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FINAL PROJECT REPORT: 08/29/2024

EXPLORING VIRTUAL REALITY IN ASTRONOMY EDUCATION: ENHANCING STUDENT UNDERSTANDING THROUGH IMMERSIVE LEARNING ENVIRONMENTS

Nandana Weliveriya & Inseok Song (Physics and Astronomy)

Introduction:

This project, designed to enhance the quality of astronomy instruction and research across STEM disciplines, addresses current limitations in astronomy lab courses. By offering students a dynamic tool to engage with real-world scenarios, the VR platform aims to cultivate essential problem-solving and decision-making skills.

Dr. Inseok and I have played integral roles in steering the STEMIn3D project's remarkable growth, witnessing active participation from approximately **10 faculty members** and **15 students** (graduate and undergraduate). Our interdisciplinary research team brings together seasoned faculty members specializing in astronomy, education research, big data, and artificial intelligence. With expertise in Virtual Reality and Multimodal 3D User Interfaces, virtual reality teaching platforms, and adept STEM instructors, our team is well-equipped to advance our objectives.

The essence of this project proposal aligns seamlessly with UGA's 2025 Strategic Plan, particularly in the domains of 'Promoting Excellence in Teaching and Learning' and 'Growing Research and Innovative Approaches to Teach and Create Research Opportunities.' Furthermore, our project harmonizes with the core themes of the Presidential Interdisciplinary Faculty Hiring Initiative in Data Science and Artificial Intelligence, emphasizing the translation of education research into health professions and STEM disciplines.

Below, we summarize the progress that we acquired thanks to CTL's Learning Technology Grants (LTG) support.

Equipment Purchase: As per the proposal to purchase, significant progress has been made in acquiring essential equipment for our project:

- We have successfully obtained the new Meta - Quest Pro, a substantial upgrade from the previous pico neo eye 3 we were using. Further with the support of Teaching Enhancement and Innovation Fund, Franklin College of Arts and Sciences, we added a few more VR heads sets.
- The next crucial addition is a high-performance workstation tailored to meet the demanding programming requirements of the project. The workstation specifications include an i9 12900KF processor overclocked to 5.2GHz with 16 cores, Windows 11 Pro, 64GB RAM, a 1000GB NVMe 4.0 SSD, a Quadro RTX A4000 GPU, and a 10TB RAID storage.
- Additionally, we have secured the domain name for the project: STEMIn3D.net. Further developments related to the website are outlined below.

Student support: As per the proposal to support students,

- Graduate student Robin Allen received full support for the fall 2023 semester and partial supported for the spring semester. Robin completed his MS degree by the end of May 2024.
- Freshman undergraduate students Emre Alia and Ridwan Haque began receiving payment starting in the latter part of the fall 2023 semester, and this support continued until the end of the grant period.
- Furthermore, 5-6 new undergraduate students joined the project, bringing fresh perspectives and enthusiasm to our team. As we continue our efforts, we plan to identify additional undergraduates to support, leveraging the remaining funds from this grant.

Designated Working Space and update on Website

Working space: The undergraduate students on our team are actively involved in coding for the development of topic-based basic simulations. In the current and upcoming phases, they will be tasked with working on more intricate modules and converting them into simulations with user interactivity, enabling changes in some aspects of simulations in real-time. To support this endeavor, the PI and the CO-PI are actively applying for internal and external research grants to secure a workstation with high computing power, as the current equipment has limitations. This new setup will enable students to log in physically or remotely, allowing them to continue working on their projects. In the image below, you can see the current state of the computers and the workstations ready for students to use in a designated room within the physics building. The intention is to create a welcoming environment for students involved in this project, providing a space to collaborate on coursework-related tasks and work on their individual projects. The goal is to foster a sense of community and productivity within this dedicated workspace. **Update**

on project website: With the invaluable support from LTG's funding, we successfully launched a live website to showcase our project. The website has gained significant traction, attracting approximately **1000** visitors per month. We are eager to maintain this momentum and ensure continuous support for the website's functionality and content. Dr. Song collaborated with the university's EITS to initiate an enterprise GitHub account specifically for the project. This initiative provides us with unlimited space to add and store student projects, accompanied by version control mechanisms to prevent potential data loss. As a notable outcome, the project has now



obtained an official myID and UGA.edu email address, enhancing our capacity to collaborate with external partners and stakeholders. This strategic move aligns with our vision for broader outreach and engagement.

Education research component

- Graduate student Robin Allen has obtained IRB approval for collecting data using commercially available VR teaching resources. This study aims to identify limitations observed by instructors and graduate teaching assistants. Beyond contributing to Robin's completion of his MS degree by the end of May, this research serves a dual purpose. It not only aids in addressing limitations promptly but also enhances the quality of simulations and activities developed over time.

Student presentations and Achievements

- Graduate student Robin Allen, currently an academic division officer at US NAVY defended his MS. thesis and the report can be found here: (https://www.researchgate.net/publication/375633052_Enhancing_Astronomy_Education_Demonstrating_Astronomical_Phenomena_using_Immersive_3D_Learning_Experiences_Motivation)
- Robin Allen is currently adapting his manuscript report into an article, which we intend to submit to the European Journal of Physics.
- Graduate student Robin Allen's work was highlighted in the recent presentation titled "Enhancing Astronomy Education: Demonstrating Astronomical Phenomena using Immersive 3D Learning Experiences Motivation" at the 90th Annual Meeting of the APS Southeastern Section, held at Eastern Kentucky University (November 9-11, 2023). The presentation is documented in the following publication: "DOI: 10.13140/RG.2.2.23135.02721" - and attached at the end of this document.
- The undergraduate students, Emre Alia, Ridwan Haque, Max Baxley, and Gioia Zincone, have applied for the spring CURO assistantship awards to continue their work on individual projects, and we are pleased to announce that all of them have been awarded the CURO assistantship. This recognition not only acknowledges their dedication and contributions but also provides them with the support needed to further excel in their respective projects during the spring semester. We are excited about the continued progress and success of these talented students in their research endeavors.
- The undergraduate student Gioia Zincone received the CURO Summer Research Fellowship to continue on her project.

Current state of the simulations and future plan

- In addition to involving graduate and undergraduate students, we have also expanded opportunities for high school students at Gwinnett School of Mathematics, Science, and Technology. During the summer of 2024, three students participated in our project, and one more joined us during the fall semester.
- With the support of both current and newly joined students, we have 2-3 simulations and associated activities nearly ready for classroom rollout. In addition to these activities, the research team plans to gather student feedback through surveys and think-aloud interviews. Below is a brief update on our simulation progress.



Figure 1: A snapshot image rendered from a 3-D simulation of the Sun-Earth-Moon system created by Blender V3.6.2. This simulation was created by two freshmen UGA students.

Eclipse simulation: Identified as a key priority and proposed as one of the initial modules in the previous round of LTG Grant proposal. Ridwan Haque and Emre Aliya; two freshman computer science majors already started the creation of the eclipse simulation module with Blender (see Figure 1). Their work was displayed during the 2024 CURO Symposium (<https://STEMin3D.net/results/presentations>). As picked up by the high school students and the new undergraduate student Jack Armstrong (at Vanderbilt) the deployment and testing of the soon-to-be fully developed eclipse 3-D model are planned within courses such as Astronomy of the Solar System (ASTR 1010) and Introductory Astronomy for Majors I (ASTR 1110) in the upcoming spring 2025 semester. This initiative endeavors to revolutionize astronomy education and make substantial contributions to the open education resource community.

Virtual Night sky: recognized as another high priority topic. Michael Cai, who joined the research team as a high school student and has continued to contribute significantly as a main program developer, even now as a freshman at Columbia University is working on his project

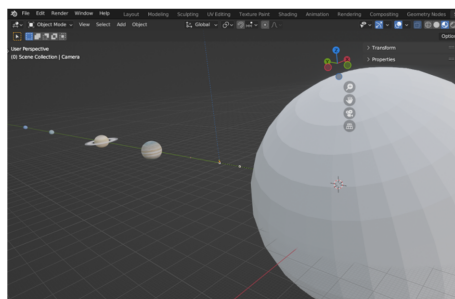


Figure 3 a: Blender Virtual Night Sky 3D-Viewport. This is one of the many windows in Blender for the SkyTracker (aka Virtual Night Sky) model development

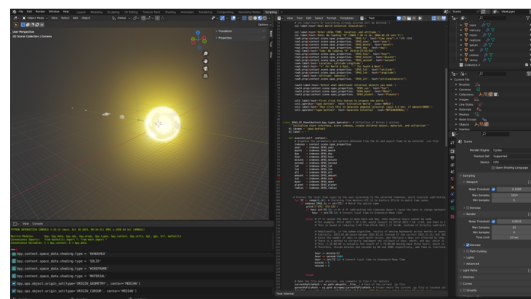


Figure 3 b: A Full-Screen view of the SkyTracker Blender window. A full window screenshot taken during the development of the SkyTracker Blender Model. 3D-viewport, Script editor, (object) Properties window, Scene, ViewLayer, and Console are displayed.

Figure 2

to simulate a realistic night sky in Blender. Michael's simulation is in progress as shown below in Figure 2, it can be used in a handful of other simulations such as 'diurnal motions of celestial objects', 'seasonal constellations', 'time and calendar', etc. These additional topics, we plan to create simulations in the near future, leveraging support from other grants, including external NSF: IUSE grants. He will explore using Unreal Engine 5 (UE5) in creating a different version of the night sky tracker since UE5 provides two advantages over Blender: (1) real-time rendering and (2) multi-user environment (i.e., a version of virtual classroom).

Broadening Research Spectrum

- The project leads successfully established significant collaborations beyond the fields of physics and astronomy, exploring topics beyond our initial suggestions. As part of this initiative, the Principal Investigators are leading one of the 2024-2025 Faculty Learning Communities (FLC) focused on Immersive Technologies. The goal of this FLC is to unite practitioners from across campus to foster interdisciplinary discussion and collaboration on utilizing immersive technologies for teaching and research.
- The collaboration between the research team and Dr. Majewska, faculty from UGA's College of Veterinary Medicine, represents an auspicious beginning towards a larger vision. This partnership marks the initial strides towards expanding the research initiative to cover a wider spectrum of UGA STEM disciplines. The detailed expanded research plan outlined below, particularly focusing on Dr. Majewska's Physiology courses, will serve as a crucial testing ground and facilitate the collection of initial data. This preparatory phase is essential in laying the groundwork for forthcoming NSF: IUSE grants, demonstrating a proactive approach to ensuring the success and sustainability of the project across diverse academic domains within STEM.

Funding opportunities beyond LTG

- **Funderd:** The PI and the Co-I applied and received funds from the internal funding opportunities below,
 - EETI Augmented, Remote, and Virtual Experimentation Grants, Engineering Education Transformations Institute (EETI), College of Engineering, University of Georgia, 2024.
 - 2024 Active Learning Change Grants
 - Provost's Affordable Course Materials Grant - AY 24
- **Rejected:** The PI lead a multidisciplinary grant proposal for the 2023 Presidential Interdisciplinary Seed Grant Program, but it was declined.
- **Pending:** As we set our sights on major external funding opportunities from esteemed agencies such as NSF/IUSE, NSF/AISL, Unreal Engine Epic Mega grant, NASA/MUREP, and others, the engagement of undergraduate students in programming and simulation design lends a unique dimension to our project. The establishment of a dedicated office space, complete with powerful computers, further fortifies our position in the pursuit of external grants.
 - Fall 2024:** EETI Augmented, Remote, and Virtual Experimentation Grants, Engineering Education Transformations Institute (EETI), College of Engineering, University of Georgia, 2024.
 - (IUSE: EDU)** Improving Undergraduate STEM Education: Directorate for STEM Education - NSF 23-510

(Beyond Boundaries: Harnessing Immersive Environments for Elevated STEM Understanding in Education.)

Spencer Foundation: Large Research Grants on Education Program

(Enhancing Astronomy Education with Immersive Technologies and Promoting Active Learning.)

Summary and Acknowledgment:

In conclusion, the past two semesters have witnessed the rapid growth and surpassing of milestones by our project, exceeding initial expectations. We extend our sincere gratitude to the Center for Teaching and Learning at the University of Georgia for their unwavering financial support, which has been instrumental in our success.

As we reflect on our journey, we anticipate submitting a comprehensive final report by the end of the semester, encapsulating the valuable achievements and highlighting the positive impact of this collaboration. We remain committed to advancing education and research, and this success is a testament to the strength of our partnerships and shared dedication to excellence.

Nandana Weliweriya, Inseok Song
Physics and Astronomy

Enhancing Astronomy Education: Demonstrating Astronomical Phenomena using Immersive 3D Learning Experiences

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Motivation:

Current astronomy resources are limited:

- 2D Illustrations of fundamentally 3D phenomena are not adequate.
- Visualization issues lead to misconceptions (e.g., Engstrom 1991).
- Blackboards, handouts, etc. cannot accurately capture astronomical scales.
- Celestial sphere difficult to accurately portray in 2D.
- Partial illumination of spherical bodies is impossible to draw on a board.



Figure 1: Screenshots of the Moon from the Star Chart VR application. Taken from different angles to illustrate the impact of location and shape on the witnessed illumination.

Example AR Simulation:



Figure 2: Image taken from sample AR simulation, to see this simulation in use scan the QR code. AR simulation developed by project team member Shameer Abdeen.

Limitations of Existing 3D Options:

Currently the availability of 3D astronomy software is limited, with few open-source options or resources that have been tailored for use in an undergraduate setting.

- Stellarium™: Main shortfall is the lack of projection to 3D hardware such as VR headsets.
- Universe Sandbox™ and SpaceEngine™: Not accessible in a classroom setting due to reliance on high quality graphics cards and requires commercial licensing.
- Star Chart™: Omits astronomically significant details like the celestial sphere and requires commercial licensing.

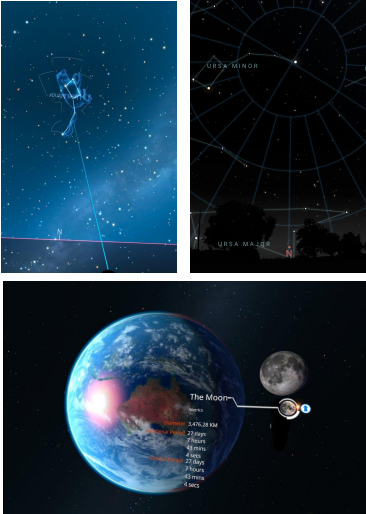


Figure 3: Sample images from Stellarium™ (top right) and Star Chart™ (top left and bottom). Top images show northern night sky from Athens GA. Bottom image shows partial illumination of the Earth.

Initial Phase:

The initial phase involves two commercially available 3D astronomy applications, SciVR and Star Chart.

- Use Star Chart™ to determine the efficacy of commercially available astronomy VR software.
- Use SciVR's (Kersting et al.) Solicit feedback on 3D tools in two different methods: 'Smart Window' and VR.

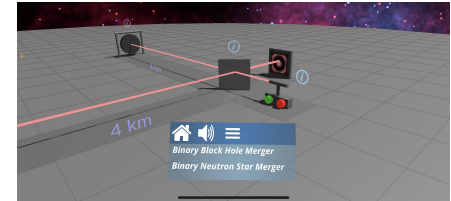


Figure 3: Sample from the LIGO function in the SciVR app.

Subsequent Phase:

Once feedback from the initial phase is compiled and reviewed new 3D learning experiences will be created for chosen 3D relevant topics. Topics include:

- Due to their inherent 3D nature: Mechanisms behind eclipses, tidal forces, and precession of the Earth
- Due to the difficulty in accurately depicting the phenomena: Projection of the celestial sphere onto the night sky, diurnal motion, and the astronomy behind the calendar



Figure 4: (left) Team member Robin Allen using Star Chart™ to explore the solar system. (right) Scan the QR code for more information on this project

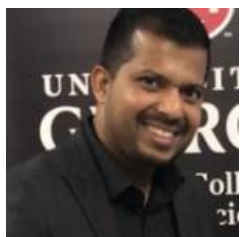
References:

Yjö Engström, Non scolae sed vitae discimus: Toward overcoming the encapsulation of school learning, Learning and Instruction, Volume 1, Issue 3, 1991, Pages 243-259, ISSN 0959-4752, [https://doi.org/10.1016/0959-4752\(91\)90006-T](https://doi.org/10.1016/0959-4752(91)90006-T)
Magdalena Kersting, Jackie Bondell, Rolf Steier & Mark Myers (2023) Virtual reality in astronomy education: reflecting on design principles through a dialogue between researchers and practitioners, International Journal of Science Education, Part B, DOI: 10.1080/21548455.2023.2238871

Project Team

Faculty Members

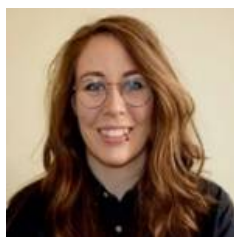
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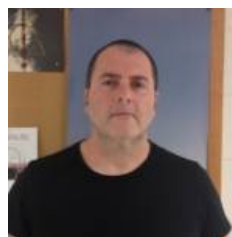
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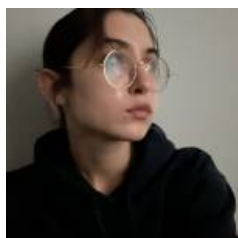
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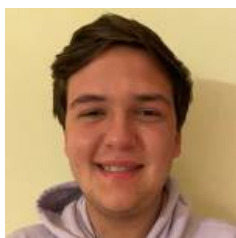
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Do you want to join?

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Potential Collaborators

Katy Smith (klaustin@uga.edu): Marine Extension and Georgia Sea Grant | Water Resources Specialist



To Prospective Students...

If you are interested in this project, contact us at STEMin3D@uga.edu.

We welcome graduate and undergraduate students with a strong interest in STEM education. If you have good programming skills and are looking for a research opportunity in creating 3D simulations, come and talk to us. If you do not have 3-D programming experience but are willing to learn it, we can start with a small task (there are many!!)

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team [STEMin3D]

for you. If you are not into programming yet interested in this project, there are project tasks that are not related to programming such as student data acquisitions and analyses, developing course activities with 3-D models, etc.

This project is supported by



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Student Works

Anna Dmitrieff's Story



Open invitation:

Are you passionate about
through the development of
Virtual Reality



Join our interdisciplinary
with the Engineering College
Reach out to nandanaw@
for more

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Showcases of undergraduate student works.

Current Projects

The proposed team research initiative consists of mainly four interconnected projects (and one active-learning project) aimed at enhancing instructional quality in STEM education and measuring their impact. The first project focuses on improving pre-lecture videos by integrating near and far transfer questions, promoting active engagement and deeper understanding. The second project explores the use of virtual reality (VR) to enhance astronomy education through immersive experiences, addressing the limitations of traditional labs and enabling better student engagement and understanding. The third project integrates VR technology with telescopes and microscopes, creating virtual labs and training experiences to overcome equipment limitations and enhance science education. The fourth project is a platform building project that support the adoption of extended reality (XR) across the STEM discipline. Lastly, the fifth project focuses on the promotion of active learning and experiential learning environment especially in the astronomy labs. In this project, we currently build curriculum activities with low-cost (<\$100) telescopes. These projects aim to increase accessibility, cost-effectiveness, engagement, and research potential in STEM education by leveraging technology. The team will collaborate to develop VR simulations, training modules, and collect data for analysis to refine teaching strategies.

Click "Projects" menu at the top navigation panel for more detailed information.

Current/Past Funding

Awarded

Proj Period	Program Name	PI	Grant Amount
FY24/25	Office of Active Learning	Song/Weliweriya	\$18,500
FY25	Faculty Learning Community	Song	\$600
AY24	Affordable Learning Georgia, Round25	Song	\$29,996
AY24	EETI Research and Innovation Grants	Weliweriya	\$4,000
AY24	 Provost Affordable Course Material	Song	\$5,000
AY24	Provost Affordable Course Material	Weliweriya	\$5,000
FY24	Teaching Enhancement and Innovation Fund	Hall,Song,Weliweriya	\$8,000
FY24	Teaching Enhancement and Innovation Fund	Weliweriya, Song	\$2,000
FY23	Affordable Course Materials Grant, Provost Office	Song	\$5,000
FY23	 Learning Technology Grant	Weliweriya	\$25,000
FY23	 EETI Research and Innovation Grants	Weliweriya	\$1,200
FY22	Affordable Course Materials Grant, Provost Office	Song	\$5,000
FY22	Affordable Course Materials Grant, Provost Office	Weliweriya	\$9,700
FY21	EETI Research and Innovation Grants	Weliweriya	\$1,200
FY21	Learning Technology Grant	Weliweriya	\$25,000
FY19	Affordable Course Materials Grant	Song	\$5,000
FY19	Affordable Learning Georgia Round14	Song	\$20,800

Total funding (since 2019) = \$170,896

This project is supported by



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aboutme [STEMin3D]