IMPROVING STEM ACCESS WITH A COLLABORATIVE 3D/VR DESIGN LAB

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Abstract

To evaluate a collaborative 3D/VR Lab established to improve STEM access and math skills at a Midwest US secondary school, three data sources were reviewed and analyzed. STEM access (course enrollment) improved early and consistently over five years but math achievement (STAR assessment) initially improved but did not reach the goal. The 3D/VR Lab struggled due to COVID closures.

Keywords: Virtual reality, connected learning, math, STEM, motivation.

1. Introduction

High school students struggling with STEM readiness and math scores are not uncommon in the US. However, in one small midwestern town nestled between multiple military facilities, this challenge was met with an uncommon opportunity to transcend, to change the usual narrative.

A generous multi-year grant was awarded by DoDEA as a Department of Defense Field Activity to increase STEM enrollment and math achievement through the implementation of a new 3D/VR Design Lab featuring robotics, virtual reality, and 3-D design applications. This effort initially targeted military-connected students.

The 3D/VR Design Lab was implemented over the course of five years providing a structure for increased student engagement and enrollment by providing "real world" tools and resources. Professional development, training, and community outreach including input from local business and industry were also integral elements. This article explores the project's results and lessons learned.

1.1. Background

The purpose of this grant was to increase military-connected student STEM enrollment and math achievement through the implementation of a hands-on Design Lab featuring Robotics, Augmented Reality, and 3-D Design applications. This lab and supporting credit frameworks were developed to provide a structure for increased student engagement and enrollment by providing "real world" tools and resources. Professional development in personalized learning and use of design tools would be an integral element of success to better prepare educators to utilize the design lab for integrated instruction.

Virtual Reality has a tremendous potential to significantly improve learning outcomes, enhance engagement and motivation, and promote active learning (Yilmaz et al., 2017). Therefore it was reasonable to think this technology might engage students of military families to develop not only engagement through increased course enrollment but also academic achievement in math as measured by the STAR Math Renaissance assessment. STEM research suggests that academic achievement scores may increase because of exposure to STEM courses (Gilmer, 2007). Exposure to STEM via a Design Lab has the potential to positively impact student perceptions and dispositions (Bagiati et al., 2010). Design Labs provide entry points for STEM engagement increasing the probability of STEM course enrollment (Easley et al., 2017).

1.2. Implementation

Due to district financial constraints, there was a limited ability to provide STEM experiences for immersion in traditional content areas, limiting access to those who enroll in specific formal STEM programming. However, expanding the design opportunity to all learners would give choices and an exposure that would encourage students to enroll in STEM specific programming. When students experience Design Software, 3D Printers, Augmented and Virtual Reality they may become more likely to enroll in formal STEM courses to further explore possibilities. The intent was to increase student math

achievement by experiencing relevant, hands-on application thus increasing capacity to be college and career ready in a world increasingly seeking creative designers.

The availability of these tools and resources would additionally allow for an after-school extra-curricular club whereby students could utilize the design lab for personalized projects. Additionally, the Design Lab would serve as an excellent entry point for students to engage in STEM activities thus increasing the probability that they will enroll in a STEM course (Easley et al., 2017). The Design Lab would also support areas of need in professional learning by providing a hands-on resource as well as monthly integration professional development opportunities which was unavailable to educators.

1.3. Goals/research questions:

Five-year project goals/strategies to be completed by 2023 were identified as follows:

RQ1: Increase the number of target students enrolled in formal STEM courses to 20% from a baseline of 5%.

- Create a structure for a STEM Extra Curricular Advisory utilizing STEM Experts.
- Design Lab Development

- Plan and deliver professional development to encourage educators to utilize the lab for instruction RQ2: Increase the average Math assessment for targeted students to 70% from a baseline of 61%.

- Establish Design Lab Coach
- Provide professional development and tools for math integration
- Recruit target students to utilize the lab

RQ3: Create a robust 3D/VR Design Lab to support community learning and industry collaboration.

- Develop, staff and equip the Design Lab with a design coach who would support content teachers
 - Provide Math integration opportunities in the Design Lab
- Recruit military-connected students for after school Design Lab extra-curricular activities

2. Methods

This effort was simultaneously a project funded by a grant and a research study to understand the academic significance of a well-funded and thoughtfully managed 3D/VR Design Lab.

2.1. As a five-year project, annual reports were prepared relative to the project goals/research questions and contained in five comprehensive reports

Assessments concerning STEM course enrollment and math achievements were relatively straightforward whereas the evaluation of the design lab itself was more nuanced and developmental over time. In addition to the reports, progress of the Design Lab was informed by various other sources gathered over the course of five years, such as observations, student/parent feedback, industry interaction and consultant interaction.

2.2. Evaluation Measures:

- STEM Course enrollment data was collected from school counselor records and reported annually.
- Math achievement data was collected from the STAR Assessment school and reported annually.
- For assessment of a robust 3D/VR Design Lab triangulation of grant reports, observations and user feedback was compiled and analyzed. In addition to the annual reports, a qualitative informal formative evaluation was undertaken, leading to observations and assessments relating to the following: community involvement (parent, business partners, military installations) and student experience: design lab projects, consultant days, focus group observations.

The lab plus supporting infrastructure was implemented over the course of several years providing a structure for increased student engagement and enrollment by providing "real world" tools and resources. Professional development and training in the use of technology and design tools were also implemented as integral elements.

3. Results / assessments

Results for each of the three research questions are summarized below. Please note that even though the data was collected over the period of five years and was impacted by the Covid epidemic leading to long delays and overall impacting the various measures especially math scores. The negative impact on math scores due to Covid and remote learning is well documented.

3.1. STEM Course enrollment: Increase military-connected students' enrollment in STEM courses to 20% by 2023

One of the initial strategies to increase STEM Course enrollment involved individual conferences with school counselors and military-connected students. Counselors shared information such as academic and career planning, shortage areas, and individual interest inventories. Parent nights were held to build support and an understanding of the importance of STEM preparation. Counselors were intentional in encouraging students who may not have planned to enter a STEM field to experience courses that they may not have originally considered. Parent and student information sessions provided relevant information of the importance of STEM foundation to a variety of careers so that students might consider adding courses to their academic plan regardless of their anticipated career track. As a result, the goal was met in the second year of the grant and continued to grow throughout the five-year progression. See graph 1 below.

Graph 1.



Note: Math achievement slipped significantly in the US during the COVID shutdown. (Bailey et al, 2021)

3.2. For MATH achievement

The Math Achievement goal was rigorous at the onset as the district hoped to increase the average percentile rank on the Math STAR assessment for military-connected 9-11th grade students to 70% from a baseline of 61%. One of the greatest challenges initially was the lack of relevant math-specific software applications for the VR Headsets. As the team re-grouped for professional development and further investigation of relevant math-specific software in the fall of 2020, they were met with the COVID-19 Pandemic early in 2020 sending all students to virtual learning for the remaining of the year and strict protocols for the following year. Because the design lab was a physical space, students were not able to access the lab and fully utilize the equipment until the fall of 2022. Additionally, math educators turned their focus to creating online content for virtual learning thus not allowing for a significant focus on AR/VR/3D math applications utilizing the Design Lab tools. Of note, however, was the growth in STAR scores in 2023 from the dips experienced during COVID-19. Because math is a scaffolded subject, the district anticipates that more time will be needed to address learning loss. See graph above.

3.3. Establishment of robust collaborative 3D/VR Design Lab (See table 1)

The Design Lab Coach, CTE Coordinator, and the building principal reached out to all the military connected students enrolled at Tomah High School. They presented the various aspects of the DoDEA STEM grant project to attract students to work with the Design Lab Coach on individual projects to further expose students to Virtual Reality (VR), Augmented Reality (AR) and 3D modeling, and to show how those are being integrated in STEM and math courses. Many students signed up to work with the Design Lab Coach to work on individual STEM projects throughout the school year. In addition, several student/parent/teacher/industry workshops held to connect the Design Lab to the wider learning community and nurture its own community of practice.

Year/ Strategy	Design Lab/ Equipment	Personnel/Prof Development	Target/ Community/ Industry
2018- 2019	Space Identified 12 HoloLens	Lab Coach Search Consultant Learning Day	Industry outreach planning
2019 - 2020	Initial Build 3D Printers COVID	Site visits COVID	Industry/parent outreach COVID
2020 - 2021	COVID Design Lab closed	COVID Design Lab closed	COVID Design Lab closed
2021 - 2022	Lab Space 22 HoloLens (upgrade)	Consultant/industry workshop 2 day/open lab	Student/parent/teacher/ industry workshops
2022 - 2023	Lab Space 3D Printers, supplies	Math focus PD/Co-Teaching Lab Coach Search	Industry outreach/ Teacher practice

Table 1. 3D/VR Design Lab Development Timeline

The Design Lab coach continues to work with high school math and STEM teachers to build engaging learning opportunities using the VR, AR, and 3D modeling equipment. The Design Lab Coach and building principal identified military connected students with lower math achievement percentile ranking. A math intervention plan with the identified students was developed to increase their math proficiency and to engage them more in STEM-related VR, AR, and 3D modeling activities. Teachers work with the design lab coach to adapt their curriculum to include the use of the VR, AR, and 3D modeling equipment to provide unique learning opportunities to expose students to various applicable technologies and to increase engagement. STEM teachers, school counselors, and the Design Lab Coach continue to introduce students to STEM curriculum, projects, and course options to increase enrollment in STEM courses.

4. Discussion

This section discusses findings; including goals met, challenges encountered, lessons learned and recommendations for further research. Of these the challenges encountered and lessons learned are perhaps the most instructive.

4.1. Goals accomplished

STEM course participation, (Goal #1) was a very clear success during the final two years exceeding the 20% goal with 35% in the final year. Goal #2, however, was not accomplished based strictly on the math achievement scores in any of the last five years. In a final report including students' feedback, they energetically described the Design Lab as cool, fun, and engaging. Beyond that, however, they shared how it provided space for just hanging out, messing around and geeking out (Boyd et al., 2008). A place where you go to "just figure things out". Furthermore, participating students maturely shared their understanding of communities of practice and the responsibility to pass forward their learned confidence and collaboration skills to the next year.

4.2. Challenges encountered

There were many challenges encountered during the five-year project. The most significant challenges include a complete closure of the design lab during Covid, difficulties in identifying and obtaining suitable resources/security, and finally the ever-present problem of professional development for key personnel. These are detailed below followed by mention of lesser challenges. Perhaps the largest challenge hit directly in the middle of the project the second and third year (2019-2021). Closure of the school impacted the development and use of the Design Lab. This delayed the equipment and personnel acquisitions further limiting collaborative efforts and community building around the 3D/VR themes.

Suitable technology acquisition was also a significant issue of selecting and acquiring the necessary hardware and software was a challenge. New headsets and updated hardware/software created compatibility issues. Surprisingly, Security constraints imposed by strict district security guidelines made outside connections very difficult. Policies restricted any real time collaboration outside the school. Access to web-based curricula were not possible and standalone programs were cost prohibitive. Clearly there was

a need to equitably balance security with innovation. Additional challenges included minimal professional development specific to operation of the VR hardware. Also noted, insufficient access to specific math content and lack of time available for students to play with the headsets and VR applications in order to build confidence, motivation and sense of connected learning (Boyd et al., 2008).

4.3. Lessons learned / implications

Often the most limiting factors of new programs are related to communication and training issues. Creating timely professional development is often a challenge for new programs, so building a community of practice was encouraged as a new way forward. This is a work in progress, however, since it often takes time and shifts in identity to develop a robust community of practice that can replace traditional collaborative learning. (Farnsworth et al., 2016).

4.4. Recommendations for the future

Continued research is recommended for the project especially now that school closures are past, and the Design Lab can function fully. The Lab has become established and is benefitting from increasing awareness and social capital among the target students.

4.5. Researcher comments

The district is to be commended for their efforts to provide a Design Lab that emulates work in the "real world". The struggle between security/firewalls and opportunities for innovative tools is one to be explored more deeply. For example, Oculus VR Headsets provided ease of use and robust applications but required a Facebook account which is blocked in the district. Also of note was the rapid pace of technological change as the features and functionality of 3D Printers and tools was rapid. Purchases needed to be justified to DoDEA as many schools were purchasing inexpensive 3D printers that needed significant support or had limited longevity. Finally, some of the technology tools may have been premature in terms of content specific applications. Inevitably, applications for math skill acquisition will be more available, but at the onset of the grant most applications were primarily for gaming.

5. Summary

In summary, the potential for a 3D/VR Design Lab to positively affect math scores in STEM enrollment was tested in this five year generously funded project. The methodology included straight forward math scores and enrollment statistics as well as annual assessments of the design lab and key strategies for success. Results were mixed but ultimately very encouraging for increasing STEM interest and activity in the target population of military-connected students in the mid-western U.S. high school. The most significant challenges were discussed, and recommendations suggested for future work. The Discussion also addressed the challenge Learning relationships and the neglected power of building community into learning environments especially 3D/VR Design Labs. Given the proven motivational nature of 3D Design, gaming and VR, their combination with powerful supportive learning communities will be instrumental in the future.

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