GIFTS Paper: Math Quest: Arithmetic Education for Underfunded Schools

Introduction

More than ever, constant technological innovation requires the education field to keep up. Math Quest was developed in response to the growing need for affordable and engaging learning tools in elementary mathematics education. Many schools in underfunded districts lack access to educational technology that can aid in student learning experiences and lessen the stress and pressure that teachers feel every day. The age of papers and packets for learning is over for many well-funded schools, and the technology gap between high-income and underfunded schools is growing ever wider. Many commonly used technological learning tools are only available through laptops or mobile devices. Underfunded schools lack the resources to provide these sorts of devices to all students or even to entire classrooms. This leaves their students at a disadvantage for learning when compared to students from well-funded schools.

Math Quest aims to solve this issue. We have created an inexpensive, effective learning tool to assist students and teachers at underfunded schools. When looking at other products in this market, our team was surprised to see how clunky and unengaging they were. This led us to design Math Quest to resemble a handheld game controller. We chose this shape since game controllers are a tried and true handheld product design that prioritizes comfort, modularity, and ease of use. This design also lets us leverage students' familiarity with gaming devices, which are common fixtures of childhood at this point. Oftentimes, the most frustrating part of learning a new skill is just getting used to the controls; this process can be frustrating and uncomfortable. Our design choice helps create immediate interest and a sense of familiarity with students, along with providing a comfortable user experience. The choice of using this tried and true design will help students be open to the idea of trying Math Quest and eliminate any early frustrations with it.

Not only do these schools lack the most common forms of educational technology, but they also lack adequately staffed classrooms. With a higher student population, more funding is needed to pay a higher number of educators. However, due to a lack of funding, many schools are "understaffed" in certain areas. This can lead to a gap in the intended curriculum [1]. Products like Math Quest are intended to bridge this gap and help the students and staff from underfunded schools.

Our Approach

Math Quest was designed with three principles in mind: affordability, engagement, and familiarity in the classroom. Traditional educational technology often utilizes touchscreens or complex interfaces that can be both expensive to produce and difficult for young students to understand. By mimicking the familiar game controller design, Math Quest leverages existing mental models that children already possess, reducing the learning curve to use Math Quest significantly. The chosen design includes tactile movements. This small motor function included in educational activities has been known to increase engagement in learning [2]. By designing a hands-on tool, students can focus more on the task at hand and less on background noise. This design is also a tried and true design for comfort and modularity. However, we had to shrink the design to better fit elementary-aged children's hands, as game controllers are generally designed to best fit the hands of teens and adults. We weighed all of our options for building this device, and we decided to use the following components and aspects that best fit the design.

1. Two analog rotary encoders that students use to input their answers. The physical turning motion reinforces a number of sequencing concepts and helps develop fine motor skills. Each encoder has 20 positions per rotation with dents for precise control and costs $3.50 per unit.
2. A built-in LCD screen that displays math problems and provides immediate feedback.

Displays math problems, feedback, and simple graphics. The $6.00 display keeps costs low while providing sufficient clarity for mathematical equations.

3. An ESP32 Microcontroller will power the device with low energy consumption while providing sufficient processing power for arithmetic operations and basic graphics. This component costs approximately $4.50
4. A 1200mAh lithium-ion battery that provides sufficient processing power for arithmetic operations and basic graphics. These components cost $4.50.
5. Durable plastic housing is designed to withstand drops and features
6. The device is programmed with math problems aligned with educational standards for grades 3-5. Problems progressively increase in difficulty as students demonstrate mastery.
7. Math Quest's low production cost comes from using readily available electronic components and an efficient manufacturing process. The durable plastic casing is designed to withstand classroom use, making it an ideal investment for schools.

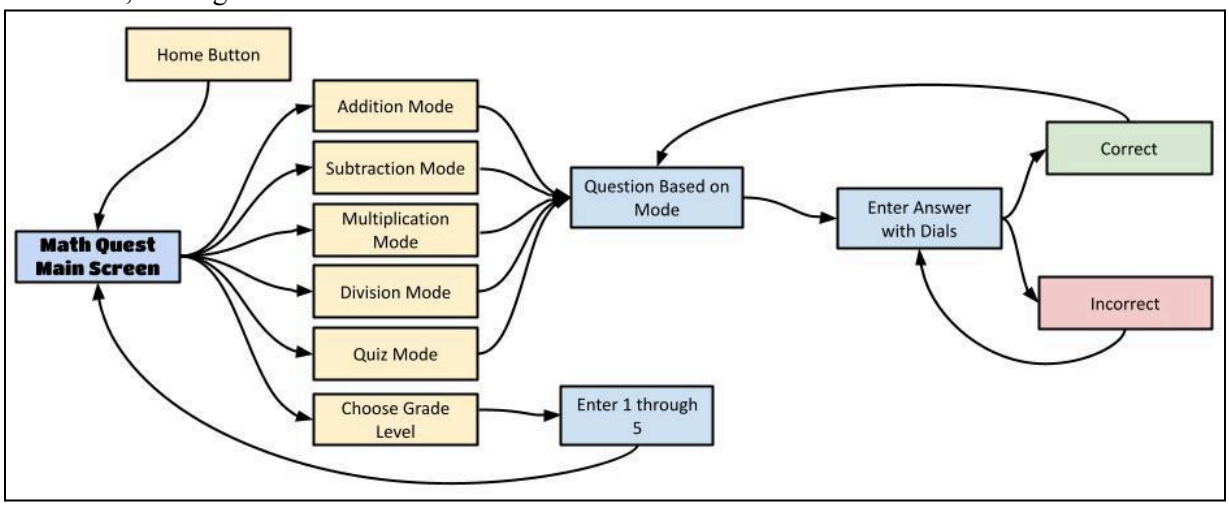

Figure 1: Flow of Software

Classroom Engagement Opportunities

Games can motivate students to combine knowledge from multiple disciplines and apply it in decision-making scenarios. They also allow students to observe how different outcomes emerge based on the choices they make throughout gameplay. Additionally, games encourage communication and coordination among participants, which helps improve social and collaborative skills. [4]. A classroom with multiple Math Quests can engage students to "game" together and work collaboratively. With a game controller shape, the Math Quest is not something the students are familiar with, but it also offers a game-like feel with the rotary digit inputs (see Figure 2). The various modes and graphics programmed onto the Math Quest make learning more fun and versatile to fit each student's needs.

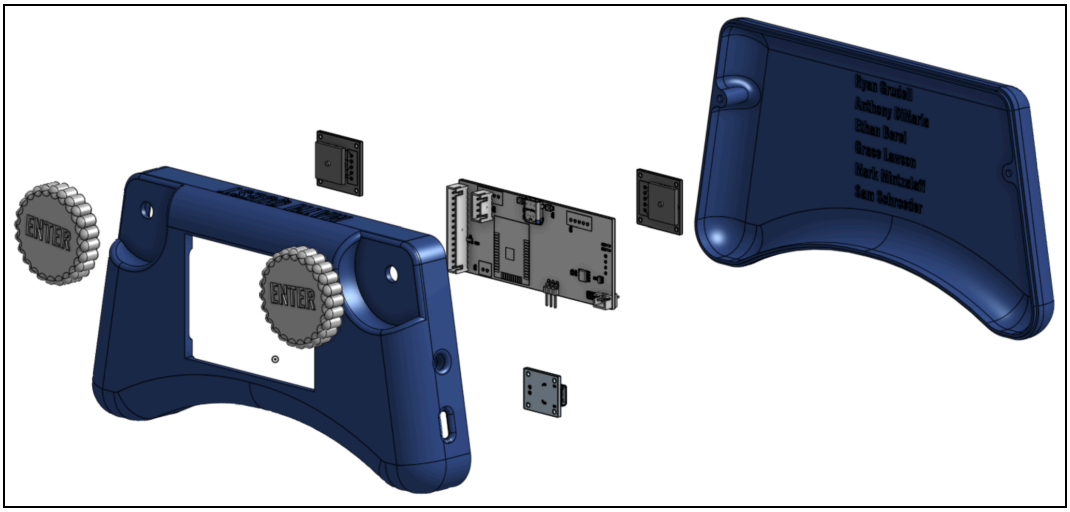

Figure 2: Exploded View

While the Math Quest promotes collaborative play, it's also useful for independent learning. Independent learning is important to have in the classroom to help solidify concepts taught by the teacher. It also allows students to learn at their own pace and offers flexibility, as can be seen in the various modes the Math Quest has. Overall, this helps to reinforce arithmetic concepts without one-on-one interaction with a teacher [5].

Another key aspect of learning is fun. Research shows that students tend to learn better when they are having fun. Not only does having fun at school make students want to be there and want to engage with the content in their classrooms, but it also makes children learn better [3]. This is another major benefit of using Math Quest; the shape of the controller, combined with the use of graphics, leads to better learning outcomes.

Results and Discussion

Due to the nature of this project, the device is untested in the field and is therefore evaluated based on theoretical findings. This product began as a school project, meant to be started and finished within one semester. Due to an interest in the project from a professor, the project was allowed to become a research experience. While no proper testing was done on the device, it should be sufficient to serve its intended purpose. In future testing, with parental consent, Math Quest could be given to a small group of children, and observations could be made, such as their engagement, ability to complete given tasks, and ability to navigate the device without significant instruction from their educator. Prior and post-test evaluations could be made, specifically any improvement in quick math skills before and after learning on the device.

Future Work

In the future, several enhancements can be made to improve the educational impact and functionality of Math Quest. One area of further development is the integration of a color display. Adding additional graphical aspects would help boost student engagement through visually appealing and interactive content. For example, images could be used to create more immersive math problems, such as counting objects in a scene (e.g., apples, carrots, and soccer balls). These make concepts more concrete and relatable for young learners. Another area for future development is the expansion of connectivity features. The ESP32 microcontroller used in Math Quest supports Wi-Fi communication. Multiple devices could be networked together, enabling teachers to send out synchronized questions or quizzes to

all students simultaneously. This would allow for real-time assessment and feedback, helping educators track student progress more efficiently. It could also support peer-based activities, such as group problem-solving, to foster a sense of community and engagement in the classroom. Any of these improvements will aim to keep the cost of the current design low, yet improve the design and functionality of Math Quest.

Acknowledgement

The Math Quest team would like to thank the faculty and staff who provided guidance throughout the development of this project. Special thanks to our research advisors, [redacted] for their support in the creation and design of this project. Finally, we are grateful for the resources and facilities provided by [redacted], which made the prototyping of this project possible.

References

[1] M. Weber, "The consequences of school underfunding," New Jersey Policy Perspective, https://www.njpp.org/publications/report/the-consequences-of-school-underfunding/

[2] K. Cherry, "What Is Kinesthesis?" Verywell Mind, Sep. 6, 2023. [Online]. Available: https://www.verywellmind.com/what-is-kinesthesis-2795309

[3][1] L. David and N. Weinstein, "Using technology to make learning fun: Technology use is best made fun and challenging to optimize intrinsic motivation and engagement - European Journal of Psychology of Education," SpringerLink, https://link.springer.com/article/10.1007/s10212-023-00734-0 (accessed Apr. 28, 2025).

[4]Adipat, S., Laksana, K., Busayanon, K., Asawasowan, A., & Adipat, B. (2021). Engaging students in the learning process with game-based learning: The fundamental concepts. International Journal of Technology in Education (IJTE), 4(3), 542-552. https://doi.org/10.46328/ijte.169

[5]S. Jihan Lubis, M. Setia Priyadi, and , "implementation of the Independent Learning Curriculum in Elementary School," Muhammadiyah University Kotabumi, Dec. 2022. Accessed: Apr. 23, 2025. [Online]. Available: https://jurnal.unimed.ac.id/2012/index.php/school