Owens Institute for Behavioral Research
UNIVERSITY OF GEORGIA

Submission Form
OIBR Faculty Seed Grant Program
Deadline: March 15, 2024 Funding
Call for FY2025

Title of Project: **Enhancing Student Understanding through Immersive Astronomy Education Resources**

Project Director/Lead Investigator: **Nandana Weliweriya**

Co-Investigators (if applicable): **Inseok Song**

Participating College(s), Centers or Workgroups: **UGA**

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Type of Research (please provide keywords – up to 5):

Astronomy Education Enhancement, STEM Education Innovation, Immersive Learning Experience, measurement and methodology

Estimated total budget (to be spent prior to June 30, 2025) : **$10,000**

*PLEASE NOTE: These OIBR funds will be managed by your home unit. Proposals resulting from this research should be submitted through OIBR and publications should also give credit to the Owens Institute for Behavioral Research.

Enhancing Student Understanding through Immersive Astronomy Education Resources

Nandana Weliweriya, Inseok Song (Physics and Astronomy)

Project Abstract:

Nandana Weliweriya, an OIBR affiliated education researcher collaborating with astronomy research faculty, Dr. Inseok Song, proposes to develop an astronomical 3-D immersive simulations with specific modules to test the effectiveness of the simulations for enhancing the quality of astronomy instruction and research, broadly STEM. The project aims to overcome the limitations and issues in current astronomy courses and provide a method for students to engage in real-world scenarios and practice problem-solving and decision-making skills in astronomy courses. The team proposes to develop on the existing technological developments made from the support of previous rounds of CTL's Learning Technologies Grants that the PI collaborated with the College of Engineering. With encouraging result from this proposed pilot study in spring 2025, the team plan to expand the scope with more modules and seek external funding support, like submitting a grant proposal to the National Science Foundation's Improving Undergraduate STEM Education Program and other opportunities.

Introduction:

Many students are attracted to the heavenly beauty of celestial objects. Students who typically enroll in our department's introductory astronomy courses expect fascinating, thought-provoking, engaging learning experiences when they sign up for these courses. However, because of various limitations as mentioned below, these courses are taught in a passive, unidirectional, lecture-based instruction mode essentially eliminating any chance for active learning experience for enrolled students.

Current astronomy education resources, especially illustrations and figures, are generally limited in 2-D that falls short in providing chances to students to grasp the underlying concepts of fundamentally 3-D phenomena. In addition, one of the main reasons that students are interested in astronomy in the first place is the awe-inspiring beauties of celestial objects. 2-D static figures are not enough to meet the expectations of students and instructors, failing to provide motivation to continue in astronomy. Almost all available illustrations were 2-D figures inadequate to depict complex 3-D real-world scenarios accurately, often hindering student's comprehensive understanding and even contributing to misconceptions. The case for 3-D simulations is worse because there are only a few freely available 3-D simulations, and they are rudimentary with solid geometrical objects. Moreover, limited opportunities to engage with and solve real-world problems, either individually or collaboratively, can diminish students' general interest in the STEM fields. To address these challenges, this project proposal aims to bridge the gap by providing essential connections to real-life scenarios and enhancing the representation of 3-D concepts frequently overlooked in traditional textbooks. With our on-going developments of 3-D open education resources our goal is to provide high-quality educational materials for our students can be accelerated.

Several faculty members in the Department of Physics and Astronomy (Weliweriya/Song/Hall/Magnani/Young) have been actively working in enhancing the STEM undergraduate education by adopting the great potential of extended reality including but not limited to Virtual Reality as education resources. Currently, nine USG faculty members including one member from Georgia State University are actively engaged in the education project called *STEMin3D*[1] with the aim of developing immersive education resources by adopting the 3-D, VR, and/or augmented reality technologies. All investigators of the current proposal are active members of the STEMin3D project.

To overcome the aforementioned limitations of the current 2-D education resources, we propose to develop a set of visually stunning, astrophysically correct, modular 3D simulations. These simulations can

[1] https://STEMin3D.net

be projected on traditional 2-D displays or projected into a virtual reality (VR) headset. Simulations can also be ported easily as separate augmented reality (AR) versions that can be viewed with smartphones or tablets (see this AR example from the project website).

With the intended creation of astronomical simulations, all future 1000-level astronomy courses offered by the Department can fully utilize with interactive simulations and hands on in-class and out of class activities. Furthermore, in-depth involvement by students in developing, adopting, and evaluating simulations provide invaluable experiential learning opportunities to student team members. They can learn details of real time programming while contributing to the project as paid student programmers. Currently, there are eleven undergraduate students and four graduate students involved in the project.

In addition to developing these 3D simulations, this project includes research components as well to study the effectiveness. These include:

- How does the integration of 3D simulations impact students' grasp of fundamental astronomical concepts?
- What are the levels of student engagement and satisfaction in new immersive 3D simulation-based astronomy education, measured by session metrics and feedback, and how do they compare to conventional teaching?
- How does the student performance with newly created 3D graphic simulations compare to traditional teaching methods in terms of stability, teaching effectiveness, and learning outcomes?

Action Plan*:*

The new immersive education resources can increase the student motivation (e.g., Atta et al. 2022, Educ. Sci., 12, 890; Blanco et al. 2018, ASP conf. 524). However, improving students' understanding of the related scientific concepts is critically dependent on the appropriateness of selected topics (Blanco et al. 2018) emphasizing the importance of identifying suitable astronomical topics for simulations. We have already identified about two dozen relevant topics (Table 1 and Table 2) where 3D simulations can immensely enhance students' comprehension of core concepts and ignite a heightened interest in those core concepts. Under the scope of this OIBR seed grant, we will create simulations for all topics in Table 1 and implemented in classrooms. Simulations for topics in Table 2 will be created in the near future with supports from other grants (including future UGA CTL's learning technologies grant, UGA's Active learning Change grants and NSF: IUSE)

Table 1 3-D simulations to be created under the scope of OIBR seed grant.

No.	Topic	Note
1	Virtual Night Sky	see Dr. Hall's stellarium-based intro video: here
2	Eclipses	Sun-Earth-Moon system with accurate
3	Diurnal Motion of Celestial bodies	Build upon "Virtual Night Sky. Need to develop a controlling
4	Origin of Seasonal Constellations	Build upon "Virtual Night Sky. Need to develop a controlling
5	Time & Calendar	Build upon "Virtual Night Sky. Need to develop a controlling
6	Solar rotation and cycle	Use real solar surface images and put on textured map on a

Created simulations can be used in several different ways including but not limited to an interactive 3D simulation projected into a VR headset. For example, using realistically created Sun, Earth, and Moon in accurate orbits, we can simulate past solar/lunar eclipses or even predict future ones. By interactively adjusting camera viewing angles, object sizes, orbital inclinations, time of observations, etc., students will have a chance to obtain invaluable insights and grasp the fundamental principles that govern the eclipse phenomenon. Such simulation can be made with any modern 3D engines such as Blender, Unity, Steam, or Unreal Engine. These simulations not only improve students' understanding of fundamental astronomy concepts but also refine their critical thinking and problem-solving abilities. Two freshman computer science majors already started the creation of the eclipse simulation module with Blender (see Figure 1).

Our project can revolutionize astronomy education and greatly contribute to the open education resource community, liberating it from traditional limitations and ushering in a new era of exploration and comprehension for all.

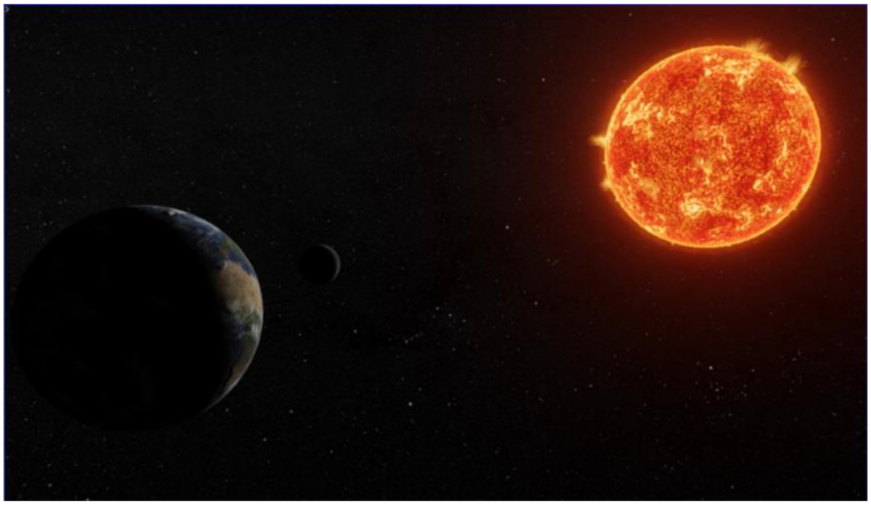

Figure 1 A snapshot image rendered from a 3-D simulation of the Sun-Earth-Moon system created by Blender V3.6.2. This simulation was created by two freshmen UGA students.

Table 2 Additional astronomy topics for future simulation creations.

No.	Topic	Note
7	Precession and change of zodiacs	
8	Light pollution	weather-free public outreach events
9	Solar System Overview	
10	Doppler Effect	can use the audio capability of a VR headset
11	Motions at the Galactic Center	
12	Gravity and Orbits	
13	Retrograde motion of Mars	time-lapse animation of real Sun images
14	Stellar evolution on the HRD	different evolution speed for each mass
15	Telescope (diffraction), atmosphere	
16	Star formation	or the simulation of Turbulent Gas
17	Latitude-dependent Shape change of	suitable for upper-level astronomy courses
18	Parallax and proper motions	
19	Blackbody radiation: color and temp	Types of spectra: Emission & absorption spectra
20	Cosmic scale	From Earth to the known Universe
21	Hubble Expansion	
22	Binary orbit: Orbital motion (and reflex	Link to the exoplanet discovery through Doppler Shift
23	Asteroids, NEA, PHA.	Good public outreach topic
24	Landing on surfaces of planets	different landscape of each Solar System planet

We finished preparatory work to collect currently available 3-D simulation developing platforms and started building a database of pros and cons of each relevant technology. Our intended simulations are curriculum/topic driven rather than limited by a single adopted platform. This means some simulations can be most optimally created with one platform (e.g., Blender) while others are more suitably developed with other platforms. For example, AR implementation of a 3-D model can be best handled by *Unity* currently.

Three astronomy faculty members (Drs. Song, Hall, & Magnani) will create a detailed simulation requirement document for each topic in Table 1 so that student programmers can be guided during the actual development of the simulations. By the time of the announcement of the accepted OIBR seed grant, we will have identified the most suitable technology platform for each topic. Simulation requirement documents will be later transformed to “storyboard” files by non-programming undergraduate students under the guidance of faculty members and these documents will be reviewed and evaluated in regular group meetings. Storyboard files are similar to lesson plans but with modern technology components such as animatics. Drs. Weliweriya and Young, science education experts, will lead efforts in implementing developed simulations into actual courses. This includes: (1) coordinating with astronomy course instructors (Song/Hall/Magnani) for securing IRB approvals, (2) developing student surveys, and (3) analyzing collected data.

Created simulations will be provided through the project webpage, published reports, and conference presentations, articles. One highlight of this initiative is all results including the resultant simulations, script files, relevant documents will be openly accessible under Creative Commons Attribution License (CC-BY).

Financial supports for this project will not only be limited to this seed proposal. We have already applied for several internal and external grants. The financial support from the OIBR seed grant will cover efforts in the creation of simulation of six topics, and it will ensure the timely creation of simulation requirement documents and storyboard files by astronomy faculty members and support undergraduate student programmers. With the support of this seed grant, we aim to (1) create simulation requirement documents and storyboard files for 6 selected topics in Table 1, (2) create simulations for the 6 topics, (3) use simulations in AY24-25 courses, (4) perform surveys to assess effectiveness, and (5) analyze the effectiveness of new simulations, activities.

Quantitative and Qualitative Measures:

In spring 2025, we will leverage students enrolled in ASTR1010, ASTR1110, and ASTR1420, to gauge the effectiveness of our 3-D simulation platform under various key factors below:

Testing Conceptual Mastery:
Method 1: collect pre- and post-test scores from students using established astronomical assessments such as the Test of Astronomy Standards (TOAST), Astronomy Diagnostic Test 2.0 (ADT2), and Star Properties Concept Inventory (SPCI).

Method 2: collect data using individuals or groups of students in think-aloud interviews. These interviews will be follow-ups to the user surveys we collect after each session.

Gathering User Feedback: collect end-of-session survey questions (using established astronomical assessments like Introductory Astronomy Questionnaire [IAQ] and Astronomy Self-Efficacy survey) and follow-up think-aloud interview queries to delve into user satisfaction, learning outcomes, and potential areas for enhancement.

Measuring Engagement: monitor student engagement by tracking the number of students accessing the platform, their session durations, and frequency of return visits. Additionally, the VR headsets will allow us to capture eye movement data and vital indicators of user engagement.

Comparative Assessment: compare the platform's performance with traditional classroom instruction and existing online learning modules, evaluating its 3D graphics quality and stability.

Exploring Representation Analysis: investigate how students interpret, construct, and switch between different representations (algebraic, gestural, graphical, verbal). By tracking students' eye movements while solving problems, we seek to understand which aspects of representations they focus on.

Timeline:

- Finalize the choice of software and VR Interface for each topic (**by Jun 1, 2024**): Song/Weliweriya/Hall/Magnani, along with our graduate and undergraduate students, will finish the on-going investigation of assessing the shortcomings of current astronomy education resources and embark on the creation simulations tailored for spring 2025 Astronomy courses.
- Simulation requirement documents and storyboard files for 6 selected topics (**by Jul 1, 2024**): Song/Hall/Magnani
- External Funding Initiative (**Jul 2024**): seek external funding by submitting a grant proposal to the National Science Foundation's Improving Undergraduate STEM Education Program (NSF: IUSE). Also submit a proposal for the Unreal Engine's Epic Megagrant opportunity.
- Finish the development of simulations by student programmers (by Jan 1, 2025): Song/Weliweriya and undergrad students.
- Adopt new simulations in 2025 Spring semesters: Song/Hall
- Student surveys: Weliweriya/Young and graduate students obtain data from the initial in-class trials and initiate the analysis (**during 2025 Spring**).
- Data Analysis and Publication (**Summer 2025**): Finish the analysis of the data obtained in 2025 Spring trials. We will prepare and present articles at prominent conferences, including AAPT (American Association of Physics Teachers) and PERC (Physics Education Research Conference). Undergraduate students will be encouraged to participate in UGA's Center for Undergraduate Research Opportunities (CURO) and present the results at CURO Symposium. *Five undergrad student team members applied for the AY2024 CURO Research Awards and all of them were selected.

Expected Outcomes and Future Grant Opportunities:

With the created six astronomical 3-D immersive simulations and pilot classroom data, we can make a strong case for several major external grants. Improving the STEM education is a high national priority and there are many funding opportunities that dovetail with the scope of our project. We plan to submit grant proposals to programs summarized in Table 2 during the 2024/2025 grant proposal cycles, and we expect the project will progress rapidly in 2025 and after with one or more of these external grants.

Table 2 *Funding opportunities that we will apply for.*

Program	Requested Amount	Due date	Note
NSF-IUSE	~$600k	07/17/2024	Improve Undergrad STEM education
NSF-AISL	~$600k	01/08/2025	Contains Education and Outreach parts as well
NSF-INCLUDES	>$1M	Future	Multi-institution project we aim to grow into
UE Epic MegaGrants	~$200k	Open	Support future 3D real-time programmers
NASA-MIRO	~$2-3M	Future	UGA cannot be the lead (needs a MSI partner)

We have already secured some VR headsets (10×Meta Quest2, 20×iPad, and 2×Meta Quest3) and a modern Linux workstation for development of the VR/AR interface. Eventually, more headsets will be purchased with support from other future grants (e.g., UGA Learning Technology Grants, NSF grants, etc.). In addition to improving the undergrad STEM education, the shared simulations created from our project can broadly impact astronomy education in underprivileged communities, oftentimes lacking qualified astronomy instructors. In addition, all involved undergraduate team members (currently 11) can receive experiential learning credits by registering for faculty-mentored research courses such as ASTR 4960/4970/4980/4990. Four active undergraduate team members applied for the UGA 2024 Spring CURO research awards and were selected. Six undergraduate members will present their research progresses during the 2024 CURO Symposium highlighting the excellent active learning and experiential learning environment we provide from the project.

Project Budget and Budget Justification:

The faculty members involved in this proposal does not request salary support nor to purchase any equipment through this seed proposal. The main budget item of this LTG proposal is to support a Physics & Astronomy department Ph.D. graduate student (Mr. Robin Allen). Also to pay hourly for undergraduate research students.

A total of **$10,000** is requested from this grant.

- Graduate students (Robin Allen): He is co-advised by Drs. Song and Weliweriya, and will lead the classroom data acquisition, analysis, and presentation. His RA support of **$6,000** is requested from this grant.
- Undergraduate student programmers: We anticipate hiring about 10 students total as paid programmers to develop 3-D simulations for 6 topics for a total of about 1,000 hours. The total amount of hourly pay requested from this grant is **$4,000**.

The research team intends to compensate undergraduate students at an hourly rate (a competitive rate of $12 per hour, each engaging for approximately 6 hours per week) while recruiting majors from Computer Science, Physics, and Astronomy. This opportunity will grant undergraduates invaluable research experience and enable them to offer feedback on our module development efforts. Collaborating with the main graduate student, Robin Allen, the hired undergraduate researchers will receive mentorship from project faculty members and actively contribute to module development, data collection and analysis. Additionally, they will have the opportunity to present their findings at esteemed local and national conferences including CURO, PERC, and AAPT. Six undergraduate members will present their research progresses during the 2024 CURO Symposium highlighting the excellent active learning and experiential learning environment we provide from the project.

With other current/previous internal funding, we already purchased some VR headsets (10×Meta Quest2, 20×iPad, and 2×Meta Quest3) for development of the VR/AR interface. We can purchase a full (N=30) set of VR headsets with future internal grants such as UGA's *Leaning Technology Grant*. Therefore, we are not requesting support to purchase equipment through this OIBR seed grant.

Project Team: Dr. Nandana Weliweriya will lead the effort in creating student surveys, securing relevant IRB approvals, obtaining classroom data, and analyzing data. He will also co-mentor undergraduate programmers with Dr. Song. **Dr. Inseok Song** will create simulation requirement documents for four selected topics and create matching storyboard files. **Drs. Cassandra Hall** and **Loris Magnani** will create a simulation requirement document for one selected topic each. They will mentor undergraduate programmers for the selected topic via regular scheduled meetings. **Dr. Nicolas Young** will participate in the project as an unfunded collaborator. He will work closely with Dr. Weliweriya in classroom implementation of the created simulations and subsequent analysis.

Sustainability Plan:

Through the project webpage, published reports, all created simulations will be shared with the broad STEM education community under CC-BY resulting in a boarder impact. A handful of research papers will be created as graduate student thesis works and other external fundings will be actively sought after. This project is to be continued over a foreseeable future hence the effort can be sustained for a long time at the department.

While the PI, Nandana Weliweriya, co-advises the Ph.D. student, Nandana will lead on reaching out to the nearby school, community centers, and libraries to host science communication events with the new tools we develop in this project. Further, Nandana is a committee members of the department's open house committee.