Boosting STEM Student Success Through Leveraging Technology and Providing Just-In-Time Content Remotely Accessible

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This project, Boosting STEM Student Success (award#P120A210015), focuses on the four years of collegiate experience and three summers during the freshman through junior years of study. The project aims to enhance STEM student success by leveraging "just in time" learning, a method where individuals access information and training when needed, in a self-paced manner. This approach is gaining popularity as seen in platforms like LinkedIn Learning, Facebook Groups, and YouTube. The project will create asynchronous content available anytime, along with a virtual reality component to enhance the learning experience. The goal is to provide students with active learning opportunities and just in time feedback to address their questions and reinforce their understanding. This project recognizes the importance of active engagement in STEM fields and the need to provide students with the tools and resources they need to succeed.

Keywords: STEM/Tech, co-curricular offerings, VR, remote content, just in time learning & undergraduate support

INTRODUCTION

Building Capacity for Remote Learning adopting and supporting models that leverage technology (e.g. universal design for learning, competency-based education, or hybrid/blended learning and provide high-quality digital learning content, applications, and tools) provides the curricular basis for efficiently providing all undergraduates core skills through 1) establishing career skills topical reviews (Upcraft,

Barefoot, and Gardner, 2005), 2) understanding how research and innovation occurs (Lopatto, 2007; 2010), and 3) how critical teamwork is to workplace and research innovation (Haas and Mortensen, 2016).

Incorporating peer led team learning facilitation provides the methodology for learning and improving teamwork for undergraduates (Steitweiser and Light, 2010). This methodology provides solving problems where students can assess their own understanding, learn how small groups can learn questioning and discussion techniques, and most importantly, put into place a peer-to-peer learning system. These instructional, support systems create a sustainable, cost-effective way of supporting retention, persistence, and on-time graduation.

At University of Houston-Downtown, the combining of computer science with engineering technology into one department in 2015 has bolstered each department with increases in undergraduates majoring in both these departments as well as increased the minors within each department. Additionally, the addition of data science as a major has increased high interest into the mathematic sciences. The addition of two female computer science professorate has also assisted in evidenced increases in females with in each department (where typically more male instructors commonly populate the professorate). Specialty areas of 1) neural networks, 2) AI/machine learning, 3) big data, 4) human computer interfacing, and 5) robotics bring an applied and emerging nature to both computer science and engineering technology and motivate undergraduates toward these two fields. Moreover, the onset of data science as an undergraduate mathematics major offers substantive support to both fields of computer science and engineering technology!

As demonstrated during the 24 months of quarantining initiated by the COVID-19 pandemic, these content areas expanded through dedicated use of online/hybrid/blended learning formats, use of audio/visual learning conference softwares (e.g., Zoom, Youtube, and other synchronous/asynchronous examples). Covid shaped the onset of just in time learning as all learners were sequestered and began initiating learning on their own. Use of the UHD computer science department data center server provided ample space for stand-alone front-end and back-end server learning and use by students in the online environment and for use of data as partner in formative assessment to influence instruction (Haley-Speca, 2016). Finally, utilizing our own university server allowed for a modicum of universal design for learning model across both departments (Rose, et.al., 2006; Rao, 2014) which in turn provided increases in student retention within the online environment (Chen, 2008; Lohmann, Hovey, & Gau).

Providing personalized and job-embedded professional learning support the capacity building of educators, workers, learners to create remote learning experiences that advance student engagement and learning through effective use of technology (e.g. synchronous and asynchronous professional learning, professional learning networks or communities, and coaching).

LITERATURE REVIEW

The Project

This project will target freshman (FTIC) course success, success retention during the first, second, and third year of university study. Further, STEM undergraduates, particularly minorities and females, are also targeted by this project, specifically because these content areas indicate far more males than females majoring in the computer science and engineering technology degree arenas. By using a curricular and co-curricular approach of support, this project targets student preparation, student competence, student confidence, and skill development in a comprehensive, continuing manner by 1) partnering PhD STEM faculty (faculty mentors) and upper division STEM undergraduates (peer mentors) as guiding forces supporting undergraduate success through relationship building within small learning communities (Holland, Major and Orvis, 2011), 2) addressing STEM curricular challenges in the first, second, and third year years seen as “barrier” STEM courses (such as biology I, chemistry I, organic 1, engineering 1, calculus 1, physics 1) through Just In Time asynchronous study materials (Malcom and Feder, 2016); through online tutorials offered through Zoom sessions by high achieving students (males and females), 3) increasing exposure to access industry/workforce STEM experts unknown to FTIC prior to college, and 4) facilitating research skill development through active, mentored research and internships, enabling students the develop

the capacity to envision their future work and connect the relevancy of current coursework and asynchronous resources to their future (Lopatto, 2009; Kuh and Hu, 2001; Hunter, Larsen, and Seymour, 2007).

Further, all of these skills may be boosted through a synchronous or asynchronous professional learning environment and/or through a learning management system portal bringing communities together and through offering "just in time training" (Wilkie, 2013; Shift, 2021). As witnessed in the upsurge of LinkedIn Learning, Facebook Groups, Instagram Groups, Youtube videos, and other examples of "just in time" learning/training, individuals are boosting their knowledge and understanding through media offerings detailing small chunks of information as the user feels they need a bit more than they know. In the arena of academia, just in time learning must incorporate active learning approaches, and opportunities for students to actively construct new knowledge extending prior knowledge. Computer science and engineering technology by their nature demand active engagement in support of learning whether this be at the undergraduate level or the secondary level. Equally important is just in time feedback to address the student questions and reaffirm their understanding as well as reinforce academic time management. Of new interest is the use in voice assistants in learning, such as Alexa (intelligent personal assistant), as an advanced learning technology either within or external to a learning management system and virtual reality.

Developing the Just in Time Access Point for All Learners

The Virtual Reality Environment

Virtual reality (VR) provides an immersive experience which enriches the context of the learning and provides a simulated action-based environment connected to the learning. Likewise, the learner participates in a customized experience. The interactivity connected to the immersion appears to be most connected to the learning improvement associated with VR (Madathil, et.al, 2017).

Introduction to the JIT Website

Examples of the VR learning models developed (and some still in development) are offered for context across the various expert disciplines of the faculty involved in this project.

Dr. Ling Xu's (computer science mobile app development with VR integration) research involves 3D modeling, VR game development, android app development, and procedural arts. In these projects, students have learned the fundamentals of Human-Computer Interaction and software development, at the same time gained hands-on expertise in interface design, prototyping, and implementation with coding for various platforms.

Dr. Ting Zhang's (computer science with web-based and robotic applications) research involves the study of robotics, neuroimaging, and artificial intelligence (AI). Specifically, the cutting-edge techniques in computer science, electrical engineering, and biomedical engineering are investigated to advance interdisciplinary research approaches.

Dr. Katarina Jegdic's (mathematics and machine learning applications) JIT research's main goal of this research project was to utilize VR (Virtual Reality) headsets to visualize multidimensional data sets in data science. An important step in machine learning modeling and in data science, in general, is Exploratory Data Analysis (EDA) that includes data visualization using a variety of graphs and charts. However, these visualization techniques are often complex due to data consisting of a large number of input variables. There are several machine learning models that enable us to reduce the number of input variables, including the Principal Component Analysis (PCA). PCA is based on the Singular Value Decomposition of matrices and the main idea is to project data points onto only the first few principal components to obtain lower dimensional data while preserving as much of the data's variation as possible.

Dr. Katherine Shoemaker's (data science with use of large databases) JIT research targets learning tools commonly used in data science analytics. The challenge was utilizing virtual reality technology to visualize the data science tools, their applications, and the deliverables.

METHODS

In the Context of Computer Science/Statistics/Machine Learning/ Emerging VR

The main goal of this research project was to utilize VR (Virtual Reality) headsets to visualize multidimensional data sets in data science. An important step in machine learning modeling and in data science, in general, is Exploratory Data Analysis (EDA) that includes data visualization using a variety of graphs and charts. However, these visualization techniques are often complex due to data consisting of a large number of input variables. There are several machine learning models that enable us to reduce the number of input variables, including the Principal Component Analysis (PCA). PCA is based on the Singular Value Decomposition of matrices and the main idea is to project data points onto only the first few principal components to obtain lower dimensional data while preserving as much of the data's variation as possible.

In the project, we used PCA to reduce the number of input variables to three and then we visualized the three-dimensional data points using the VR headset. The software we used to create a three-dimensional graph is Unity since a 3D project created on Unity is accessible to Oculus (a popular Virtual Reality device). The dataset we used in the project is the well-known iris dataset, which is simple enough to run a very first demonstration. The iris data set consists of four input variables; namely, patel length and width and sepal length and width. The first step was to apply PCA and save the data projected onto the first three principal components as a new csv file. The second step was to upload the new csv file onto the Unity project to create a three-dimensional graph. In the Unity project, we created a prefab object and incorporated the prefab object to each data point at the location determined by the three principal components' coordinates. The last step was to publish the Unity project on the Oculus device.

We were able to successfully visualize the 3D graph through Oculus device. We were able to move around in the graph in the Unity platform; however, we could not move around in the graph through the Oculus device since we were not able to incorporate a personal character in the project due to time limitation and limitation of the computational capacity. Our future work includes learning more about how to manipulate the Unity platform to add more features in the video including personal characters and their movements.

In the Context of Computer Science

Elementary and middle school students often struggle with attention difficulties, which negatively impact their academic performance and overall development (Reynolds & Shirey, 1988; Cicekci & Sadik, 2019). Research in psychology has demonstrated that attentional regulation can be effectively developed through consistent practice (Olney et al., 2015; Wadlinger & Isaacowitz, 2011; Hanif et al., 2012). However, current attention training practices often require professional intervention and are not easily accessible. To address these challenges, we intend to utilize the advantages of virtual reality (VR) technology to enhance the attention training experience via an immersive VR game.

Our work is based on research that emphasizes the benefits of physical movement and interaction with objects in games for enhancing both engagement and the effectiveness of attention training (Bavelier & Green, 2019, Anguera et al., 2023). In this project, we constructed a 3D virtual environment where players will overcome a few challenges targeted at movement and interactions in the game world. Players will use VR headsets and motion controllers to navigate the virtual world, search and count hidden objects, and complete specific challenges that require focus and perceptual skills. Additionally, our game incorporates VR-specific features such as spatial audio, which provides a more realistic and immersive auditory experience. Sound cues and clues are spatially positioned, allowing players to use their auditory perception to locate hidden objects and complete tasks. These VR-specific enhancements not only make the game more engaging but also leverage multiple sensory modalities to reinforce attention training.

This project involves a computer science undergraduate student mentored by a faculty mentor. We aim to create an interactive system that combines the game design principles, VR techniques, and psychology findings for attention training methods. We expect to provide a novel and effective tool to improve the attention skills in an engaging and immersive manner. At the same time, we introduce the system to our

student communities, and expect to motivate students to explore how computer science and VR can contribute to interdisciplinary collaborations such as psychology, education, and healthcare.

VR Products Selected for Use

We currently have two VR headsets were purchased, a Meta Quest 2 (being used by Brenda) and a Meta Quest Pro (being used by Huy). The following is the introduction to the headsets and Unity.

The Meta Quest 2 (formerly known as the Oculus Quest 2) is a virtual reality (VR) headset developed by Meta (previously Facebook). The Quest 2 has a LCD display panel and two touch controllers used to track hand movements and gestures, providing users immersive experience exploring the virtual world. The Meta Quest Pro is a later released high-end VR headset that targets at more advanced features (compared with the Meta Quest 2), such as eye-tracking and face-tracking functions. These premium features support our project for attention studies by investigating how users switch their attentions and gazes in the virtual world.

VR Software Development Environment Selected for Use

Unity is one of the most popular game development engines in the world. It provides an integrated environment with powerful functions to developers to create 2D/3D games, interactive applications, and experience for multiple platforms. In our projects, we use Unity to create 3D and VR games for attention training and other applications for education and healthcare purposes.

PROJECT IMPLEMENTATION AND RESULTS

Introduction to the JIT Website and Content Creation

Accessible at the JIT website - (https://uhd.edu/academics/sciences/scholars/booting-stem-just-in-time/index.aspx).

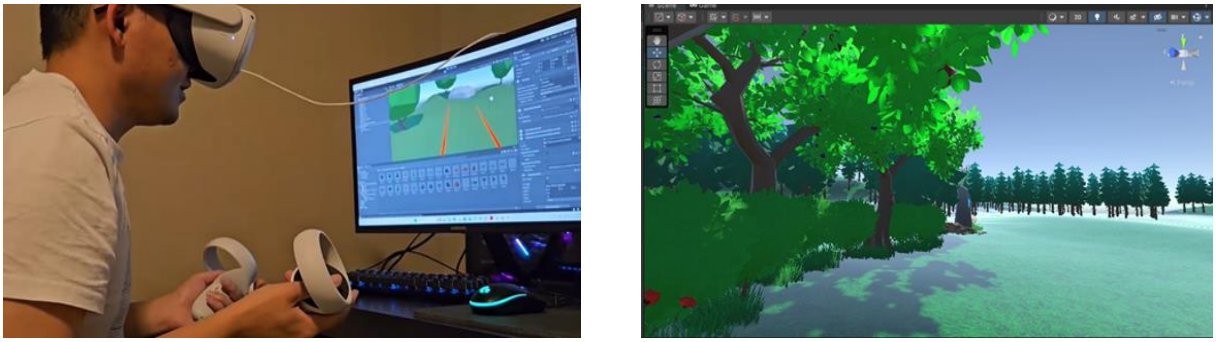
Building Capacity for Remote Learning can mean adopting and supporting models that leverage technology within the asynchronous environment for any learner to access at any time.

Excerpt for Dr. Xu's Page

Dr. Ling Xu's research involves 3D modeling, VR game development, android app development, and procedural arts. In these projects, students have learned the fundamentals of Human-Computer Interaction and software development, at the same time gained hands-on expertise in interface design, prototyping, and implementation with coding for various platforms.

Key Just In Time projects include: The Development of Virtual 3D Game for Attention Training; for Attention Training; How to build your first VR project in Unity; Study of Assessment Methods for VR Meditation Applications; and VR How-to; Tutorials for VR Application Development; Explore the basics of using Unity - add objects, transform, and light; create prefabs; apply materials, shaders, and textures; and add natural objects to your scene (See Figure 1.)

FIGURE 1
SCENES DEVELOPED IN UNITY USING VR HEADSET TO BE USED IN GAMING APPLICATION



Excerpt for Dr. Zhang's Page

Dr. Ting Zhang's research involves the study of robotics, neuroimaging, and artificial intelligence (AI). Specifically, the cutting-edge techniques in computer science, electrical engineering, and biomedical engineering are investigated to advance interdisciplinary research approaches.

Key Just In Time projects include: A Journey into Immersive Virtual Worlds; DOED Virtual Reality Project; and Static Meshes and Intro to Nanite & Datasmith; Robotics Hardware- Arduino Blink Onboard LED; Arduino Blink LED on breadboard; and Arduino Serial Monitor Output, Keyboard Input, Loops, Functions; Potentiometer and Sensors Part I; Potentiometer and Sensors Part II; Arduino Sensor Reading; Arduino Stepper Motor; and ROS and OpenCV (See Figure 2).

FIGURE 2
EXAMPLES OF TUTORIAL MOVIE SESSIONS USING VR AND OCULUS HEADSET

Excerpt for Dr. Katarina Jegdic's Page

In the project, we used PCA to reduce the number of input variables to three and then we visualized the three-dimensional data points using the VR headset. The software we used to create a three-dimensional graph is Unity since a 3D project created on Unity is accessible to Oculus (a popular Virtual Reality device). The dataset we used in the project is the well-known iris dataset, which is simple enough to run a very first demonstration. The iris data set consists of four input variables; namely, patel length and width and sepal length and width. The first step was to apply PCA and save the data projected onto the first three principal components as a new csv file. The second step was to upload the new csv file onto the Unity project to create a three-dimensional graph. In the Unity project, we created a prefab object and incorporated the prefab object to each data point at the location determined by the three principal components' coordinates. The last step was to publish the Unity project on the Oculus device.

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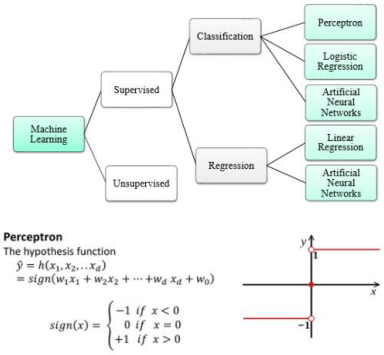
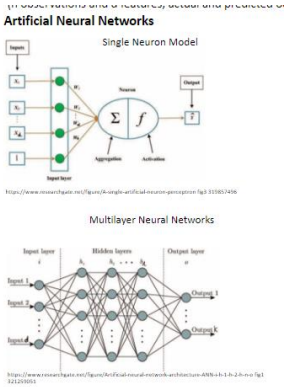
Key Just In Time projects include: Perceptron and Logistic Regression; Introduction to ML (machine learning); Classification using single neuron models; Logistic Regression Example – digits data set; Perceptron, Logistic Regression, and Artificial Neural Networks (poster); Introduction of PCA (movie); Creating Scatterplot on Unity (movie); 3D Data Visualization on Oculus and Unity (See Figure 3).

FIGURE 3
PERCEPTRON, LOGISTIC REGRESSION, AND ARTIFICIAL NEURAL NETWORKS

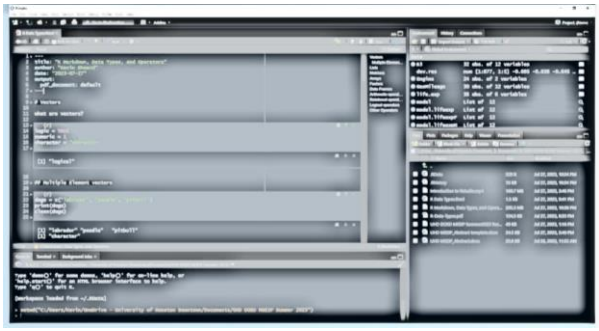


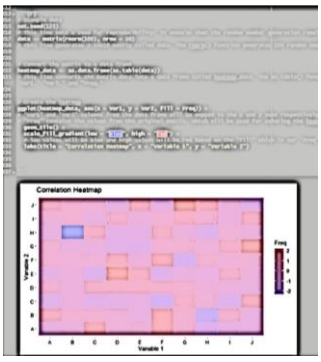


Excerpt From Dr. Katherine Shoemaker's Page

Key Just In Time projects include: JIT Modules for R Studio; Introduction to RStudio; R Basics; Data Visualization; Introduction to DPYLER; Functions in R (movie); Control Structures in R; Data Visualizations (movie) (See Figure 4).

FIGURE 4
RSTUDIO PROGRAMMING AND DATA VISUALIZATION





DISCUSSION

Houston has experienced one of the largest population increases in the nation & Texas during the past decade. As the energy, chemical, medical, financial, and data science capital of the world, Houston/Harris County offers career opportunities in food, computer hardware/SCADA, robotic, chemical, drone, DNA/healthcare/biometric, and pathogenic security. A recent INDEED.com search of cybersecurity and other emerging technology jobs indicated over 336 unfilled jobs identified within a 25-mile radius of Houston. A recent review of US Census employment characteristics of Harris County found that married-couple families had both husband and wife in the labor force 51.9% of the time. Single parent families led by female head of household were in the labor force 53.7%. Among single parent families regardless of head of household found 22.6% were not in the labor force at all (American Factfinder). With a median household of $49,977, a poverty rate of 16.3, and a level of persons living below the poverty level at 19.2%, this densely populated Houston community demonstrates levels of poverty connected to levels of unemployment, even while Houston holds a level of unemployment rate of 3.7%. Unemployment and race in Harris County indicates unemployment rates rising even higher than the overall rate. Among college-aged minorities and whites, current rates of unemployment increase three and four times the overall levels.

Much training/education is needed to positively influence these impacting factors for minorities or the underrepresented for Houston's future. A recent study from the Texas Comptroller's Office (King, 2019) indicates a gender gap in cybersecurity as well as other technology fields. There remains a need to attract and retain a highly diverse labor pools for the Texas. Cybersecurity Ventures was cited in this same article as indicating over one million cybersecurity jobs unfilled worldwide currently and anticipates over 3.5 million by 2021.

Texas and US changing demographics comprising the workforce. These demographics coupled with the surge in cybersecurity crimes of stolen confidential information and intellectual property reported by McAfee (Feb 2018) at two-thirds of the world population and Accenture reports and average of 130 security breaches per company per year (2017). Both factors demand future/current workers be trained to address the growing need. The education targeted by this project focused on 1) practical training to remove skill & knowledge gaps and cultivating proficiencies for employment in the most timely manner possible; 2) providing support of current college emerging workforce while also offering anytime learning access; and 3) hands-on practical experiences with cutting edge computer and emerging technologies, such as virtual reality immersion. UHD as a minority-serving and Hispanic-serving federally designated institution attracting underrepresented populations coming from the four historical wards, representing the most diverse populations and minority populations across Houston is in a position to fully influence increased access to asynchronous learning and self-training.

Results From the Project Study in Year Two

Primary goals were to 1) Increase Minority STEM Enrollment, 2) Increase Minority STEM Graduation Rates, and 3) Increase Minority STEM Female Success. Initial baseline data provided annual self-reflection. Minority STEM enrollment was measured to be 172/201(62.6%) while minority STEM graduation rates were measured as 201/333 (60%) and finally increased success of female STEM majors was measured at 1008/967 (93%).

Over a 10 year period minority STEM graduates were viewed as increasing with programs like this (See Figure 5). Comparison of year .5 to year 2.5 of the project examining minority growth in computer science and data science is highlighted in Figure 6.

FIGURE 5
TEN YEAR ANALYSIS OF MINORITY GRADUATES BY GENDER AND ETHNICITY

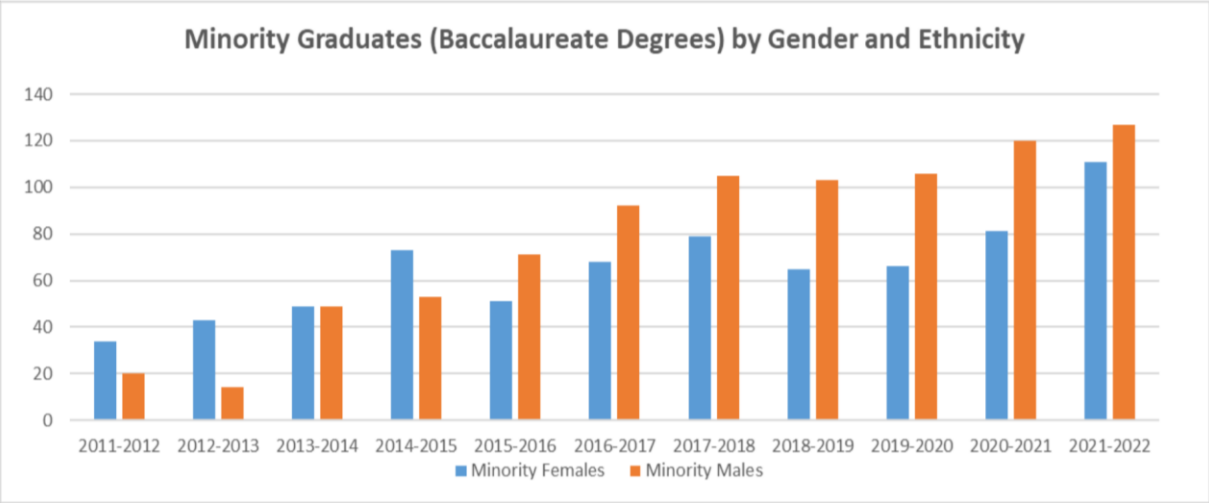
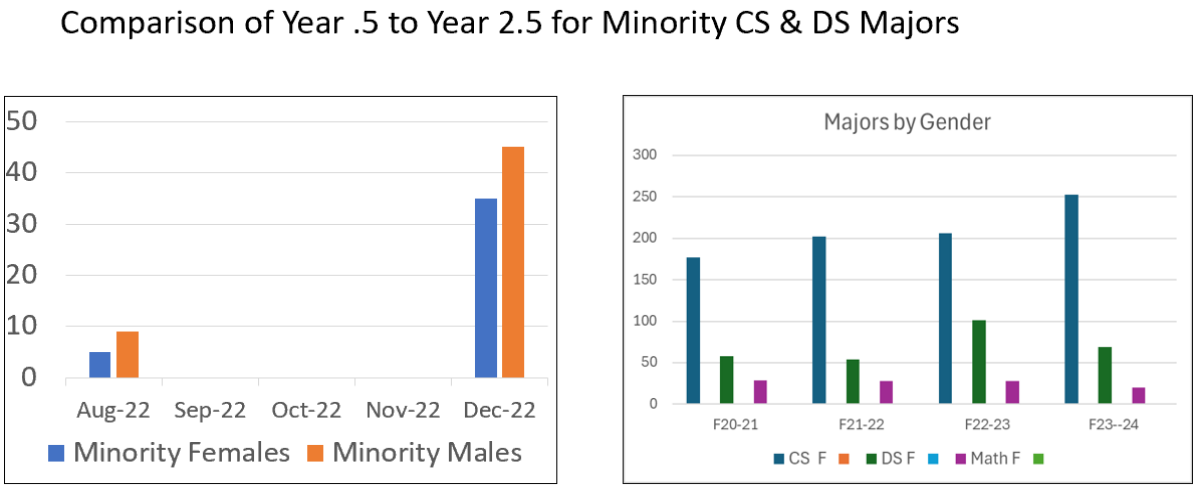


FIGURE 6
WHILE IN GENERAL STEM UNDERGRADUATE MINORITIES AND FEMALES ARE INCREASING ACROSS THE UNIVERSITY, THIS PROJECT INVESTIGATES THREE DISCIPLINE AREAS WHERE SIGNIFICANT CAN AND MUST BE MADE



UHD OIE, 2023

IMPLICATIONS FOR PRACTICE AND POLICY

Boosting STEM Student Success (award#P120A210015) project offers a multi-pathway for academia and industry to examine and implement Just In Time learning opportunities. Additionally, adding emerging technologies such as virtual reality can extend enthusiasm and creativity for learners. The Just In Time approach provides foundational material to be learned on the learners' own time, thereby bringing creative applications to the course time where the expertise of the professorate is best utilized and tapped by the learners. In this manner academia best supports future learners by providing information for access. This model can also be used within industry and business for ongoing professional development opportunities.

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