COVER SHEET FOR PROPOSAL TO THE NATIONAL SCIENCE FOUNDATION

PROGRAM ANNOUNCEMENT/SOLICITATION NO./ DUE DATE
NSF 23-510 07/17/2024

☐ Special Exception to Deadline Date Policy

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NSF PROPOSAL NUMBER

FOR CONSIDERATION BY NSF ORGANIZATION UNIT(S) (Indicate the most specific unit known, i.e. program, division, etc.)
DUE - IUSE- Engaged Student Learning: Level I

DATE RECEIVED	NUMBER OF COPIES	DIVISION ASSIGNED	FUND CODE	UEI(Unique Entity Identifier)	FILE LOCATION
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581353149

SHOW PREVIOUS AWARD NO. IF THIS IS
☐ A RENEWAL
☐ AN ACCOMPLISHMENT- BASED RENEWAL

IS THIS PROPOSAL BEING SUBMITTED TO ANOTHER FEDERAL AGENCY? YES ☐ NO ☒ IF YES, LIST ACRONYM(S)

NAME OF ORGANIZATION TO WHICH AWARD SHOULD BE MADE
UNIVERSITY OF GEORGIA RESEARCH FOUNDATION, INC.

AWARDEE ORGANIZATION CODE (IF KNOWN)

ADDRESS OF AWARDEE ORGANIZATION, INCLUDING 9 DIGIT ZIP CODE
310 E CAMPUS RD RM 409
ATHENS,GA 30602-1589 US

NAME OF PRIMARY PLACE OF PERF
University of Georgia

ADDRESS OF PRIMARY PLACE OF PERF, INCLUDING 9 DIGIT ZIP CODE
310 E CAMPUS RD RM 409
ATHENS,GA 30602-1589 US

IS AWARDEE ORGANIZATION (Check All That Apply)
☐ SMALL BUSINESS
☐ FOR-PROFIT ORGANIZATION
☐ MINORITY BUSINESS
☐ WOMAN-OWNED BUSINESS

☐ IF THIS IS A PRELIMINARY PROPOSAL THEN CHECK HERE

TITLE OF PROPOSED PROJECT
Beyond Boundaries: Harnessing Immersive Environments for Elevated STEM Understanding in Education

SHOW LETTER OF INTENT ID IF APPLICABLE

REQUESTED AMOUNT	PROPOSED DURATION (1-60 MONTHS)	REQUESTED STARTING DATE	SHOW RELATED PRELIMINARY PROPOSAL NO. IF APPLICABLE
$ **397,504**	36 months	**01/01/2025**	

THIS PROPOSAL INCLUDES ANY OF THE ITEMS LISTED BELOW

☒ TYPE OF PROPOSAL **Research**
☒ COLLABORATIVE STATUS **Non-Collaborative**
☐ BEGINNING INVESTIGATOR
☐ DISCLOSURE OF LOBBYING ACTIVITIES
☐ PROPRIETARY & PRIVILEGED INFORMATION
☐ HISTORIC PLACES
☐ LIVE VERTEBRATE ANIMALS IACUC App. Date
PHS Animal Welfare Assurance Number

☒ HUMAN SUBJECTS Human Subjects Assurance Number
Exemption Subsection **1 and 2** or IRB App. Date
☐ FUNDING OF INT'L BRANCH CAMPUS OF U.S IHE
☐ FUNDING OF FOREIGN ORGANIZATION OR FOREIGN INDIVIDUAL
☐ INTERNATIONAL ACTIVITIES: COUNTRY/COUNTRIES INVOLVED
☐ POTENTIAL LIFE SCIENCES DUAL USE RESEARCH OF CONCERN
☐ OFF-CAMPUS OR OFF-SITE RESEARCH
☐ POTENTIAL IMPACTS ON TRIBAL NATIONS

PI/PD DEPARTMENT
Physics and Astronomy

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706-542-2492

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CERTIFICATION PAGE

Certification for Authorized Organizational Representative (or Equivalent)
By electronically signing and submitting this proposal, the Authorized Organizational Representative (AOR) is: (1) certifying that statements made herein are true and complete to the best of the individual's knowledge; and (2) agreeing to accept the obligation to comply with NSF award terms and conditions if an award is made as a result of this proposal. Further, the proposer is hereby providing certifications regarding conflict of interest, flood hazard insurance, responsible and ethical conduct of research, organizational support, and safe and inclusive working environments for off-campus or off-site research, as set forth in the NSF Proposal & Award Policies & Procedures Guide (PAPPG). Willful provision of false information in this application and its supporting documents or in reports required under an ensuing award is a criminal offense (U.S. Code, Title 18, Section §1001).

Certification Regarding Conflict of Interest
The AOR is required to complete certifications stating that the organization has implemented and is enforcing a written policy on conflicts of interest (COI), consistent with the provisions of PAPPG Chapter IX.A.; that, to the best of the individual's knowledge, all financial disclosures required by the conflict of interest policy were made; and that conflicts of interest, if any, were, or prior to the organization's expenditure of any funds under the award, will be, satisfactorily managed, reduced or eliminated in accordance with the organization's conflict of interest policy. Conflicts that cannot be satisfactorily managed, reduced or eliminated and research that proceeds without the imposition of conditions or restrictions when a conflict of interest exists, must be disclosed to NSF via use of the Notifications and Requests Module in Research.gov.

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Two sections of the National Flood Insurance Act of 1968 (42 U.S.C § 4012a and § 4106) bar Federal agencies from giving financial assistance for acquisition or construction purposes in any area identified by the Federal Emergency Management Agency (FEMA) as having special flood hazards unless the: (1) community in which that area is located participates in the national flood insurance program; and (2) building (and any related equipment) is covered by adequate flood insurance. By electronically signing the Certification Pages, the Authorized Organizational Representative (or equivalent) located in FEMA-designated special flood hazard areas is certifying that adequate flood insurance has been or will be obtained in the following situations: (1) for NSF awards for the construction of a building or facility, regardless of the dollar amount of the award; and (2) for other NSF awards when more than $25,000 has been budgeted in the proposal for repair, alteration or improvement (construction) of a building or facility.

Certification Regarding Responsible and Ethical Conduct of Research (RECR)
(This Certification applies to proposals submitted prior to July 31, 2023, and is not applicable to proposals for conferences, symposia, and workshops.)
By electronically signing the Certification Pages, the Authorized Organizational Representative is certifying that, in accordance with the NSF Proposal & Award Policies & Procedures Guide, Chapter IX.B., the institution has a plan in place to provide appropriate training and oversight in the responsible and ethical conduct of research to undergraduates, graduate students and postdoctoral researchers who will be supported by NSF to conduct research. The AOR shall require that the language of this certification be included in any award documents for all subawards at all tiers.

Certification Regarding Responsible and Ethical Conduct of Research (RECR)
(This Certification applies to proposals submitted on or after July 31, 2023, and is not applicable to proposals for conferences, symposia, and workshops.)
By electronically signing the Certification Pages, the Authorized Organizational Representative is certifying that, in accordance with the NSF Proposal & Award Policies and Procedures Guide, Chapter IX.B., the institution has a plan in place to provide appropriate training and oversight in the responsible and ethical conduct of research to undergraduate students, graduate students, postdoctoral researchers, faculty, and other senior/key personnel who will be supported by NSF to conduct research. As required by Section 7009 of the America Creating Opportunities to Meaningfully Promote Excellence in Technology, Education, and Science (COMPETES) Act (42 U.S.C 1862o-1), as amended, the training addresses mentor training and mentorship.
The AOR shall require that the language of this certification be included in any award documents for all subawards at all tiers.

Certification Regarding Organizational Support
By electronically signing the Certification Pages, the Authorized Organizational Representative (or equivalent) is certifying that there is organizational support for the proposal as required by Section 526 of the America COMPETES Reauthorization Act of 2010. This support extends to the portion of the proposal developed to satisfy the Broader Impacts Review Criterion as well as the Intellectual Merit Review Criterion, and any additional review criteria specified in the solicitation. Organizational support will be made available, as described in the proposal, in order to address the broader impacts and intellectual merit activities to be undertaken.

Certification Regarding Dual Use Research of Concern
By electronically signing the certification pages, the Authorized Organizational Representative is certifying that the organization will be or is in compliance with all aspects of the United States Government Policy for Institutional Oversight of Life Sciences Dual Use Research of Concern.

Certification Requirement Specified in the William M. (Mac) Thornberry National Defense Authorization Act for Fiscal Year 2021, Section 223(a)(1) (42 USC 6605(a)(1))
By electronically signing the Certification Pages, the Authorized Organizational Representative is certifying that each individual employed by the organization and identified on the proposal as senior/key personnel has been made aware of the certification requirements identified in the William M. (Mac) Thornberry National Defense Authorization Act for Fiscal Year 2021, Section 223(a)(1) (42 U.S.C § 6605(a)(1)).

Certification Regarding Safe and Inclusive Working Environments for Off-Campus or Off-Site Research
(This certification applies only to proposals in which data/information/samples are being collected off-campus or off-site, such as fieldwork and research activities on vessels and aircraft.)
By electronically signing the Certification Pages, the Authorized Organizational Representative is certifying that, in accordance with the NSF Proposal & Award Policies and Procedures Guide, Chapter II.E.9, the organization has a plan in place for this proposal regarding safe and inclusive working environments.

Certification Regarding Malign Foreign Talent Recruitment Programs
By electronically signing the Certification Pages, the Authorized Organizational Representative is certifying that, in accordance with Section 10632 of the CHIPS and Science Act of 2022 (42 U.S.C. 19232), all senior/key personnel associated with the proposal have been made aware of and have complied with their responsibility under that section to certify that they are not a party to a malign foreign talent recruitment program.

AUTHORIZED ORGANIZATIONAL REPRESENTATIVE	SIGNATURE	DATE
NAME		

TELEPHONE NUMBER	EMAIL ADDRESS	FAX NUMBER

Division of Undergraduate Education

Project Data Form

Project Information

Name of Principal Investigator/Project Director: **Inseok Song**

Name of Primary Organization: **University of Georgia Research Foundation Inc**

SAM Legal Business Name: **UNIVERSITY OF GEORGIA RESEARCH FOUNDATION, INC.**

Program Information

Program-track to which the proposal is submitted: **IUSE- Engaged Student Learning: Level I**

Category: **Not applicable for the selected program**

Prime Organization Information

Highest Degree: **Doctorate (D)**

Institution Type: **Public (PUBL)**

Project Data

1. Discipline: **Physics and Astronomy**

   Subdiscipline: **Astronomy and Astrophysics**

2. Discipline:

   Subdiscipline:

3. Discipline:

   Subdiscipline:

4. Discipline:

   Subdiscipline:

5. Discipline:

   Subdiscipline:

Primary Academic Focus Level: **Lower Division Undergraduate (LO)**

Private Sector Participation: **No. The proposed project will not have private sector participation.**

Audience(s):

1. **Underrepresented Minorities (M)**
2.
3.
4.
5.
6.
7.
8.

Strategic Area:

Project Feature(s):

1. **Educational Uses of Technology (3)**
2. **Integration of Research and Education (2)**
3. **Research on Teaching and Learning (1)**
4. **Undergraduate Research Experiences (8)**
5.

Estimated Number of Individuals Involved

Estimated number of individuals in each of the following categories to be directly affected by the activities of the project during its operation:

PreK-12 Students: **0**

PreK-12 Teachers: **0**

Undergraduate Students: **300**

Graduate Students: **1**

Postdoctoral Fellows: **0**

Higher Education Faculty: **2**

Other Organizations

Other Organizations involved in the project's operation:

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Project Summary

Overview

Enhancing STEM education is a national priority and astronomy is one of the key disciplines in STEM. Many young students are attracted to astronomy; however, currently available astronomy education resources are insufficient to provide continued stimulation to students' curiosity. Most astronomical illustrations are 2-D and fall short of describing the underlying 3-D phenomena.

Intellectual Merit

The proposed project aims to enhance STEM education, with a focus on astronomy, by incorporating immersive technologies. The project identifies the need for a shift from traditional teacher-centered approaches to student-centered learning environments that foster active learning opportunities. The project plans to develop a set of scientifically accurate, immersive, engaging, visually stunning, and modular 3-D astronomical models as open educational resources. These models are designed to enhance students' understanding of fundamental astrophysical concepts and cover about 30 topics where 3-D models can significantly enhance comprehension and generate interest. The project also includes an assessment plan to gauge the effectiveness of the models, including testing students' understanding of concepts, measuring user engagement, collecting user feedback, comparing the efficacy of the models with other instructional resources, and evaluating technical performance.

Broader Impacts

The project has several broader impacts beyond its intellectual merits. It provides experiential learning opportunities for high school interns and undergraduate students, some of whom will be paid programmers. These students will gain valuable hands-on experience in real-time 3-D programming. All developed 3-D models, including source scripts and tutorials, will be publicly shared under the CC-BY license, enriching the pool of resources available for astronomy education. The shared educational resources will enhance equity in STEM education, allowing schools in underprivileged communities to utilize the products to stimulate interest in STEM fields among young minds. The positive results from the study have the potential to usher in a paradigm shift in STEM education through the expedited adoption of immersive technologies. The project results can be readily applied to other STEM disciplines, potentially triggering a change in thinking in general STEM education, thereby motivating more students into the STEM fields. The project also has the potential to revolutionize astronomy education and significantly contribute to the open education resource community.

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For font size and page formatting specifications, see PAPPG section II.B.2.

*Proposers may select any numbering mechanism for the proposal. The entire proposal however, must be paginated. Complete both columns only if the proposal is numbered consecutively.

0. Results from Prior NSF Support

N/A. Neither PI nor Co-PI has performed an NSF funded study over the past five years.

1. Significance of Our Proposed Study

Reports from around the world and within our nation indicate a growing need for our students to be better informed about STEM (Science, Technology, Engineering, and Mathematics) degrees and the associated career opportunities. These fields hold the promise of a bright future. There is a pressing need to bolster STEM education, with a special emphasis on astronomy, by incorporating contemporary resources like immersive technologies. Such an approach will not only draw more students towards STEM but also sustain their interest and curiosity over time.

1.1 Importance of STEM education

Enhancing STEM education across the nation is a top priority, as underscored in the strategic goals, mission statements, and reports from the Department of Education, NSF, and NASA: "*To maintain the nation's leadership in science and technology discovery, we must create an approach to STEM education that prepares and advances the U.S. for the future … we must consider the entire education ecosystem so that children of all backgrounds, race, ethnicity, gender, religion and income levels can learn the wonders and possibilities of STEM and maintain that interest and passion throughout their lives.*" STEM educators must prepare students with necessary skills and experiences to become tomorrow's creators and STEM workforce. Our project, as outlined in this proposal, offers training, support, community, and resources to students majoring in STEM, providing them with invaluable experience with modern immersive technologies. Our proposed work represents a shift in thinking about STEM education, aligning with the national priorities mentioned earlier.

In comparison to major countries like China, Russia, and Germany, where approximately 40% of graduates major in STEM fields, the United States stands at 20% as of 2020 [1]. It's crucial to attract more students to the STEM field and sustain their motivation to uphold our leadership in STEM talent in a progressively competitive global landscape. STEM educators must discover effective methods to continuously engage and challenge students already pursuing STEM majors.

Despite acknowledging the importance of STEM education and our concerted efforts, we've seen limited success in motivating students to pursue STEM careers [2]. This is largely due to the traditional teacher-centered approach, which assumes knowledge can be directly transferred from the instructor to the students. Over the years, technology has revolutionized our world and daily lives. Along with that, technology has also begun to change the roles of teachers and learners in all settings. Technology plays a crucial role

in facilitating collaborative learning while it helps students research subjects, share ideas and learn specific skills. Besides, during the mid-part of the spring 2021 semester, the COVID-19 pandemic forced the conversion of well-designed in-person instruction methods to online teaching methods. Modern learning theories, such as situated cognition, suggest that knowledge is constructed within a student's socio-historical context through active sense-making processes [2, 3, 4]. Therefore, it is essential to transition to a student-centered learning environment that fosters active learning opportunities.

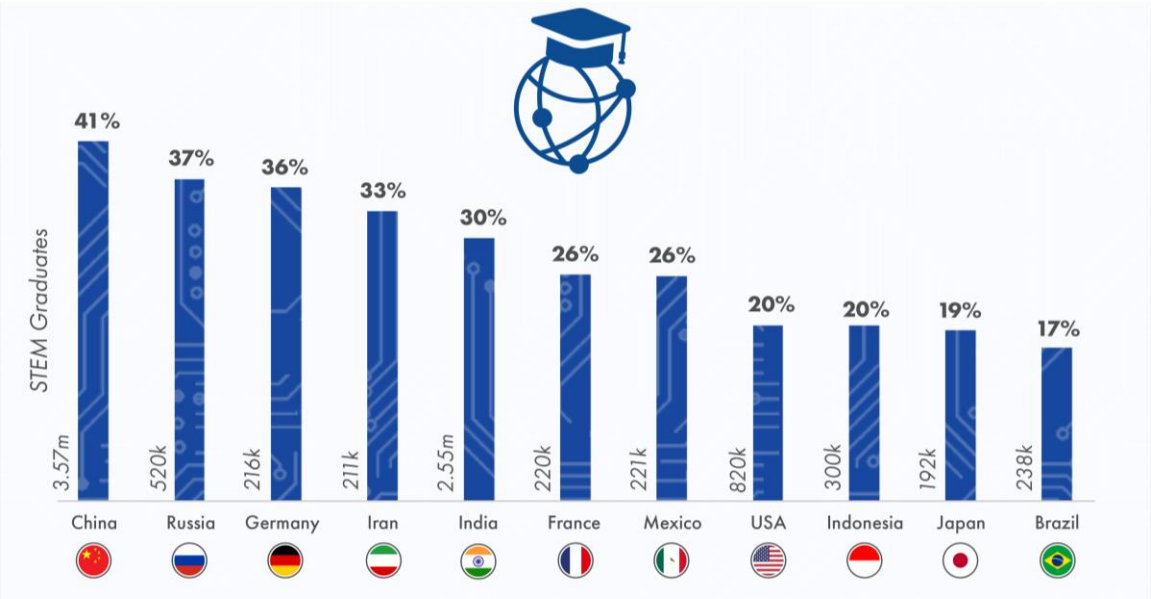

Figure 1: Percentage of total graduates in STEM fields among noticeable countries [1]

1.2 Importance of Astronomy Education

Astronomy, a key subject in the STEM field, plays a vital role in STEM education [5]. The study of the universe and celestial bodies often ignites curiosity and inspires students to learn more about nature, potentially leading to a lifelong passion for learning and scientific discovery. It offers an interdisciplinary learning platform, integrating aspects of mathematics, physics, chemistry, computer science, and other STEM disciplines. This interconnectedness helps students understand how different STEM fields complement each other. Astronomy, a testbed for innovative technologies and discoveries like radio communications, detectors, and telescopes, allows students to gain a hands-on experience of these technologies and their research applications. Furthermore, astronomy provides a global perspective, emphasizing our shared place in the universe and promoting unity and shared responsibility for our planet. With the growing interest in space exploration and potential human colonization of other planets, astronomy knowledge will become increasingly important. Students with an astronomy background will be well-prepared for careers in this exciting field.

Despite the benefits of astronomy education, including its interdisciplinary nature, inspirational value, and global perspectives, we live in a world grappling with immediate problems like hunger, poverty, energy, and climate change. Pursuing fundamental questions in astronomy may require practical justifications compared to other STEM fields like engineering, which have more immediate real-world applications. However, as Dr. Ahmed Zewali, the 1999 Nobel Laureate in Chemistry, stated, "*Preserving knowledge is easy, and transferring knowledge is also easy. But making new knowledge is neither easy nor profitable in the short term. Yet, fundamental research proves profitable in the long run, and, as importantly, it is a force that enriches the culture of any society with reason and basic truth*." As one of humanity's most fundamental research fields, astronomy is at the forefront of STEM, answering fundamental questions and driving innovation.

Therefore, it is essential to inspire curiosity, create opportunities for hands-on experiments/trials, and prepare future generations for a world of exploration and discovery [5]. Moreover, learning about space and astronomy is an excellent way for students to enhance their understanding of math and physics and improve their 3-D problem-solving abilities [6]. Enhancing STEM and astronomy education with modern approaches is imperative.

2. Framework

Traditional astronomy education frequently uses 2-D illustrations to represent complex 3-D real-world scenarios, leading to misunderstandings and obstacles that impede a thorough understanding. The gap between textbook concepts, problem representations, and real-world applications can result in increasing student frustration and a declining interest in pursuing STEM fields.

2.1 Digital Transformation in Education

Recent innovative pedagogical approaches in Physics and Engineering have adopted modern technology in instruction [7-15]. For instance, Wieman et al. and Christian et al. have spearheaded the development of virtual physics using interactive computer simulations (PhET and Physlet simulations) to illustrate fundamental physics concepts [16-18]. While these simulations can help students visualize physical concepts, they do not promote active learning in real-world contexts, and these PhET/Physlet simulations are still 2-D.

Immersive technologies, including virtual reality (VR), augmented reality (AR), and extended reality (XR), are driving digital transformation in education and offer numerous advantages over traditional educational materials [19]. They can enhance engagement, improve understanding, increase accessibility, develop cutting-edge skills, facilitate cost-effective learning, enhance collaboration, provide real-world applications, prepare

students for STEM careers, foster creativity and innovation, and creates opportunities for research on assessments [20-22].

Recognizing the importance of enhancing astronomy education amid ongoing digital transformation, we aim to develop a set of **scientifically accurate, immersive, engaging, visually stunning, and modular 3-D astronomical models** as open educational resources within the scope of this proposal. These 3-D models, designed to enhance students' understanding of fundamental astrophysical concepts, cover about 30 topics where 3-D simulations can significantly enhance comprehension and generate interest.

Our 3-D models will be adaptable and accessible, catering to various educational settings. They are purpose-built to teach specific astronomical concepts and can be deployed in multiple formats, including traditional VR, AR, and 2-D dynamic web simulations. Simulation-related tasks can be assigned as pre-class work preparing for each class or in-class activities. For instance, an activity/worksheet developed around a 3-D model embedded into a QR code can be displayed in the classroom that invites individuals or groups of students to engage with the 3-D model, leading to a deeper understanding of complex concepts. We are also working to integrate AR capabilities, making these simulations accessible via smartphones or tablets. Our ultimate goal is to develop interactive immersive 3-D models that can serve as practical labs, ensuring a comprehensive, hands-on learning experience. Thanks to the diversified deployment possibilities of these models, the limitations of devices owned by students can be overcome.

High-quality 3-D models with interactive and intuitive user controls can captivate students, allowing them to gain invaluable insights into related astronomical phenomena. These immersive simulations can enhance students' understanding of the content by improving their ability to visualize challenging content [23]. This approach allows for active and flexible engagement in astronomy education, and engaging more senses in the learning process can enhance the understanding and retention of difficult topics [24].

As we progress with this project, assessing the effectiveness of our models is crucial. This assessment will include testing students' understanding of concepts, measuring user engagement, collecting user feedback, comparing the efficacy of our models with other instructional resources, evaluating technical performance, and comparing different instruction modes.

3. Methods

With the support from several small internal and external grants, we've already obtained approximately 20 sets of VR headsets. These will be utilized for the creation of 3-D models and pilot tests in the classroom.

3.1 Developing N~30 astronomical 3-D models

Current astronomy education resources, particularly illustrations and figures, are generally limited in 2-D, hampering students' ability to grasp the underlying concepts of fundamentally 3-D phenomena. One of the main reasons students are drawn to astronomy is the awe-inspiring beauty of celestial objects. However, 2-D static figures often do not meet students' and instructors' expectations, leading to a lack of motivation to continue in astronomy and broadly in STEM. These 2-D figures, inadequate for accurately depicting complex 3-D real-world scenarios, often hinder students' comprehensive understanding and even contribute to misconceptions. The situation for 3-D illustrations is worse, with only a limited number of freely available ones, often rudimentary with solid geometrical objects. Limited opportunities to engage with and solve real-world problems can diminish students' interest in the STEM fields. Our project aims to address these challenges by providing essential connections to real-life scenarios and enhancing the representation of 3-D concepts often overlooked in traditional astronomy education resources.

Several faculty members in the Department of Physics and Astronomy at PI's institution have been actively working to enhance STEM undergraduate education by adopting the potential of immersive technologies, including VR. Currently, nine faculty members from the University System of Georgia, including one from Georgia State University, are actively engaged in our education project, STEMin3D, with the aim of developing immersive education resources by adopting 3-D immersive technologies. Investigators of the current proposal are the leaders of the STEMin3D project.

Two educational theories, cognitive load theory and social semiotics, can be applied to design and measure the impact of using 3-D models in astronomy education, in addition to standard performance-based metrics. Cognitive load refers to the demands on a student's memory to process information and solve problems. Semiotic resources refer to the means a student employs to convey meaning and can be displayed in many forms [25]. Schnotz and Kürschner [26] explain three main types of cognitive load: intrinsic, extraneous, and germane loads. Intrinsic load comes from the natural complexity of a learning task. Within astronomy, many topics have high intrinsic loads due to their 3-D nature and interactions. The extraneous load comes from the format of instruction or task. The difficulty in mapping inherently 3-D concepts down to two dimensions and creating scientifically correct diagrams leads to increased extraneous load. The germane load refers to the mental task of integrating new information into previous knowledge. This task is often difficult in astronomy as students often hold misconceptions about astronomical phenomena [27-28]. As proved in the pioneering study with VR for the topic of lunar phase, Blanco et al. [29] emphasized the importance of carefully selected topics to maximize the pedagogical potential of immersive technologies. Otherwise, new

approaches can be deemed to be similarly inefficient compared to those of traditional approaches.

Out of the topics discussed in undergraduate level astronomy courses, we have already identified about 30 relevant topics (Table 1 and Table 2) where 3-D models can significantly enhance students' comprehension of core concepts and ignite a heightened interest in those core concepts. Our selections represent topics with high intrinsic and extraneous loads, but, with the 3-D models, lowering the germane loads to absorb new concepts. During the first year of the project, we will create models for all topics in Table 1 and deploy them in the classrooms. Based on the collected student data, with any necessary adjustments, we will develop all the remaining models for topics in Table 2.

Table 1 High priority topics that will be addressed during the 1st year of the project

No.	Topic	Note
1	Virtual Night Sky	
2	Diurnal Motion of Celestial bodies	Can utilize Virtual Night Sky model
3	Origin of Seasonal Constellations	Can utilize Virtual Night Sky model
4	Time & Calendar	Can utilize Virtual Night Sky model
5	Solar rotation and cycle	Two periods (~30 days [rotation] and 11 yrs)
6	Eclipses	Reproduce/predict/simulate solar or lunar

3-D models can be utilized in various ways, including interactive 3-D simulations projected into a VR headset. For instance, we can simulate solar/lunar eclipses using realistically created Sun, Earth, and Moon in accurate orbits. By interactively adjusting camera viewing angles, object sizes, orbital inclinations, etc. in the 3-D programming, students can grasp the fundamental principles governing the eclipse phenomenon. Such simulations can be created with any modern 3-D engines, such as Blender, Unity, Godot, or Unreal Engine. These simulations not only enhance students' understanding of fundamental astronomy concepts but also hone their critical thinking and problem-solving abilities. Two first-year computer science majors have already begun creating the eclipse simulation module with Blender (see Figure 1). Since Blender model cannot provide real-time user interface, interactive versions of the model will be developed with "real" game engines such as Unity and Unreal Engine. Our project has the potential to revolutionize astronomy education and significantly contribute to the open education resource community, freeing it from traditional limitations and ushering in a new era of exploration and comprehension.

Figure 2 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 first-year UGA students.

A single 3-D model can be used in many related topics. For example, an accurately modeled Sun-Earth-Moon system can be used to highlight the lunar phases, libration of the Moon, and eclipses by adjusting the aspects of the viewing camera.

Table 2 Additional astronomy topics for 3-D model creations.

No	Topic	Note
7	Retrograde motion of Mars	
8	Precession and change of zodiacs	
9	Light pollution	weather-free public outreach events
10	Solar System (SS) Overview	Regularities and exceptions.
11	Doppler Effect	Can use audio capability of a VR headset
12	Motions at the Galactic Center	Supermassive blackhole
13	Solar System scale	
14	Stellar evolution on the HR Diagram	different speed for each mass

15	Telescope (diffraction), atmosphere effect, etc.	
16	Star Formation	or Simulation of Turbulent Gas
17	Latitude-dependent Shape change of the Moon	May be for upper-level astronomy courses
18	Parallax and proper motions	
19	Blackbody radiation: color and temperature	type of spectrum = emission, absorption, & blackbody
20	Cosmic scale	
21	Hubble Expansion	
22	Binary orbit: Orbital motion (and reflex motions)	
23	Asteroids, Near Earth Asteroids, Potentially Hazardous Asteroids.	Good public outreach topic
24	Landing on Surfaces of SS planets	Use real NASA planet surface images
25	Gravity and orbits	
26	Orbital Elements	Six orbital elements
27	Meteor showers	

We have completed preparatory work to gather currently available 3-D simulation development platforms and have built a database of the pros and cons of each relevant technology. Our models are curriculum/topic-driven, not limited by a single platform. This means some models can be efficiently created with one platform (e.g., Blender), while others are better developed with platforms that provide real-time, high-quality user interactions (e.g., Unity, Unreal Engine, or Godot). Table 3 in Appendix (before References) shows selected topics from Tables 1 & 2, with more detailed information on each model, learning objective, limitations and affordances, and recommended immersive technologies.

PI will create a detailed simulation requirement document for each topic in Tables 1 & 2 to guide student programmers during the actual development of the simulations. By the time of the announcement of the selection of this proposal, we will have identified the most suitable technology platform for each topic. Simulation requirement documents will be transformed into “storyboard” files by non-programming undergraduate students under faculty guidance, and these documents will be reviewed and evaluated in regular group

meetings. A storyboard file is like a detailed lesson-plan on how to implement a specific 3-D model into the classroom activities. The Co-PI, Dr. Weliweriya, science education expert, will lead efforts to implement developed 3-D models into actual courses. This includes: (1) coordinating with astronomy course instructors for securing necessary IRB approvals, (2) developing student surveys, and (3) analyzing collected data.

Created simulations will be provided through the project webpage, published reports/papers, and other common OER repositories such as the OER common. All results, including the resultant 3-D models, script files, rendered results, and relevant documents, will be made openly accessible under the Creative Commons Attribution License (CC-BY).

Three critical tasks that we will accomplish during years 1 & 2 are:

- ✓ Creating simulation requirement documents and storyboard files: This effort will be conducted by the PI. A simulation requirement document describes details of the intended simulation like a scenario for a short movie. Then, each file will be transformed into a storyboard file (e.g., detailed lesson-plan). We anticipate about 2 days of effort (~10 hours) per single topic.
- ✓ Developing actual 3-D models will be done by paid undergraduate programmers under close mentoring by the PI. As has been done previously, PI and Co-PI will continue announcing opportunities and recruiting capable undergraduate students among physics/astrophysics majors and engineering students. Course credits for these efforts can be formalized under the experiential learning program initiative of the host institution. Although the range of scope and depth for each simulation varies extensively, we anticipate about 30 students' hours to create one draft model. Experienced students can tutor the next group of new students through hands-on interactive sessions and/or detailed tutorials.
- ✓ Use the created simulations in actual classroom lectures, perform prepared surveys, analyze data, and present the result.

In year 3, we will focus on publishing and sharing the project results (please see Timeline for details).

3.2 Quantitative and Qualitative Measures

Learning Outcomes of astronomical 3-D models:

The proposed astronomical 3-D models can offer a variety of learning outcomes.

Improved understanding of astronomical concepts: The 3-D immersive experience in our proposed immersive platform can help students better understand basic astronomical

concepts (e.g., the solar system's structure) and more complex concepts such as eclipses, tides, and 3-D space motion (parallax and proper motions).

Improved critical thinking and problem-solving skills: Astronomy involves analyzing data, making predictions, and evaluating evidence. Using 3-D models, students can develop their critical thinking and problem-solving skills by exploring astronomical phenomena, interpreting data, and testing hypotheses.

Enhanced spatial reasoning skills: Astronomy involves thinking about objects and phenomena on a vast scale, often at distances and sizes that are difficult to comprehend. Students can use an immersive platform to develop their spatial reasoning skills by visualizing and manipulating astronomical objects in three dimensions.

Increased engagement with astronomy: A well-designed immersive platform can be highly engaging, motivating users to explore and learn more about astronomy. This can lead to a greater interest in astronomy and may encourage users to seek further information or resources.

Exposure to scientific research methods: Astronomy is a highly data-driven field, and scientific research methods are essential to the discipline. Using an immersive platform allows users to gain exposure to these methods, such as observing phenomena, collecting data, and interpreting results.

Asses the effectiveness of the 3D models:

In fall 2025, we will leverage students enrolled in the introductory astronomy courses (ASTR1010 [Astronomy of the Solar System], ASTR1110 [Introduction to Astronomy], and ASTR1420 [Life in the Universe]), to gauge the effectiveness of our 3-D models under various key factors.

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). These tests will measure students' general astronomy content knowledge across topics including gravity, star and stellar evolution, evolution and structure of the solar system, seasons, scale, yearly patterns, daily patterns, and moon phases.
- 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 immersive 3-D model(s), their session durations, and frequency of return visits. Additionally, modern VR headsets will allow us to capture eye movement data and vital indicators of user engagement. Furthermore, STEM research on students' ability to solve physics problems found that students have difficulties interpreting, constructing, and switching between representations (algebraic, gestural, graphical, and verbal). In our team's recent work on upper-division student problem-solving processes, we use students' oral exam data to look at representations at a microscopic level. We used social semiotic resources' disciplinary affordances to describe how the representations are developed, determined to be insufficient, and replaced or augmented by new ones brought in by the students [30]. Previous analysis solely depends on student reasoning and the interviewer's notes on the reason for students' thought processes. As the next step of the assessment, we will explore if we could track students' eye movements to investigate what representations or features of representations, they pay attention to while solving problems.

Comparative Assessment: Compare the 3-D model's performance with traditional classroom instruction and existing online learning modules, evaluating its 3-D 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.

4. Dissemination of the Result

In addition to publishing and sharing project results in conferences and research journals, we will share all developed 3-D models and related materials, such as simulation requirement documents and storyboard files, under the Creative Commons Attribution License (CC-BY).

Our project has the potential to revolutionize astronomy education and significantly contribute to the open education resource community, freeing it from traditional limitations and ushering in a new era of exploration and comprehension for all. The results of our proposed research project will not only enhance students’ understanding of fundamental astronomy concepts but also refine their critical thinking and problem-solving abilities. Our project results can be readily applied to other STEM disciplines, potentially triggering a

change in thinking in general STEM education with the new immersive technologies, thereby motivating more students into the STEM fields. In fact, we have already started inter-disciplinary collaboration across multiple STEM departments & schools such as veterinary medicine, oceanography, psychology, geography, etc. Furthermore, students' in-depth involvement in developing and evaluating 3-D models provides invaluable experiential learning opportunities. They can learn details of real-time programming while contributing to the project as paid student programmers. Currently, eleven undergraduate students, four graduate students, and three high school interns participate in the project.

By releasing our project results as openly accessible education resources, we encourage replications of our research studies at different types of institutions and with different student bodies to produce deeper knowledge about the effectiveness and transferability of findings. Our OERs can serve as useful educational materials, especially for underprivileged communities, and have high potential for broader societal impacts. For instance, broader impacts can include improved diversity of students and instructors participating in STEM education, professional development for instructors to ensure the adoption of new and effective pedagogical techniques that meet the changing needs of students, and projects that promote institutional partnerships for collaborative research and development. We will actively seek collaborators among educators at minority serving institutes. Our project is an evidence-based and knowledge-generating study aimed at understanding and improving STEM learning and learning environments, improving the diversity of STEM students and majors, and preparing STEM majors for the workforce. Our study has impacts beyond the host institution, and our project results contribute more broadly to our understanding of effective teaching and learning practices.

5. Broader Impacts

Our proposed work, in addition to its intellectual merits such as educational research on the efficacy of adopting immersive technologies, creation of open education resources, and publication of research results, has several broader impacts:

1. **Experiential Learning**: Throughout the project, we anticipate engaging several high school interns and undergraduate students, some of whom will be paid programmers. At present, our team includes three high school interns and >10 undergraduate students. These students will gain valuable hands-on experience in real-time 3-D programming, providing them with active and experiential learning opportunities.
2. **Resource Sharing**: All developed 3-D models, including source scripts and tutorials, will be publicly shared under the CC-BY license. This will enrich the pool of resources available for astronomy education.
3. **Enhancing Equity in STEM Education**: The shared educational resources will enhance equity in STEM education. Schools in underprivileged communities can utilize our products to stimulate interest in STEM fields among young minds.
4. **Paradigm Shift in STEM Education**: The positive results from our study have the potential to usher in a paradigm shift in STEM education through the expedited adoption of immersive technologies.

6. Timeline and Milestones of the Project

- Year 1
  - Jan 2025: Start of the Project
  - by Q2 2025: Finish the creation of simulation requirement documents and storyboard files for 6 selected high priority topics [IS]
  - by Q2 2025: Finish creations of in-class surveys [NJW, graduate student]
  - by Q3 2025: Finish the creation of 6 high priority topics [IS + undergraduates]
  - by Q3/Q4 2025: Pilot tests of created 3-D models in class [IS/NJW/grad]
  - Q4 2025: Testing 3-D models [NJW]
- Year 2
  - Q1 2026: Present project results in conferences [IS/NJW]
  - Q1 2026: Continue evaluating 3-D models [NJW]
  - by Q2 2026: Create all simulation requirement documents [IS]
  - by Q1 2026: Revision of student surveys [NJW]
  - by Q2 2026: Create all storyboard files [NJW + undergraduates]
  - by Q3 2026: Publish the early result [graduate student]
  - by Q4 2026: Finish the development of all 3-D models [IS + undergraduates]
  - Spring/Fall 2026: Implementation of 3-D models in astronomy courses [All]
- Year 3
  - Q1 2027: Present project results in conferences [IS/NJW]
  - Q2 2027: Organize the project results for public release [IS + graduate]
  - Q3 2027: Public release of all project files [IS]
  - Q4 2027: Preparation and submission of the final report [IS/NJW]

In the above list, IS stands for the PI (Inseok Song) and NJW stands for the C-PI (Dr. Weliweriya).

We will present results at prominent conferences, including AAPT (American Association of Physics Teachers) and PERC (Physics Education Research Conference). Undergraduate students will be encouraged to participate in the University's Center for Undergraduate Research Opportunities (CURO) program and present the results during the annual CURO symposium.

7. Appendix

Table 3. Detailed information on selected topics for 3-D visualization.

Topic	Description & Classification	Learning Objective	2D vs. 3D - Limitations & Affordances	Recommend Platform
Virtual Night Sky	Projection of the local night sky showing named stars, constellations, and planets. Simulates local naked eye observation. Fundamentally 3D and Enhanced Viewing.	Identify key points like Polaris and constellations in the night sky to orient oneself and make further naked eye observations.	**2D:** Limited due to distortion that occurs in mapping 3D sky to 2D image which increases extraneous load. **3D:** Accurate spacing, size, and location of stars and constellations matches the real night sky. Affordance can be increased, and extraneous load decreased by adding labels to objects making them easier to identify.	VR or AR
Solar/Lunar Eclipses	Interactive 3D environment allowing motion about the environment to show several views of alignment of the Earth, Moon, and Sun during an eclipse. Fundamentally 3D, Spatially and Temporally Limited, and Enhanced Viewing.	Demonstrate the effect relative size, distance and alignment of the Earth, Moon, and Sun have on where the lunar shadows (umbra and penumbra) cross the Earth.	**2D:** Cannot demonstrate the relative positions of the Earth, Moon, and Sun while simultaneously showing the inclination of the Moon`s orbit and its shadows. Increased extraneous load due to separation of relevant information. **3D:** Reduces extraneous load by displaying each astronomical concept simultaneously. Increases disciplinary affordance by demonstrating each relevant concept in an astronomical setting.	VR

Diurnal Motion of the Sky	Projection of objects motion across the sky due to the rotation of the Earth. Fundamentally 3D, Spatially and Temporally Limited, and Enhanced Viewing.	Demonstrate the effect the rotation of the Earth has on the locations of objects in the night sky as the night progresses.	**2D:** Limited due to distortion that occurs in mapping 3D sky to 2D image which increases extraneous load. **3D:** Depicting accurate motion throughout the night sky reduces extraneous load.	VR
Origin of Seasonal Constellations	Simulated 3D environment showing the Earth`s orbit around the Sun with the celestial sphere projected out around the Earth-Sun system. Fundamentally 3D, Spatially and Temporally Limited	Demonstrate how Earth`s motion around the Sun changes the constellations that are visible in the night sky.	**2D:** Cannot simultaneously depict motion of Earth around the Sun and the constellations. Increased extraneous load stems from loss of spatial relationship between the night side of the Earth and the constellations. **3D:** Increased disciplinary affordance and decreased extraneous load caused by simultaneous depiction of relative locations of the Earth, Sun, and constellations.	AR or Computer 3D Video
Solar Rotation and Cycle	Project images of the Sun into 3D to track the amount of and migration of sunspots. Fundamentally 3D, Spatially and Temporally Limited.	Demonstrate the differential rotation of the Sun, changing solar activity, and latitude dependency of solar activity.	**2D:** Limited due to distortion that occurs in mapping 3D sun to 2D image which alters path of sunspots across the surface of the Sun, increasing extraneous load. **3D:** Accurate motion of sunspots decreases extraneous cognitive load. Increased disciplinary affordance from accurate differential motion showing the Sun`s differential rotation.	AR or Computer 3D Video

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SUMMARY PROPOSAL BUDGET

YEAR 1

FOR NSF USE ONLY		
PROPOSAL NO.	DURATION (months) Proposed	Granted
AWARD NO.		

ORGANIZATION: University of Georgia Research Foundation Inc

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR: Inseok Song

A. SENIOR/KEY PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior/ Key Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. Inseok Song - Principal Inv	1.0			11,965	
2. Nandana Weliweriya Liyanage	1.0			7,742	
3.					
4.					
5.					
6. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.0			0	
7. (2) TOTAL SENIOR/KEY PERSONNEL (1 - 6)	2.0			19,707	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (0) POST DOCTORAL SCHOLARS	0.0			0	
2. (0) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.0			0	
3. (1) GRADUATE STUDENTS				34,825	
4. (4) UNDERGRADUATE STUDENTS				5,760	
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0	
6. (0) OTHER				0	
TOTAL SALARIES AND WAGES (A + B)				60,292	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				5,926	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				66,218	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				0	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				4,236	
2. INTERNATIONAL				0	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ 0					
2. TRAVEL 0					
3. SUBSISTENCE 0					
4. OTHER 0					
TOTAL NUMBER OF PARTICIPANTS (0) TOTAL PARTICIPANT COSTS				0	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				3,000	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				2,000	
3. CONSULTANT SERVICES				0	
4. COMPUTER SERVICES				0	
5. SUBAWARDS				0	
6. OTHER				16,196	
TOTAL OTHER DIRECT COSTS				21,196	
H. TOTAL DIRECT COSTS (A THROUGH G)				91,650	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) MTDC (Rate: 51.0, Base:75454)					
TOTAL INDIRECT COSTS (F&A)				38,482	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				130,132	
K. FEE				0	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				130,132	

M. COST SHARING PROPOSED LEVEL $ 0 AGREED LEVEL IF DIFFERENT $

PI/PD NAME: Inseok Song

ORG. REP. NAME*

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Date Checked	Date Of Rate Sheet	Initials - ORG

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SUMMARY PROPOSAL BUDGET

YEAR 2

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PROPOSAL NO.	DURATION (months) Proposed	Granted
AWARD NO.		

ORGANIZATION: University of Georgia Research Foundation Inc

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR: Inseok Song

A. SENIOR/KEY PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior/ Key Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. Inseok Song - Principal Inv	1.0			12,324	
2. Nandana Weliweriya Liyanage	1.0			7,974	
3.					
4.					
5.					
6. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.0			0	
7. (2) TOTAL SENIOR/KEY PERSONNEL (1 - 6)	2.0			20,298	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (0) POST DOCTORAL SCHOLARS	0.0			0	
2. (0) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.0			0	
3. (1) GRADUATE STUDENTS				35,869	
4. (4) UNDERGRADUATE STUDENTS				6,111	
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0	
6. (0) OTHER				0	
TOTAL SALARIES AND WAGES (A + B)				62,278	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				6,104	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				68,382	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				0	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				4,236	
2. INTERNATIONAL				0	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ 0					
2. TRAVEL 0					
3. SUBSISTENCE 0					
4. OTHER 0					
TOTAL NUMBER OF PARTICIPANTS (0) TOTAL PARTICIPANT COSTS				0	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				3,000	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				2,000	
3. CONSULTANT SERVICES				0	
4. COMPUTER SERVICES				0	
5. SUBAWARDS				0	
6. OTHER				16,682	
TOTAL OTHER DIRECT COSTS				21,682	
H. TOTAL DIRECT COSTS (A THROUGH G)				94,300	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) MTDC (Rate: 51.0, Base:77618)					
TOTAL INDIRECT COSTS (F&A)				39,585	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				133,885	
K. FEE				0	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				133,885	

M. COST SHARING PROPOSED LEVEL $ 0 AGREED LEVEL IF DIFFERENT $

PI/PD NAME: Inseok Song

ORG. REP. NAME*

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Date Checked	Date Of Rate Sheet	Initials - ORG

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SUMMARY PROPOSAL BUDGET

YEAR 3

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PROPOSAL NO.	DURATION (months) Proposed	Granted
AWARD NO.		

ORGANIZATION: University of Georgia Research Foundation Inc

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR: Inseok Song

A. SENIOR/KEY PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior/ Key Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. Inseok Song - Principal Inv	1.0			12,694	
2. Nandana Weliweriya Liyanage	1.0			8,214	
3.					
4.					
5.					
6. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.0			0	
7. (2) TOTAL SENIOR/KEY PERSONNEL (1 - 6)	2.0			20,908	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (0) POST DOCTORAL SCHOLARS	0.0			0	
2. (0) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.0			0	
3. (1) GRADUATE STUDENTS				36,945	
4. (4) UNDERGRADUATE STUDENTS				3,147	
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0	
6. (0) OTHER				0	
TOTAL SALARIES AND WAGES (A + B)				61,000	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				6,287	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				67,287	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				0	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				4,236	
2. INTERNATIONAL				0	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ 0					
2. TRAVEL 0					
3. SUBSISTENCE 0					
4. OTHER 0					
TOTAL NUMBER OF PARTICIPANTS (0) TOTAL PARTICIPANT COSTS				0	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				1,500	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				4,000	
3. CONSULTANT SERVICES				0	
4. COMPUTER SERVICES				0	
5. SUBAWARDS				0	
6. OTHER				17,182	
TOTAL OTHER DIRECT COSTS				22,682	
H. TOTAL DIRECT COSTS (A THROUGH G)				94,205	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) MTDC (Rate: 51.0, Base:77023)					
TOTAL INDIRECT COSTS (F&A)				39,282	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				133,487	
K. FEE				0	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				133,487	

M. COST SHARING PROPOSED LEVEL $ 0 AGREED LEVEL IF DIFFERENT $

PI/PD NAME: Inseok Song

ORG. REP. NAME*

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SUMMARY PROPOSAL BUDGET

Cumulative

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PROPOSAL NO.	DURATION (months) Proposed	Granted
AWARD NO.		

ORGANIZATION: University of Georgia Research Foundation Inc

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR: Inseok Song

A. SENIOR/KEY PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior/ Key Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. Inseok Song - Principal Inv	3.0			36,983	
2. Nandana Weliweriya Liyanage	3.0			23,930	
3.					
4.					
5.					
6. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)					
7. (2) TOTAL SENIOR/KEY PERSONNEL (1 - 6)	6.0			60,913	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (0) POST DOCTORAL SCHOLARS	0.0			0	
2. (0) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.0			0	
3. (3) GRADUATE STUDENTS				107,639	
4. (12) UNDERGRADUATE STUDENTS				15,018	
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0	
6. (0) OTHER				0	
TOTAL SALARIES AND WAGES (A + B)				183,570	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				18,317	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				201,887	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				0	
E. TRAVEL 1. DOMESTIC (INCL. U.S. POSSESSIONS)				12,708	
2. INTERNATIONAL				0	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ 0					
2. TRAVEL 0					
3. SUBSISTENCE 0					
4. OTHER 0					
TOTAL NUMBER OF PARTICIPANTS (0) TOTAL PARTICIPANT COSTS				0	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				7,500	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				8,000	
3. CONSULTANT SERVICES				0	
4. COMPUTER SERVICES				0	
5. SUBAWARDS				0	
6. OTHER				50,060	
TOTAL OTHER DIRECT COSTS				65,560	
H. TOTAL DIRECT COSTS (A THROUGH G)				280,155	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE)					
TOTAL INDIRECT COSTS (F&A)				117,349	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				397,504	
K. FEE				0	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				397,504	

M. COST SHARING PROPOSED LEVEL $ 0 AGREED LEVEL IF DIFFERENT $

PI/PD NAME: Inseok Song

ORG. REP. NAME*

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Date Checked	Date Of Rate Sheet	Initials - ORG

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Budget Justification – University of Georgia

PI: Inseok Song and **Co-PI**: Nandana Weliweriya

TITLE: Beyond Boundaries: Harnessing Immersive Environments for Elevated STEM Understanding in Education

Project Dates: 1/01/2025 - 12/31/2027

A. Senior Personnel

Inseok Song, PI, requests 1.0 summer month support each year for the duration of the project. The PI will oversee all aspects of the project and provide daily mentoring for one graduate student. He will create all simulation requirement documents and guide undergraduate student programmers during the 3-D model development. He will attend a conference during year 1 to advertise the project. The PI's rate of pay is $107,689 per academic year.

Nandana Weliweriya, Co-PI, requests 1.0 summer month of effort support for the duration of the project. Dr. 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 the PI. The Co-I's rate of pay is $69,680 per academic year.

B. Other Personnel

Graduate Student Research Assistant: Salary support is requested for one Ph.D. graduate research assistant at 50% FTE for 12 months each project year. Under close supervision of the Co-PI, the graduate student will gather and analyze classroom data, present the result at conferences, and lead the preparation for research journal articles. Support for tuition and fees is requested.

Undergraduate Student Research Assistants: Salary support is requested for undergraduate research assistants (salary estimated at $12.00 per hour) to carry out 3-D model programming. In years 1 and 2 of the project, we anticipate having approximately four active undergraduate student programmers. While the exact pay will vary based on the complexity of assigned tasks, we plan to provide consistent support to these students, allocating 3 hours per week for 40 weeks in each of the first two project years. By year 3, 3D model development should be nearly complete, and most programming tasks will involve debugging and packaging. At this stage, we expect that 50% support will be adequate.

C. Fringe Benefits

Fringe rates are estimated at: 23% for faculty summer effort and 4% for graduate research assistant salaries. Fringe benefits are charged at actual rates as these expenses accrue. Estimated fringe benefit rates are adjusted annually and include FICA, Retirement, Life Insurance, and Health Insurance.

E. Travel

E1. Domestic Travel

Domestic Conferences: In each project year, team members will go to 1 domestic conference. In year 1, two team members (PI and Co-PI) will attend a conference to advertise the project. In years 2 and 3, two team members will attend a domestic conference to present the results of the current research. Funds are requested to support these domestic conference travels. Cost estimates include funds for airfare, lodging, per diem, local transportation, and registration fees.

Year 1, 2, and 3: 2 travelers, 1 trip

#Travelers	# Day	# Nights	Lodging (per trip)	Per Diem (per trip)	Flight (per trip)	Local Transport	Registration Fees (per person)	Total Cost (per trip)
2	3	3	$1200	$426	$1200	$300	$1110	$4236

G. Other Direct Costs

G2. Publication Costs

Funds are requested for publication costs in the amount of $2,000 in years 1 and 2 and $4,000 in year 3 of the project. Results from the project will be suitable to be published in Physics Review Physics Education Research.

G4. Computer Services

Cloud PC computing fee support ($600 per year per account) is requested in each project year. In years 1 & 2, five accounts (4 students' and 1 admin) will be used ($600x5 = $3,000 each year). In year 3, most programming will be focused on debugging and we request $1,500 for cloud computing.

G6. Other – Tuition & Fees

Graduate tuition support & fees are requested each project year for the Ph.D. graduate student working on this project. The estimated yearly tuition cost (3 semesters) per student is $14,352 in year 1 (with 3% increase per year). The estimated yearly fees cost (3 semesters) is $1,844 in year 1 (with 3% increase per year).

I. Indirect Costs

Indirect costs are calculated at the University of Georgia's federally negotiated rate of 51% MTDC for on-campus research per the F&A Rate Agreement negotiated with the Department of Health & Human Services dated 4/5/2021. Modified Total Direct Costs (MTDC) excludes equipment, capital expenditures, charges for patient care, tuition remission, rental costs of off-site facilities, participant support, scholarships, and fellowships as well as the portion of each subaward in excess of $25,000. Cognizant Agent: DHHS, Steven Zuraf, (301)492-4855.

Facilities, Equipment and Other Resources

From our team members' previous internal grants, we have already secured the following resources:

- Two 3-D programming workstations
- 20 sets of VR headsets (10 Quest Pro and 18 Quest 3)
- 20 sets of iPads (for testing Augmented Reality models)

We are currently in the process of securing 10 more sets of VR headsets. With the available resources, we will be able to implement 3-D models in the classroom environment. Our track record of successfully obtaining internal grants leads us to believe that securing the additional resources won't be challenging.

However, if we cannot secure additional resources in time, we have a contingency plan: students will be assigned to small groups (2 students per group) to share the existing resources. We do not require any other resources to successfully complete the proposed project.

IDENTIFYING INFORMATION:

NAME: Song, Inseok

ORCID iD: https://orcid.org/0000-0002-5815-7372

POSITION TITLE: Associate Professor

PRIMARY ORGANIZATION AND LOCATION: University of Georgia, Athens, Georgia, United States

Professional Preparation:

ORGANIZATION AND LOCATION	DEGREE (if applicable)	RECEIPT DATE	FIELD OF STUDY
University of Georgia, Athens, Georgia, United States	PHD	05/2000	Physics
Seoul National University, Seoul, Not Applicable, N/A, Korea South	MED	02/1991	Science Education
Seoul National University, Seoul, Not Applicable, N/A, Korea South	BS	02/1989	Earth Science Education

Appointments and Positions

2008 - present	Associate Professor, University of Georgia, Athens, Georgia, United States
2008 - 2013	Assistant Professor, University of Georgia, Athens, Georgia, United States
2007 - 2008	Staff Research Scientist, Spitzer Science Center, IPAC/Caltech, Pasadena, California, United States
2004 - 2007	Assistant Astronomer, Gemini Observatory, Hilo/HI, Hilo, Hawaii, United States
2002 - 2004	Assistant Astronomer, UCLA, Department of Physics and Astronomy, Los Angeles, California, United States
2000 - 2002	Postdoctoral Researcher, UCLA, NASA Astrobiology Institute, IGPP, Los Angeles, California, United States

Products

Products Most Closely Related to the Proposed Project

1. Allen R, Seiden D, Weliweriya N, Song I. Enhancing Astronomy Education: Demonstrating Astronomical Phenomena using Immersive 3D Learning Experiences. 90th Annual Meeting of the APS Southeastern Section. 2023 November 09.
2. Zincone G, Weliweriya N, Song I. The Role of Storyboard Design in the Development of 3-D STEM Educational Simulations. Center for Undergraduate Research Opportunities (CURO) Symposium, The University of Georgia. 2024 April 08.
3. Dmitrieff A, Weliweriya N, Song I. Accessibility in STEM Education through Low-Cost & Self-Assembly Telescopes. Center for Undergraduate Research Opportunities (CURO) Symposium, The University of Georgia. 2024 April 08.
4. Haque R, Aliya E, Weliweriya N, Song I. 3D Astronomy Simulations for Learning: Simulating Solar and Lunar Eclipses. Center for Undergraduate Research Opportunities (CURO) Symposium, The University of Georgia. 2024 April 08.
5. Allen R, Seiden D, Weliweriya N, Song I. Enhancing Astronomy Education: Demonstrating

Astronomical Phenomena using Immersive 3D Learning Experiences. University System of Georgia Teaching & Learning Conference. 2024 April 01.

Other Significant Products, Whether or Not Related to the Proposed Project

1. Zuckerman B, Song I. Young Stars Near the Sun. Annual Review of Astronomy and Astrophysics. 2004 September 22; 42(1):685-721. Available from: https://www.annualreviews.org/doi/10.1146/annurev.astro.42.053102.134111 DOI: 10.1146/annurev.astro.42.053102.134111
2. Song I, Zuckerman B, Weinberger AJ, Becklin EE. Extreme collisions between planetesimals as the origin of warm dust around a Sun-like star. Nature. 2005 Jul 21;436(7049):363-5. PubMed PMID: 16034411.
3. Marois C, Macintosh B, Barman T, Zuckerman B, Song I, Patience J, Lafrenière D, Doyon R. Direct Imaging of Multiple Planets Orbiting the Star HR 8799. Science. 2008 November 28; 322(5906):1348-1352. Available from: https://www.science.org/doi/10.1126/science.1166585 DOI: 10.1126/science.1166585
4. Melis C, Zuckerman B, Rhee JH, Song I, Murphy SJ, Bessell MS. Rapid disappearance of a warm, dusty circumstellar disk. Nature. 2012 Jul 4;487(7405):74-6. PubMed PMID: 22763553.
5. Macintosh B, Graham JR, Barman T, De Rosa RJ, Konopacky Q, Marley MS, Marois C, Nielsen EL, Pueyo L, Rajan A, Rameau J, Saumon D, Wang JJ, Patience J, Ammons M, Arriaga P, Artigau E, Beckwith S, Brewster J, Bruzzone S, Bulger J, Burningham B, Burrows AS, Chen C, Chiang E, Chilcote JK, Dawson RI, Dong R, Doyon R, Draper ZH, Duchêne G, Esposito TM, Fabrycky D, Fitzgerald MP, Follette KB, Fortney JJ, Gerard B, Goodsell S, Greenbaum AZ, Hibon P, Hinkley S, Cotten TH, Hung LW, Ingraham P, Johnson-Groh M, Kalas P, Lafreniere D, Larkin JE, Lee J, Line M, Long D, Maire J, Marchis F, Matthews BC, Max CE, Metchev S, Millar-Blanchaer MA, Mittal T, Morley CV, Morzinski KM, Murray-Clay R, Oppenheimer R, Palmer DW, Patel R, Perrin MD, Poyneer LA, Rafikov RR, Rantakyrö FT, Rice EL, Rojo P, Rudy AR, Ruffio JB, Ruiz MT, Sadakuni N, Saddlemyer L, Salama M, Savransky D, Schneider AC, Sivaramakrishnan A, Song I, Soummer R, Thomas S, Vasisht G, Wallace JK, Ward-Duong K, Wiktorowicz SJ, Wolff SG, Zuckerman B. Discovery and spectroscopy of the young jovian planet 51 Eri b with the Gemini Planet Imager. Science. 2015 Oct 2;350(6256):64-7. PubMed PMID: 26272904.

Certification:

I certify that the information provided is current, accurate, and complete. This includes but is not limited to current, pending, and other support (both foreign and domestic) as defined in 42 U.S.C. § 6605.

I also certify that, at the time of submission, I am not a party to a malign foreign talent recruitment program.

Misrepresentations and/or omissions may be subject to prosecution and liability pursuant to, but not limited to, 18 U.S.C. §§ 287, 1001, 1031 and 31 U.S.C. §§ 3729-3733 and 3802.

Certified by Song, Inseok in SciENcv on 2024-07-11 11:30:52

IDENTIFYING INFORMATION:

NAME: Weliweriya Liyanage, Nandana

POSITION TITLE: Lecturer

PRIMARY ORGANIZATION AND LOCATION: University of Georgia, Athens, Georgia, United States

Professional Preparation:

ORGANIZATION AND LOCATION	DEGREE (if applicable)	RECEIPT DATE	FIELD OF STUDY
Kansas State University, Manhattan, Kansas, United States	PHD	05/2019	Physics - Physics education research
Kansas State University, Manhattan, Kansas, United States	MS	07/2015	Physics - Physics education

Appointments and Positions

2022 - present Lecturer, Graduate Faculty, University of Georgia, Athens, Georgia, United States

2019 - 2022 Lecturer, University of Georgia, Athens, Georgia, United States

2013 - 2019 Graduate teaching/ research assistnat, Kansas State University, Manhattan, Kansas, United States

Products

Products Most Closely Related to the Proposed Project

1. Rosenzweig EQ, Chen X, Song Y, Baldwin A, Barger MM, Cotterell ME, Dees J, Injaian AS, Weliweriya N, Walker JR, Wiegert CC, Lemons PP. Beyond STEM attrition: changing career plans within STEM fields in college is associated with lower motivation, certainty, and satisfaction about one's career. International Journal of STEM Education. 2024 March 04; 11(1):15. Available from: https://link.springer.com/article/10.1186/s40594-024-00475-6
2. Weliweriya N, Sayre EC, Zollman D. Case study: Coordinating among multiple semiotic resources to solve complex physics problems. European Journal of Physics. 2019 January 11; 40(2). Available from: https://iopscience.iop.org/article/10.1088/1361-6404/aaf5d5/meta
3. Weliweriya N, Sayre EC, Zollman D. The effectiveness of "pencasts" in physics courses. The physics teacher. 2018 March 01; 56(3):161-164. Available from: https://pubs.aip.org/aapt/pte/article/56/3/161/278213/The-Effectiveness-of-Pencasts-in-Physics-Courses
4. Weliweriya N, Huynh T, Sayre EC. Standing fast: Translation among durable representations using evanescent representations in upper-division problem solving. PERC proceedings. 2017 July 04; 1(1):1. Available from: https://www.per-central.org/items/perc/4839.pdf
5. Weliweriya N. Investigating students' use of mathematical tools and representations in undergraduate physics problem-solving. 1 ed. In: Weliweriya N, editor. Investigating students' use of mathematical tools and representations in undergraduate physics problem-solving [Internet] Manhattan, KS: Kansas State University; 2019. 256p. Available from: https://www.proquest.com/docview/2320958081?pq-origsite=gscholar&fromopenview=true&sourcetype=Dissertations%20&%20Theses

Other Significant Products, Whether or Not Related to the Proposed Project

1. Zipperer E, Weliweriya N, Cotten T, Dassanayake M, Karunaratne A. Online teaching-learning in STEM SCALE-UP classrooms during the COVID-19 pandemic: feedback from students. Proceedings of the Physics Education Research Conference (PERC). 2021 October 01; 1(1):474-479. Available from: https://www.researchgate.net/profile/Nandana-Weliweriya-Liyanage/publication/353428757_Online_teaching-learning_in_STEM_SCALE-UP_classrooms_during_the_COVID-19_pandemic_feedback_from_students/links/62aed1c7e1193368baa960dc/Online-teaching-learning-in-STEM-SCALE-UP-classrooms-during-the-COVID-19-pandemic-feedback-from-students.pdf
2. ROMICK C, Weliweriya N, COTTEN T. PERSONAS OF STEM STUDENTS COMPLETING ONLINE INSTRUCTIONS DURING THE COVID-19 PANDEMIC. Journal of Science of the University of Kelaniya Sri Lanka. 2022 November 01; 15(2):132-146. Available from: https://josuk.sljol.info/articles/10.4038/josuk.v15i2.8066
3. Weliweriya N. Workshop on Active Learning. outh Carolina Section of the American Association of Physics Teachers (SACS-AAPT); 2024 April 08; Columbia, SC, USA.
4. Weliweriya N. Effective Active Learning: Exploring Both Challenges and Solutions,. Tech Ed 2024, Macmillan Learning; 2024 June 07; Austin, TX, USA.
5. Weliweriya N. Re-engineering the Way We Teach Studio Physics While Supporting Education Research in STEM Problem-Solving. in 1 Research Showcase - The Scientists Engaged in Educational Research (SEER) Center; 2014 March 06; Athens, GA, USA.

Certification:

I certify that the information provided is current, accurate, and complete. This includes but is not limited to current, pending, and other support (both foreign and domestic) as defined in 42 U.S.C. § 6605.

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Certified by Weliweriya Liyanage, Nandana in SciENcv on 2024-07-15 12:19:54

Data Not Available

CURRENT AND PENDING (OTHER) SUPPORT INFORMATION

Provide the following information for the Senior/key personnel and other significant contributors.
Follow this format for each person.

*NAME: Song, Inseok

PERSISTENT IDENTIFIER (PID) OF THE SENIOR/KEY PERSON: https://orcid.org/0000-0002-5815-7372

*POSITION TITLE: Associate Professor

*ORGANIZATION AND LOCATION: University of Georgia, Athens, Georgia, United States

Proposals/Active Projects

***Proposal/Active Project Title:** Faculty Learning Community for Immersive Technologies

***Status of Support:** Current

Proposal/Award Number:

***Source of Support:** UGA Center for Teaching and Learning

***Primary Place of Performance:** University of Georgia

***Proposal/Active Project Start Date: (MM/YYYY):** 08/2024

***Proposal/Active Project End Date: (MM/YYYY):** 12/2024

***Total Anticipated Proposal/Project Amount:** $600

*** Person Months per budget period Devoted to the Proposal/Active Project:**

Year	Person Months
2024	0.25

***Overall Objectives:** Create a faculty learning community where UGA faculty and post-doctoral scholars can meet regularly and share common visions regarding the use of immersive technologies in education and/or research. Through the forum, we can share ideas, resources, and expertise.

***Statement of Potential Overlap:** Minimal overlap.

***Proposal/Active Project Title:** Adoption of the free OpenStax textbook for multiple astronomy courses

***Status of Support:** Current

Proposal/Award Number:

***Source of Support:** UGA Office of Provost

***Primary Place of Performance:** University of Georgia

***Proposal/Active Project Start Date: (MM/YYYY):** 05/2024

***Proposal/Active Project End Date: (MM/YYYY):** 12/2024

***Total Anticipated Proposal/Project Amount:** $5,000

*** Person Months per budget period Devoted to the Proposal/Active Project:**

Year	Person Months
2024	1

***Overall Objectives:** Change the structure of introductory astronomy courses to adopt an open source textbook from OpenStax

***Statement of Potential Overlap:** Minimal overlap

***Proposal/Active Project Title:** Enhancing Active and Experiential Learning with Low-Cost Telescopes

***Status of Support:** Current

Proposal/Award Number:

***Source of Support:** UGA Office of Active Learning

***Primary Place of Performance:** University of Georgia

***Proposal/Active Project Start Date: (MM/YYYY):** 05/2024

***Proposal/Active Project End Date: (MM/YYYY):** 05/2025

***Total Anticipated Proposal/Project Amount:** $18,500

*** Person Months per budget period Devoted to the Proposal/Active Project:**

Year	Person Months
2024	1

***Overall Objectives:** Revise the astronomy lab curricula to provide active learning environments to students. Instead of using the centralized, department-operated large telescope, each student will be given a low-cost telescope (< $100) to carry out hands-on astronomical projects individually.

***Statement of Potential Overlap:** No overlap.

***Proposal/Active Project Title:** Enhancing Student Understanding through Immersive Astronomy Open Education Resources

***Status of Support:** Current

Proposal/Award Number: 711

***Source of Support:** University System of Georgia, Affordable Learning Georgia

***Primary Place of Performance:** University of Georgia

***Proposal/Active Project Start Date: (MM/YYYY):** 05/2024

***Proposal/Active Project End Date: (MM/YYYY):** 05/2025

***Total Anticipated Proposal/Project Amount:** $29,996

*** Person Months per budget period Devoted to the Proposal/Active Project:**

Year	Person Months
2024	1

***Overall Objectives:** Explore the development of 3-D astronomical models with immersive technologies (for a handful of high priority topics).

***Statement of Potential Overlap:** This can be regarded as a preliminary pilot study of this IUSE project.

***Proposal/Active Project Title:** Beyond Boundaries: Harnessing Immersive Environments for Elevated STEM Understanding in Education

***Status of Support:** Pending

Proposal/Award Number:

***Source of Support:** NSF/IUSE

***Primary Place of Performance:** University of Georgia

***Proposal/Active Project Start Date: (MM/YYYY):** 01/2025

***Proposal/Active Project End Date: (MM/YYYY):** 12/2027

***Total Anticipated Proposal/Project Amount:** $397,504

*** Person Months per budget period Devoted to the Proposal/Active Project:**

Year	Person Months
2025	1
2026	1
2027	1

***Overall Objectives:** This project aims to develop about 30 3-D astronomical models as open education resources, and they will be used in classrooms in 2025-2026 to collect students data. By analyzing classroom data, the efficacy of those models will be evaluated withing the education theory.

***Statement of Potential Overlap:** No overlap.

***Proposal/Active Project Title:** Enhancing Astronomy Education with Immersive Technologies and Promoting Active Learning

***Status of Support:** Pending

Proposal/Award Number:

***Source of Support:** Spencer Foundation

***Primary Place of Performance:** University of Georgia

***Proposal/Active Project Start Date: (MM/YYYY):** 01/2025

***Proposal/Active Project End Date: (MM/YYYY):** 12/2027

***Total Anticipated Proposal/Project Amount:** $247,325

*** Person Months per budget period Devoted to the Proposal/Active Project:**

Year	Person Months
2025	1
2026	1
2027	1

***Overall Objectives:** This proposal aims to develop 3-D astronomy education models to enhance students' understanding of complex 3-D astronomical phenomena.

***Statement of Potential Overlap:** This Spencer Foundation is a scaled-down project of this IUSE project.

***Proposal/Active Project Title:** Holistic Study of Nearby Young Moving Groups

***Status of Support:** Pending

Proposal/Award Number:

***Source of Support:** NASA/ADAP

***Primary Place of Performance:** University of Georgia

***Proposal/Active Project Start Date: (MM/YYYY):** 01/2025

***Proposal/Active Project End Date: (MM/YYYY):** 12/2027

***Total Anticipated Proposal/Project Amount:** $477,301

*** Person Months per budget period Devoted to the Proposal/Active Project:**

Year	Person Months
2025	1
2026	1
2027	1

***Overall Objectives:** Carrying out astrophysical investigations on the members of young, nearby stellar moving groups.

***Statement of Potential Overlap:** No overlap.

Certification:

I certify that the information provided is current, accurate, and complete. This includes but is not limited to current, pending, and other support (both foreign and domestic) as defined in 42 U.S.C. § 6605.

I also certify that, at the time of submission, I am not a party to a malign foreign talent recruitment program.

Misrepresentations and/or omissions may be subject to prosecution and liability pursuant to, but not limited to, 18 U.S.C. §§ 287, 1001, 1031 and 31 U.S.C. §§ 3729-3733 and 3802.

Certified by Song, Inseok in SciENcv on 2024-07-15 14:51:47

CURRENT AND PENDING (OTHER) SUPPORT INFORMATION

Provide the following information for the Senior/key personnel and other significant contributors.
Follow this format for each person.

*NAME: Weliweriya Liyanage, Nandana

*POSITION TITLE: Lecturer, Graduate Faculty

*ORGANIZATION AND LOCATION: University of Georgia, Athens, Georgia, United States

Proposals/Active Projects

***Proposal/Active Project Title:** Enhancing Active and Experiential Learning with Low-Cost Telescopes

***Status of Support:** Current

Proposal/Award Number:

***Source of Support:** Active Learning Change Grants, The Office of Active Learning

***Primary Place of Performance:** University of Georgia

***Proposal/Active Project Start Date: (MM/YYYY):** 06/2024

***Proposal/Active Project End Date: (MM/YYYY):** 07/2025

***Total Anticipated Proposal/Project Amount:** $25,000

*** Person Months per budget period Devoted to the Proposal/Active Project:**

Year	Person Months
2024	0.25
2025	0.5

***Overall Objectives:** We aim to identify and evaluate the ease of use and assembly, portability, accessibility, and viewing quality of each equipment setup before applying them to a rigorous astronomical project such as measuring and analyzing a brightness variation of a bright variable star over a multi-day period to reproduce the textbook example in the real world environment. Through a more accessible hands-on experience, we aim to improve experiential learning opportunities and educational measures for undergraduate students, expanding the depth of astronomy curriculum and furthering educational measures, potentially through the implementation of a class focused on telescope construction and usage.

***Statement of Potential Overlap:** Our goal is to foster a welcoming environment that promotes academic exploration and intellectual curiosity. By distributing these open-source resources across the University System of Georgia, we ensure that all students have the opportunity to engage with and marvel at the wonders of the cosmos.

***Proposal/Active Project Title:** Developing 3D Astronomical Simulations as Open Education Resources

***Status of Support:** Current

Proposal/Award Number:

***Source of Support:** Affordable Learning Georgia (ALG)'s Affordable Materials Gra

***Primary Place of Performance:** University of Georgia

***Proposal/Active Project Start Date: (MM/YYYY):** 05/2024

***Proposal/Active Project End Date: (MM/YYYY):** 07/2025

***Total Anticipated Proposal/Project Amount:** $29,996

*** Person Months per budget period Devoted to the Proposal/Active Project:**

Year	Person Months
2024	0.25
2025	0.5

***Overall Objectives:** I co-lead the innovative STEMin3D project (https://www.stemin3d.net/), which focuses on creating a collection of scientifically accurate, immersive, and visually captivating 3D astronomical models designed as open educational resources. This initiative aims to enhance STEM education through modular, interactive tools that bring complex astronomical concepts to life.

***Statement of Potential Overlap:** This is the same project we apply for NSF:IUSE to get external funding to support this project. In this role, I mentor graduate, undergraduate, and high school students, providing them with practical programming experience and fostering their professional and research skills. Additionally, we implement these 3D models in classroom settings to assess and measure their impact on student learning and engagement.

***Proposal/Active Project Title:** Empowering Experiential Learning: A Hands-On Game Engine Programming Initiative for Engineering majors

***Status of Support:** Current

Proposal/Award Number:

***Source of Support:** EETI Augmented, Remote, and Virtual Experimentation Grants

***Primary Place of Performance:** University of Georgia

***Proposal/Active Project Start Date: (MM/YYYY):** 04/2024

***Proposal/Active Project End Date: (MM/YYYY):** 06/2025

***Total Anticipated Proposal/Project Amount:** $4,000

*** Person Months per budget period Devoted to the Proposal/Active Project:**

Year	Person Months
2024	0.25
2025	0.25

***Overall Objectives:** this main project focuses on creating a collection of scientifically accurate, immersive, and visually captivating 3D astronomical models designed as open educational resources. This initiative aims to enhance STEM education through modular, interactive tools that bring complex astronomical concepts to life.

***Statement of Potential Overlap:** This is the same project we apply for NSF:IUSE to get external funding to support this project. In this role, I mentor graduate, undergraduate, and high school students, providing them with practical programming experience and fostering their professional and research skills. Additionally, we implement these 3D models in classroom settings to assess and measure their impact on student learning and engagement.

***Proposal/Active Project Title:**	PHYS 1251-Studio Physics I: Flipping the Introductory Level Studio Physics-I course with Enhanced Pre-Lecture Videos and Integrated Near and Far Transfer Questions
***Status of Support:**	Current
Proposal/Award Number:	
***Source of Support:**	Provost's Affordable Course Materials Grant - AY 24-25
***Primary Place of Performance:**	University of Georgia
***Proposal/Active Project Start Date: (MM/YYYY):**	02/2024
***Proposal/Active Project End Date: (MM/YYYY):**	05/2025
***Total Anticipated Proposal/Project Amount:**	$5,000

*** Person Months per budget period Devoted to the Proposal/Active Project:**

Year	Person Months
2024	1
2025	0.25

***Overall Objectives:** This project produces concise, engaging videos that integrate lecture material with interactive PhET simulations. These videos are designed to prepare students for each lecture, enhancing their understanding before they even enter the classroom. The project involves collaboration with graduate, undergraduate, and high school students, offering them valuable experience in science communication and professional development while contributing to the creation of accessible educational resources.

***Statement of Potential Overlap:** Our goal is to foster a welcoming environment that promotes academic exploration and intellectual curiosity. By distributing these open-source resources across the University System of Georgia and beyond, we ensure that all students have the opportunity to engage with and marvel at the wonders of the science.

***Proposal/Active Project Title:**	Beyond Boundaries: Harnessing Immersive Environments for Elevated STEM Understanding in Education

***Status of Support:** Pending

Proposal/Award Number:

***Source of Support:** NSF: IUSE

***Primary Place of Performance:** University of Georgia

***Proposal/Active Project Start Date: (MM/YYYY):** 01/2025

***Proposal/Active Project End Date: (MM/YYYY):** 12/2027

***Total Anticipated Proposal/Project Amount:** $397,504

*** Person Months per budget period Devoted to the Proposal/Active Project:**

Year	Person Months
2025	1
2026	1
2027	1

***Overall Objectives:** This project aims to develop about 30 3-D astronomical models as open education resources, and they will be used in classrooms in 2025-2026. By analyzing classroom data, the efficacy of those models will be evaluated within the education theory.

***Statement of Potential Overlap:** -

Certification:

I certify that the information provided is current, accurate, and complete. This includes but is not limited to current, pending, and other support (both foreign and domestic) as defined in 42 U.S.C. § 6605.

I also certify that, at the time of submission, I am not a party to a malign foreign talent recruitment program.

Misrepresentations and/or omissions may be subject to prosecution and liability pursuant to, but not limited to, 18 U.S.C. §§ 287, 1001, 1031 and 31 U.S.C. §§ 3729-3733 and 3802.

Certified by Weliweriya Liyanage, Nandana in SciENcv on 2024-07-15 15:22:16

Table 1

1	Your Name:	Your Organizational Affiliation(s), last 12 mo	Last Active Date
	Song, Inseok	University of Georgia	

Table 2

2	Name:	Type of Relationship	Optional (email, Department)	Last Active Date

Table 3

3	Advisor/Advisee Name:	Organizational Affiliation	Optional (email, Department)
T	Schneider, Adam	US Naval Observatory	
T	Sgro, Lauren	SETI Institute	
T	Jinhee, Lee	Korea Astronomy and Space Science Institute	

Table 4

4	Name:	Organizational Affiliation	Optional (email, Department)	Last Active Date
A	Lee, Jinhee	Korea Astronomy and Space Science Institute		
A	Hom, Justin	Arizona State Univ.		
A	Patience, Jenny	Arizona State Univ.		
A	Chen, Christine	Space Telescope Science Institute		
A	Duchene, Gaspar	UC Berkeley		
A	Mazoyer, J.	LESIA, Observatoire de Paris		
A	Millar-Blanchaer, M.	University of California, Santa Barbara		
A	Esposito, T.	University of California, Berkeley		
A	Kalas, Paul	University of California, Berkeley		
A	Crotts, K.	University of Victoria		
A	Gonzales, E.	San Francisco State University		
A	Kolokolova, L.	University of Maryland		
A	Lewis, B.	UCLA		
A	Matthews, B.	Herzberg Astronomy & Astrophysics Research Centre		
A	Rice, M.	Yale Univ.		

A	Weinberger, A.	Carnegie Institution for Science		
A	Wilner, D.	Center for Astrophysics, Harvard & Smithsonian		
A	Wolff, S.	University of Arizona		
A	Bruzzone, S.	University of Western Ontario		
A	Choquet, E.	CNRS		
A	Debes, J.	Space Telescope Science Institute		
A	de Rosa, R.	European Southern Observatory		
A	Donaldson, J.	Carnegie Institution for Science		
A	Draper, Z.	University of Victoria		
A	Fitzgerald, M.	UCLA		
A	Hines, D.	Space Telescope Science Institute		
A	Hinkley, S.	University of Exeter		
A	Hughes, A.	Wesleyan University		
A	Lopez, R.	UCLA		
A	Marchis, F.	SETI Institute		
A	Metchev, S.	University of Western Ontario		
A	Moro-Martin, A.	Space Telescope Science Institute		
A	Nesvold, E.	UCLA		
A	Nielsen, E.	New Mexico State University		
A	Oppenheimer, R.	American Museum of Natural History		
A	Padgett, D.	Jet Propulsion Laboratory, CalTech		
A	Perrin, M.	Space Telescope Science Institute		
A	Pueyo, L.	Space Telescope Science Institute		
A	Rantakyro, F.	Gemini Observatory		
A	Ren, B.	Université Grenoble Alpes/CNRS		
A	Schneider, G.	Steward Observatory		
A	Soummer, R.	Space Telescope Science Institute		
A	Stark, C.	NASA Goddard Space Flight Center		
A	Zhang, Z. Yimiao	UC San Diego		
A	Ansdell, M.	NASA Headquarters		
A	Konopacky, Q.	UC San Diego		
A	Chiang, E.	UC Berkeley		
A	Macintosh, B.	Stanford Univ.		
A	Ward-Duong, K.	Smith College		
A	Wolff, S.	Steward Observatory		
A	Bailey, V.	JPL/Caltech		
A	Barman, Travis	Univ. of Arizona		

A	Bulger, J.	Univ. of Hawaii		
A	Chilcotte, J.	University of Notre Dame		
A	Doyon, R.	Université de Montréal		
A	Follette, K.	Amherst College		
A	Gerard, B.	Univ. of Victoria		
A	Goodsell, S.	Durham University		
A	Graham, J.	UC Berkeley		
A	Greenhaum, A.	IPAC/Caltech		
A	Hibon, P.	European Southern Observatory		
A	Hung, Li-Wei	National Park Service		
A	Ingraham, P.	Vera C. Rubin Observatory		
A	Maire, J.	UC San Diego		
A	Marley, M.	NASA Ames Research Center		
A	Marois, C.	Herzberg Astronomy & Astrophysics Research Centre		
A	Palmer, D.	Lawrence Livermore National Laboratory		
A	Poyneer, L.	Lawrence Livermore National Laboratory		
A	Rajan, A.	Space Telescope Science Institute		
A	Ruffio, J.	CalTech		
A	Savransky, D.	Cornell University		
A	Sivaramakrishnan, A.	Space Telescope Science Institute		
A	Thomas, S.	Vera C. Rubin Observatory		
A	Wang, Jason	CalTech		
A	Wiktorowicz, S.	The Aerospace Corporation		
A	Murphy, S.	The University of New South Wales		
C	Kastner, Joel	Rochester Institute of Technology		

Table 5

5	Name:	Organizational Affiliation	Journal/Collection	Last Active Date
B	Steve Howell	Ames Research Center	Frontiers in Astronomy and Space Sciences	

Table 1

1	Your Name:	Your Organizational Affiliation(s), last 12 mo	Last Active Date
	Weliweriya Liyanage, Nandana J.	University of Georgia, Athens, GA, USA	

Table 2

2	Name:	Type of Relationship	Optional (email, Department)	Last Active Date

Table 3

3	Advisor/Advisee Name:	Organizational Affiliation	Optional (email, Department)
G	Sayre, Eleanor C	Kansas State University	depaola@phys.ksu.edu, Physics
T	DePaola, Brett	Kansas State University	esayre@phys.ksu.edu, Physics
T	Bennett, Andrew	Kansas State University	bennett@ksu.edu, Mathematics
G	Rebello, Sanjay	Purdue University	rebellos@purdue.edu, Science education

Table 4

4	Name:	Organizational Affiliation	Optional (email, Department)	Last Active Date
A	Rosenzweig, Emily Q	University of Georgia, Athens, GA	emily.rosenzweig@uga.edu, Educational Psychology	
C	Young, Nicholas B	University of Georgia, Athens, GA	nicholas.young@uga.edu, Physics and astronomy	
C	Bork, Sarah J	University of Georgia, Athens, GA	sjbork@uga.edu, ENGR-Electrical & Computer	

Table 5

5	Name:	Organizational Affiliation	Journal/Collection	Last Active Date

NSF Senior Personnel Synergistic Activities

Name: Song, Inseok [PI]
ORCID: 0000-0002-5815-7372
Position Title: Associate Professor
Primary Organization and Location: University of Georgia, Athens, GA 30605

List of five distinct examples of synergistic activities.

1. **Multidisciplinary STEM Education Project (STEMin3D)**
   The principal investigator (PI) and co-PI launched the STEMin3D project with the goal of enhancing STEM education. The project, which began approximately 1.5 years ago, focuses on multidisciplinary approaches. Interested individuals can access the project via STEMin3D.net or STEMin3D.uga.edu. The project website attracts around 1,000 visitors per month and the team has secured several internal and external research and educational grants.

2. **Faculty Learning Community for Immersive Technology**
   The PI initiated a faculty learning community at the University of Georgia (UGA) called the “Faculty Learning Community for Immersive Technologies.” Officially recognized by UGA’s Center for Teaching and Learning, this community will convene twice a month during the 2024 Fall semester. Faculty members will discuss and share news related to immersive technologies.

3. **Enhancing Astronomy Education with Low-Cost Telescopes**
   The PI is currently implementing a project to enhance introductory astronomy curriculum. Instead of relying solely on department-owned centralized large telescopes, students will carry out individual astronomy observation projects using low-cost telescopes (priced below $100). This approach fosters active learning and engagement. Additionally, the PI’s team (including graduate and undergraduate students) will conduct public outreach programs in nearby minority communities using the same set of telescopes.

4. **US-Korea Exoplanet Research Collaboration**
   As an active leader, the PI collaborates on exoplanet research between the United States and Korea. The Great Magellan Telescope plays a crucial role in this international collaboration.

5. **Engagement in the Astronomy Community**
   The PI contributes significantly to the astronomy community by serving on various review panels (for research journals, grant reviews, and telescope time allocation committees). Additionally, the PI serves as an associate editor for the international astronomy research journal, *Frontiers in Astronomy and Space Sciences*.

SYNERGISTIC ACTIVITIES
Nandana Weliweriya Liyanage

Synergistic Activity #1

I co-lead the innovative STEMin3D project (https://www.stemin3d.net/), which focuses on creating a collection of scientifically accurate, immersive, and visually captivating 3D astronomical models designed as open educational resources. This initiative aims to enhance STEM education through modular, interactive tools that bring complex astronomical concepts to life. In this role, I mentor graduate, undergraduate, and high school students, providing them with practical programming experience and fostering their professional and research skills. Additionally, we implement these 3D models in classroom settings to assess and measure their impact on student learning and engagement.

Synergistic Activity #2

I spearhead the physics pre-lecture video project, funded by multiple internal and external funding resources (Affordable Learning Georgia and provost's affordable learning), which produces concise, engaging videos that integrate lecture material with interactive PhET simulations. These videos are designed to prepare students for each lecture, enhancing their understanding before they even enter the classroom. The project involves collaboration with graduate, undergraduate, and high school students, offering them valuable experience in science communication and professional development while contributing to the creation of accessible educational resources. These educational videos are freely available on YouTube (https://www.youtube.com/@nandanaweliweriya-physicsa997), ensuring that quality learning materials are accessible to everyone.

Synergistic Activity #3

Supported by the UGA Center for Teaching and Learning and the Active Learning Initiative, I lead the redesign of the Studio Physics 1 and 2 courses at the University of Georgia. This comprehensive overhaul includes revamping laboratory exercises and refining both individual and group activities conducted within and beyond the classroom. My dedication to improving educational experiences has been recognized through multiple accolades, including three consecutive CTL Learning and Teaching Grants and Affordable Course Materials Grants from the UGA Provost's Office and the University System of Georgia. Recently, I was honored with the prestigious Franklin College Sandy Beaver Excellence in Teaching Award (2024) and the UGA Creative Teaching Award (2024), reflecting my commitment to advancing pedagogical practices.

Synergistic Activity #4

To empower the next generation of educators, I lead the graduate teaching seminar in the UGA Physics and Astronomy Department. These seminars focus on practical scenarios for effective active learning, addressing both challenges and solutions, and fostering inclusive and supportive classroom environments. We also emphasize enhancing science communication skills to improve teaching efficacy. As a key component of the seminar, graduate teaching assistants complete a final project involving visits to local schools and community engagement activities, allowing them to apply their skills in real-world settings and strengthen their connection with the broader community.

Data Management and Sharing Plan

Data Management Plan

This project will create following data:

- Simulation requirement documents for N~30 topics
- Storyboard files for the above topics
- 3-D model source scripts for these topics created in one of the following 3-D game engines: Unity, Unreal Engine, or Blender
- Step-by-step tutorials on how to create/use the model from the scratch
- Rendered 3-D models
- Student surveys and responses
- Research papers to report the results

During the development and debug phase of the project, all files will be stored in a dedicated GitHub Organization repositories (https://github.com/STEMin3D/STEMin3D). Because our GitHub entry is an organization under host institution's Enterprise model, there is no storage limit, and the content is automatically backed-up.

Data Sharing Plan

During the dissemination phase of the project, we will change the abovementioned GitHub repositories from "private" to "public" so that anyone can download the project results including all source scripts, tutorials, and rendered 3-D models under the CC-BY license. The availability of such data will be advertised in relevant conferences and through relevant websites.

We will also upload the 3-D models in common education resource sharing places such as OER Commons.

Graduate Student Mentoring Plan

One full-time graduate student will be involved in the entire duration of the project, and we have already identified the candidate.

- **Candidate**: Mr. David Seiden, a first-year student, has already been actively engaged in related project activities since the summer of 2023 during his gap year. His background as a former Physics teacher in a middle school provides valuable context.
- **Guidance and Career Path**: The Principal Investigator (PI) and Co-PI will offer guidance to Mr. Seiden beyond this project and throughout his Ph.D. program. We will discuss the overall project structure, career milestones, and the timeline for his doctoral studies. Additionally, PI/Co-PI will assist him in navigating official requirements, including securing relevant Institutional Review Board (IRB) approval.
- **Orientation**: At the project's outset, the PI will provide an orientation, covering both project specifics and Mr. Seiden's potential career trajectory. This will ensure he is well-prepared for his role.
- **Career Counseling**: Jointly provided by the PI and Co-PI, career counseling will be available to Mr. Seiden. He will also have access to individual counseling services through UGA's professional counseling resources.
- **Grant Proposal Training**: Building on the past experience, the PI and Co-PI will involve Mr. Seiden in grant proposal writing. He will contribute to a proposal section, participate in iterative revisions, and receive redacted copies of the final submissions.
- **Leadership in Publications and Presentations**: Mr. Seiden will take the lead in presenting project results at annual conferences. Additionally, he will spearhead research paper preparation as the lead author.
- **Mentoring Opportunities**: Given the involvement of 5-10 undergraduate students in our project, Mr. Seiden will have abundant mentoring opportunities. During group meetings, he will interact with junior team members and serve as a mentor, gaining valuable experience.
- **Professional Development**: Encouraged to participate in university workshops, Mr. Seiden will receive written evaluations during mandatory annual evaluations. These assessments will focus on areas for improvement, including professional relationships, work ethics, and collaborative skills.

Data Not Available

Data Not Available

Data Not Available