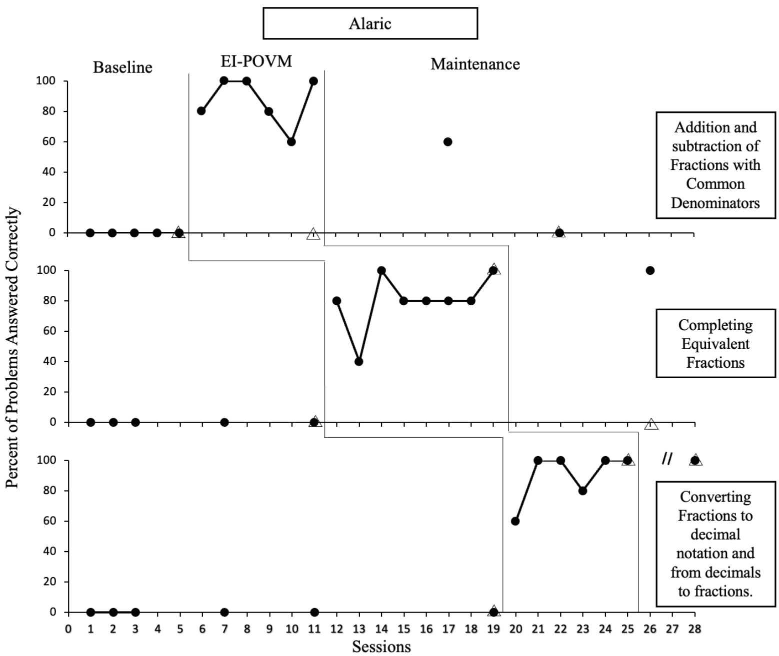

Figure 3. Percent of response accuracy for Alaric across three rational number skills, including: addition and subtraction of fractions with like denominators, completing equivalent fractions, and converting fractions to decimal notation and converting decimal notation to fractions. Note: // = Sessions more than five days apart. Δ = Generalization data point. EI= Explicit instruction. POVM = Point-of-view video modeling.

Alaric's graphs were analyzed using visual analysis as follows. The level changed when the intervention was implemented for all three graphs and had an immediate upward gap for each skill. Using the split middle method (White & Haring, 1980), the intervention phase's data increased for two of the three intervention phases, skill two, completing equivalent fractions, and skill three, converting decimals to fractions and fractions to decimals. The intervention phase data variability was deemed stable for all three graphs (skill 1, skill 2, and skill 3), with 80% of the data being within a 25% range of the median value (Barton et al., 2018). Alaric's overall average maintenance score across the three skills was 65%. His average generalization score was 66.67%. His average generalization score in the maintenance phase was 33.33%.

Social Validity

Overall, the students rated the intervention favorably, with an average rating of 5 out of 6. The students' responses to the first question about what they liked were "it rily [really] helped," "great," and "it is kole [cool]." The student responses to the second question about what they disliked were: "being bord [bored], "nothing," "to sort [too short]." Their responses to the final question about what they would change were "I do not no [know]," "nothing," and "more fon [fun]." Overall, the teachers rated the intervention favorably, with 5.67 being the average rating, out of 6. One teacher said her student had a greater self-efficacy and confidence in mathematics after the intervention.

Discussion

The purpose of this study was to evaluate the effects of an intervention featuring explicit instruction and point-of-view video modeling to teach rational number problem-solving mathematics skills to students identified with LD. Visual analysis was conducted on the trend, level, and variability of the graphed data. The results demonstrated a functional relationship between the intervention and the rational number problem-solving performance for three 4^{th}-grade students identified with LD who received special education services in mathematics. There was a marked increase in their rational number problem-solving performance at implementing the intervention. On average, each of the students performed better on the intervention phase's fractions than the baseline phase. Participants were in the intervention phase for an average of 6.1 sessions to have completed five data points at 80% or above.

The participants had the most difficulty with computing equivalent fractions which was expected because of their conceptual difficulty (Li, 2000). Fraction equivalence problems have more steps than the other skills and the increased cognitive demands involved in the additional steps may have affected performance (Mammarella et al., 2018). Fraction equivalence is a foundational concept for students' understanding of rational numbers (Kamii & Clark, 1995; Li, 2000). A possible change in the delivery of this intervention that may have provided additional support to the participants for learning fraction equivalence could have been to provide printed copies of number lines to them (Schumacher et al., 2018).

Maintenance and Generalization

Because mathematics skills often build upon each other, maintenance of skills is important. The results in the maintenance phase varied for the first two skills. This could have resulted from the participants not obtaining enough practice (see Fuchs et al., 2017). Even though each participant demonstrated that they could do five problems with 80% or higher accuracy on at least five separate occasions, this may not have provided a dense enough practice schedule for optimal retention of these rational number skills.

Generalization was collected in baseline, intervention, and maintenance phases. In baseline, both the intervention baseline measures and the generalization baseline measures were zero. For the remaining generalization probes, the students' performance was either equal to or lower than the intervention and maintenance phase data. Generalization was not programmed for in the instruction. Students were not taught strategies to successfully generalize word problems. Additionally, the students' reading ability may have been a confounding variable negatively affecting their ability to generalize the skills taught through this intervention.

Social Validity

In general, both the students and teachers rated the intervention positively. Students responded to the first open-ended question, asking about things they liked about the intervention, with statements such as it "really helped," it was "great," and that it was "cool." However, while the students reported that they liked the intervention, they were not always enthusiastic about leaving their class for the intervention. Sometimes an intervention session occurred when their class was performing an enjoyable in-class activity or, on occasion, a non-academic activity, or for one student, the read-aloud time of high interests' books, which made going to do mathematics less appealing. The interventionist did work around the participants' schedule, and if there was a "special" extracurricular activity like art or physical education, we did not pull the students at that time but if possible attempted to do an intervention session right after the "special."

The teacher social validity responses reported that they felt that they were "pleased" with the results and that the "effects were tremendous!" One teacher commented that there was possibly too much time between the sessions and identified this as potentially affecting their retention (e.g., the varied maintenance scores).

Implications for Practice

This intervention may facilitate special educators' ability to supplement the diverse needs of learners with exceptionalities. We demonstrated the potential to increase special educators' efficiency at differentiating instruction by simultaneously delivering explicit instruction to many students at differing instructional levels. To do this, a teacher, a group of teachers, or researchers, would create a library of videos and worksheets. The teachers would then be able to provide their students with an iPad or tablet device to assist in explicitly teaching mathematics skills while the teacher assumes more of a facilitating role (e.g., to check for student understanding, answer questions, conduct error correction procedures, provide feedback, and reteach). Being able to provide direct instruction for students in the same group with differing ability and skill levels, while still being able to work individually with students at key points in the instructional process (e.g., checking for understanding, error correction, determining the sequence of skill presentation, and providing reinforcement for appropriate behavior) could be beneficial.

Implications for Research

Future research should continue to evaluate explicit instruction effects combined with video modeling to teach students with LD academic and behavioral skills.

Areas where this could be done, include implementing this intervention to other rational number-related skills, other mathematics skills beyond rational numbers, participants at different grade levels, and students with other disabilities. Additionally, a replication of this study could be done to support further findings, especially by incorporating extended maintenance and generalization to further measure the impact of the intervention on student outcomes. Research should also consider identifying ways to incorporate text input to further automate student progress through various stages of the explicit instruction (e.g., to verify students' ability to perform prerequisite skills, to determine the rate of systematic fading in the guided practice stage, to check for understanding, etc.). Conducting a study that incorporates explicit instruction and video modeling delivered on a device equipped with eye-gaze tracking technology may provide further insight into where students' visual attention is focused, helping to evaluate its impact on their results. Other future research could evaluate the effects of this intervention on a wider range of participants without disabilities and within inclusionary settings. A key area that would strengthen this research would be to have the teachers themselves implement the intervention.

Limitations

The findings from this study should be viewed with the following limitations in mind. A limitation with the digital delivery of explicit instruction is an inadequate ability to provide authentic feedback through the videos. The interventionist provided feedback in the explicit instruction process's check stage, but the feedback was limited during the instructional videos. Having text input or intelligent software with voice recognition could help automate the instruction further and allow greater authentic feedback to students about their performance.

Another limitation is that depending on the skill the maintenance data was collected between seven and 14 days. One week may not be sufficient time to determine whether a skill was maintained. Additionally, where only one maintenance probe was collected because of time constraints, the maintenance results should be viewed with caution. Future studies should collect more maintenance data.

Conclusion

The field of special education has a great need for socially valid intensive interventions to help students learn mathematics skills, impacting students' post-secondary educational prospects and employment opportunities (Lee, 2012). This study demonstrates that an intervention using explicit instruction and video modeling delivered through an augmented reality platform was an effective means for teaching rational number concepts and calculation skills to 4th-grade students with LD. The intervention has potential to increase the ability for special education teachers' role to be more of a facilitator by using video instruction to simultaneously provide direct instruction to students on different concepts and levels. Future research should continue to evaluate this intervention on a range of participants, with and without disabilities, on additional mathematics skills, other academic skills, and behavioral skills.

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Author Note

The authors declare that they have no conflicts of interest.