



Virtual Reality and Algebraic Visualizations

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Background & Purpose of Study

Background:

Using VR technology to improve secondary school aged student's algebraic formula manipulation understanding

Purpose of our Study:

- **To supplement existing curriculum for manipulating algebraic expressions (by way of using VR technology) to better understand the concept as well as practical application.** This will increase accessibility for mathematics to help with learner performance and transfer of knowledge. Algebra was chosen as it is such a major base that much of the rest of mathematics is built upon.
- This project makes the following contributions: * Increase ease of learning * Increase mathematics literacy * Decrease frustration with math * Increase accessibility to STEM careers for underrepresented groups

Problem Statement

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- Foundational mathematics skills are critical for learners of all ages. Students in primary and secondary school may miss out on important Algebraic foundations, such as equation manipulation, which impedes their confidence and ability to prepare for careers in STEM. **Schools need novel tools to help struggling students reach proficiency in base algebraic skills which will open the door for opportunities for many marginalized learners.**

Sweller, J. (1989). Cognitive technology: Some procedures for facilitating learning and problem solving in mathematics and science. *Journal of educational psychology*, 81(4), 457.

Justification: Why Algebra?

- Mathematics is based on cumulative knowledge
 - Foundational skills are extra important
 - Low proficiency is difficult to recover from
- Math literacy impacts career choices
 - Affects already underrepresented groups
 - Impacts confidence and is a barrier for entry to STEM fields
- Gaps in existing tools
 - Novel approaches have been created for Geometry, Calculus, some Linear Algebra etc.

Justification: Why VR?

- Common Current Learning Tools
 - Worksheets
 - You do, We do, I do
- Improved Learning Tools
 - MathLabs and Khan Academy
 - More feedback and guidance
- Needs for New Learning Tools
 - Accessible, visual, and novel approach to catch and empower struggling students

Example Problems:

Algebraic formula manipulation

- Easy
 - Addition, Subtraction, Multiplication, and Division
 - Variable only as a numerator
- Medium
 - Addition, Subtraction, Multiplication, and Division
 - Variable includes fractions as coefficient.
 - Equation may require distribution
- Hard
 - Addition, Subtraction, Multiplication, Division, and Roots.
 - Variable in the denominator
 - May be a formula that needs rearranging instead of an equation that can be solved

Solve for x Goal: isolate the variable

$$\text{step 1 } \begin{array}{r} 3x + 5 = 7x - 3 \\ -5 \quad -5 \end{array}$$

Combine non-variable values if possible

$$\text{step 2 } \begin{array}{r} 3x = 7x - 8 \\ -7x \quad -7x \end{array}$$

Combine values with same variable and power

$$\text{step 3 } \begin{array}{r} -4x = -8 \\ -4 \quad -4 \end{array}$$

$$x = 2$$

Isolate variable by relocating coefficient

Done

can be done in either order

Example Easy Problem and Solution

How: Research Methods

- **Mixed Methods Approach**- collecting both qualitative & quantitative data
 - Participants- secondary school math students
 - **Materials / Apparatus** - use of VR developed in Unity and utilizing Oculus Rift headset and hand controllers
 - **Design**- Mixed Design with Two level between-subjects factor
 - **Procedure**- running two sets of users through experiment
 - 1 group handling math problems on paper
 - other running VR to work through math problems
- Independent Variable: VR Technology
- Dependent Variables:
 1. Performance: Percent correct, and response time, time on task
 2. NASA-TLX after each math scenario

TAM & Systems Usability Scale

How: Our Research Questions

- 1.Cognitive load:** How does VR affect cognitive load between low, medium and high-level algebraic math skill tasks?
- 2.Performance/Perception:** What is the difference in situational awareness (SA) measured by response time and accuracy based upon the algebraic math skill task in VR?
- 3.Complexity:** How does VR affect how participants handle the difference between low- and high-level complexity of algebraic math skill tasks?
- 4.(For Future Considerations) Practical Application:** How does VR help learners understand algebraic skills and their transfer between similar and distinct applications? (between classroom and practical applications)

How: Our Hypotheses

- **Cognitive Load:** There will be a statistically significant difference in cognitive load, such that the VR condition will have lower NASA-TLX scores than the traditional paper format.
- **Performance:** There will be a statistically significant difference as measured by performance (ie: response time and time on task) that under the VR condition due to ease of use, reduction of cognitive load, and improved spatial awareness.
- **Complexity:** There will be a statistically significant difference between high and low complexity scores based on performance parameters under the VR condition.

Storyboarding Prototype

- Randomly generated problems based on High, Medium, Low difficulties.
- Amount of time to solve problem is recorded to show delta in performance.
- Assisted, non-assisted, test modes available to help get familiar with the system.



References/Resources

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Thank you....any questions?