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Application Summary

Competition Details

Competition Title:	Faculty Seed Grants in the Sciences and Engineering (Social, Life and Physical Sciences)
Category:	Internal Grant Opportunities
Cycle:	FY25
Submission Deadline:	03/1/2024 11:59 PM

Application Information

Application Title:	Improving STEM Education with Immersive 3-D Simulations
Application ID:	6109
Submission Date:	03/1/2024 11:00 AM

Personal Details

Applicant First Name:	Inseok
Applicant Last Name:	Song
Applicant Email:	song@uga.edu
Applicant Primary Organization/Unit:	Physics and Astronomy
Applicant's Primary Appointment Title:	Associate Professor
Year of initial faculty appointment at UGA:	2008
Detailed EFT - Please list your Effort Full Time allocation for Instruction, Research, Service and Administration by Academic Year, Summer or 12 month.:	20.8% Instruction, 66.7% Research, 12.5% Administration (Associate Head)
Eligibility qualification 1.:	I confirm that I have not received a Faculty Seed Grant from this program in the past three years (FY22, FY23 or FY24).
Eligibility qualification 2.:	I confirm that I do not have access to more than $25,000 in institutional or discretionary research funding (e.g., start-up, salary returns or IDC returns) during the award year of this potential grant (July 1, 2024 - June 30, 2025).
Eligibility qualification 3. (For tenured applicants only. Others should check "Not applicable" below.):	I confirm that I have not received more than $50,000 in institutional research support in the past three years (FY22 or later).
Eligibility certification 4. Extramural funding certification. Please select the option below that applies to you.:	I confirm that I do not currently have extramural funding.

Compliance and Reporting Requirements Acknowledgement:	If awarded a Faculty Seed Grant, I certify that I will meet the compliance requirements of the proposed research and the reporting requirements of this program.
Proposal/Application Title:	Improving STEM Education with Immersive 3-D Simulations
Select the primary general category that best describes your proposal.:	Physical Sciences and Engineering
Optional: Select a secondary general category that may also apply to your proposal.:	Education, Family and Consumer Sciences
Keyword 1:	STEM
Keyword 2:	Astronomy
Keyword 3:	Immersive Technology
Optional - additional keywords:	Education
Recommended faculty peer reviewer(s).:	Nicholas Young (Physics Education, nicholas.young@uga.edu) Marni Shindelman (School of Art, marni@uga.edu) Georgia Wood Hodges (Science Education, georgiahodges@uga.edu)
Summary of compliance assurances and information.:	We have submitted an IRB request for the initial data collection focused on instructors and TAs. When this proposal is accepted, we will submit a separate IRB request to conduct student surveys and collection of classroom data.
Amount Requested for Personnel Funding:	24996
Amount Requested for Equipment:	0
Amount Requested for Supplies/General Expenses:	0
Amount Requested for Travel:	0
TOTAL PROJECT BUDGET:	24996
Is this proposal a re-submission of a previously un-awarded Faculty Research Grant?:	No
Describe how support by the Faculty Research Grant program will lead to extramural grant support and the plan for future grant submission. Please list specific funding mechanisms.:	Using the pilot project result obtained through the support of this FSG proposal, we will build a strong case for several external grants that include (1) NSF Improving Undergraduate STEM Education (IUSE), (2) NSF Advancing Informal STEM Learning (AISL), (3) NSF Inclusion across the Nation of Communities of Learners of Underrepresented Discoverers in Engineering and Science (INCLUDES). Even a commercial sector funding possibility such as Unreal Engine Epic Mega Grants exists that we will apply for a grant. Within a few years, we (UGA) can serve as the lead institution of the multi-million-dollar STEM education research hub. Faculty Seed Grants in Science & Engineering will be a timely fertilizer in this rapidly growing, crucial project.
Additional Email Addresses for Notifications/Email Addresses for notifications:	song@uga.edu,nandanaw@uga.edu,

Biographical Sketch

(updated on February 28, 2024)

Objective

Apply my experience/knowledge in astronomy research and education to enhance our understanding of the planet formation and evolution. This ties to one of the most fundamental questions of mankind, “Is there other life in the Universe?” and “How did we start?”

1 Personal

Department of Physics and Astronomy
The University of Georgia
Athens, GA 30602-2451

E-mail: song@uga.edu

Phone: (770) 405-9427

2 Education

1994 - 2000	Ph.D.	University of Georgia
1989 - 1991	M.Ed.	Seoul National University (Korea, Science Education)
1985 - 1989	B. Sc.	Seoul National University (Korea, Earth Science)

3 Awards

2024 Fulbright US Scholar Award (US-Korea Presidential STEM Initiatives)
2010 AAAS Newcomb Cleveland Award
2009 Ralph E. Powe Faculty Award: Oak Ridge Association of University
2005 Outstanding Young Researcher Award : Association of Korean Physicists in America (AKPA)
1999 Korean Honor Scholarship (awarded by the Korean Embassy in US)
1991 Edu. General’s Award (Outstanding trainee) : The 3rd Military Academy (Korea)

4 Employment & Position History

2013 - now	Associate Professor	University of Georgia
2015 - 2018	Graduate Coordinator	University of Georgia
2008 - 2013	Assistant Professor	University of Georgia
2007 - 2008	Staff Research Scientist	IPAC / Caltech
2004 - 2007	Assistant Astronomer	Gemini Observatory
2002 - 2004	Assistant Scientist	UCLA
2000 - 2002	Post-doctoral researcher	UCLA

5 Activities and Experiences

- Age determination of field stars
- Discovery of nearby young stellar groups (e.g., TWA, Tuc/HorA, β-Pic, AB_Dor, and Columba groups)
- Infrared excess stars in the solar neighborhood
- Direct imaging search for exoplanets
- Management of huge astronomical catalogs (with $\sim 10^9$ entries) in relational databases (e.g., MySQL)
- Software developments and support for Keck/OSIRIS, Gemini/NIFS, & Spitzer/IRAC
- Associate Editor: Astronomy and Space Science (Frontier), 2023-
- Executive Committee, Gemini Planet Imager, 2010/10-2014/8
- Science Steering Committee, Gemini Planet Imager, 2010/10-2017/8

6 Recent Professional Highlights

- Executive and Science steering committee member of the Gemini Planet Imager (GPI) Exoplanet Survey team
- Discovery of young Sun analogs undergoing "Heavy Bombardments" or "Planetary Collisions" (e.g., BD+20 307 and HD 23514)
- Co-discoverer of the planetary system with multiple planets in direct imaging (HR 8799)
- Co-discoverer of the rapidly disappeared debris disk around TYC 8241 2652 1
- Co-discoverer of the first imaged planetary mass object beyond our Solar System (2M1207b)
- Recipient of the 2010 Newcomb-Cleveland Award which is given to the author(s) of the best paper published in Science in 2009
- Over 300 nights of Optical/IR photometric/spectroscopic observing experience at Gemini, Keck, Lick, Las Campanas, Siding Spring, etc.

7 Teaching/Mentoring Experience

2015 - now Teaching "Astronomy Lab"
2014 - now Teaching "Astronomy Seminar"
2013 - now Teaching "Stellar & Galactic Astronomy"
2011 - now Teaching "First Year Odyssey Seminar"
2010 - now Teaching "Observational Astronomy" & "Introduction to Astronomy: The Solar System" courses
2008 - now Teaching "Life in the Universe"
2017 -2024 Advising a graduate student [David Jordan]
2020 - 2024 Advising a PhD student [Robin Allen]
2014 - 2021 Advised a PhD student [Lauren Sgro]
2013 UGA Online Learning Fellow
2013 - 2020 Advised a PhD student [Jinhee Lee]
2009 - 2022 Hosting high school Interns via UGA's Young Dawgs Program (10 students to date)
2008 - 2013 Advised a PhD student [Adam Schneider]
2010 - 2016 Advised a PhD student [Tara Cotten]
2016 - 2022 Teaching "Intro to Scientific Programming, Data Analysis, and Visualization for Physicists"
2008 - 2010 Advised MS student [Ben Ruskin]
2007 - 2011 PhD Supervisory committee member for Simon Murphy (Australian Nat'l Univ.)
2006 - 2009 mentored a UCLA PhD student (Carl Melis)
2004 - 2007 mentored two post-docs and two intern students at Gemini

8 Service

Professional

- Referee & Peer Review : serving regularly as a referee for major journals (ApJ, MNRAS, AJ, A&A, As-tron.Note, Nature, Science, etc.), grant proposals (both national and international), NASA Post-doctoral Program, and Telescope Time Allocation Committees (NASA/Keck, NOIRlab, K-GMT).
- Associate editor of *Frontier Astronomy Journal*

University Service

2015-2016 Chair of the Executive Committee at Franklin Faculty Senate
2013-2016 Franklin Faculty Senate
2015,2017 UGA Faculty Research Grant review

2015-present Reviewers for several University-wide award competitions: Dissertation Completion Awards, Graduate School Research Assistantship, Presidential Scholarship, Carmen Scholarship, Innovative and Interdisciplinary Research Grants, etc.

9 Current and Former Students

Adam Schneider (PhD, USNO staff), Tara Cotten (PhD, lecturer at UGA), Jinhee Lee (PhD, post-doc KASI), Lauren Sgro (PhD, post-doc SETI), Ben Ruskin (MS, high school teacher), Simon Murphy (PhD, Univ. of New South Wales astronomer), Adric Riedel (PhD, STScI software engineer), David Jordan (6th year), Robin Allen (3rd year)

10 Research Grants

Current and past grants (Total $947,684: Amounts listed are actual $$ given to Inseok Song)

Period	Role	Amount	Agency	Project Title
2003-2004	PI	$115,000	NASA ADP	Search for Warm InfraRed Excess around Stars with Hipparcos, IRAS PSC & FSC, MSX, and 2MASS data
2004	PI	$8,000	NASA/Keck	3.5 μm Search for Planets Around Vega-like Stars
2004-2005	co-I	$35,243	NASA TPF	Whole Earth Spectra from AIRS
2003-2008	coll.	N/A	NASA NAI	NASA National Astrobiology Institute Cooperative Agreement Notice to UCLA (CAN Cycle-3)
2004-2006	PI	$173k to PI	HST Cycle 13	Coronagraphic Survey for Giant Planets Around Nearby Young Stars (GO10176, 116 orbits)
2004-2007	PI	$51,590	Spitzer Cycle 1	Disk Census of Nearby Young Stellar Groups, GO#3600
2006-2007	co-I	$15,000	HST Cycle 14	Near-IR Spectrophotometry of 2MASSWJ 1207334393254b - An Extra-Solar Planetary Mass Companion to a Young Brown Dwarf
2006-2007	co-I	$20,000	Spitzer Cycle 2	An Amazingly Dusty Sun-like Star: Studying Cosmic Collisions at 1 AU
2007-2009	co-I	$28,398	HST Cycle 15	NICMOS Imaging Survey of Dusty Debris Around Nearby Stars Across the Stellar Mass Spectrum, GO11157, 48 orbits
2007-2011	PI	$117,583	NASA ADP	Searches for Extra Solar Zodiacal Material during the Era of Heavy Bombardment
2009-2010	PI	$7,600	Spitzer Cycle 5	IRS View of a planetary collision in Pleiades
2009-2010	PI	$5,000	ORAU	How common are planetary systems in the Universe?
2009-2012	co-I	$90,000	Spitzer Cycle 6	Young Stellar Object Variability (YSOVAR): Mid Infrared clues to accretion disk physics and protostar rotational evolution
2009-2012	PI	$60,335	Spitzer Cycle 5	Do massive primordial disks evolve into massive debris disks?

2011-2013	co-I	$5,000	Herschel Cycle 1	HERSCHEL characterization of the new class of dusty first-ascent giant stars
2011-2014	co-I	$35,000	Spitzer Cycle 7	YSOVAR II : Mapping inner disk structure in NGC2264 with simultaneous Spitzer and CoRoT time series photometry
2013-2015	PI	$6,435	SOFIA	Cataloging Debris Disks within 100 pc
2013-2016	PI	$3,000	SOFIA	Characterizing a young, isolated, dusty star HD166191
2014-2015	PI	$13,500	SOFIA	FORCAST Spectroscopy of Extreme Debris Disks
2015-2017	PI	$53,000	SOFIA	Characterizing the Warm Disk with FORCAST photometry for the Dustiest Debris Disk
2015-2017	PI	$68,000	SOFIA	Characterizing the Disk of a Recent Massive Collisional Event
2019	PI	$5,000	UGA	Affordable Course Material Grant (UGA internal)
2019-2020	PI	$20,800	Univ. System of Georgia	Affordable Learning Georgia (Round 14) : Adoption of OpenStax Astronomy Textbook
2022-2023	PI	$5,000	UGA	Affordable Course Material Grant
2023-2024	co-PI	$8,000	UGA	Teaching Enhancement and Innovation
2023-2024	co-PI	$25,000	UGA	Learning Technology Grant
2023-2024	co-PI	$1,200	UGA	EETI Research and Innovation grant
2024-	PI	$5,000	UGA	Provost Affordable Course Material
2024-	co-PI	$4,000	UGA	EETI Research and Innovation grant
2024-	co-PI	$5,000	UGA	Provost Affordable Course Material

11 Publications (chronological order)

SELECTED REFEREED JOURNALS ONLY

1. Ben Zuckerman, Inseok Song, Mike Bessell, and Rich Webb, “The *β* Pictoris moving group”, 2001, ApJL, 562, L87
2. Inseok Song, Mike Bessell, and Ben Zuckerman, “Lithium Depletion Boundary in a Pre-Main Sequence Binary System”, 2002, ApJL, 581, L43
3. Ben Zuckerman and Inseok Song, “Young Stars Near Earth”, *Annual Review of Astronomy and Astrophysics*, 2004, 42, 685
4. Inseok Song, B. Zuckerman, A. Weinberger, & E. Becklin, “Extreme collisions between planetesimals as the origin of warm dust around a Sun-like star”, 2005, Nature, 436, 363.
5. G. Chauvin, A.-M. Lagrange, C. Dumas, B. Zuckerman, Inseok Song, J.-L. Beuzit, and P. Lowrance, “Giant planet companion to 2MASSW J1207334-393254”, 2005, A&A, 438, L25
6. B. Zuckerman, M.-S. Bessell, Inseok Song, & S. Kim, “The Carina-Near Moving Group”, 2006, ApJL, 649, 115.

7. J. Rhee, Inseok Song, B. Zuckerman, and M. McElwain, “Characterization of Dusty Debris Disks: the IRAS and Hipparcos Catalogs”, 2007, ApJ, 660, 1556
8. J. Rhee, Inseok Song, and B. Zuckerman, “Warm dust in the terrestrial planet zone of a sun-like Pleiad: Collisions between planetary embryos?”, 2008, ApJ, 675, 777
9. C. Marois, B. Macintosh, T. Barman, B. Zuckerman, Inseok Song, J. Patience, D. Lafreniere, R. Doyon, “Direct Imaging of Multiple Planets Orbiting the Star HR 8799”, 2008, Science, 322, 1348-1352
10. C. Melis et al. (4th), “Rapid disappeatance of a warm dusty circumstellar disk”, 2012, *Nature*, 487, 74
11. Inseok Song, B. Zuckerman, & M. Bessell, “New Members of the Scorpius Centaurus Complex and Ages of its sub-regions”, 2012, AJ, 144, 8
12. B. Macintosh et al. (alphabetical order after the PI, 88 authors), “Discovery and spectroscopy of the youngjovian planet 51 Eri b with the Gemini Planet Imager”, 2015, *Science*, 350, 64
13. T. Cotten and Inseok Song, “A Comprehensive Census of Nearby Infrared Excess Stars”, 2016, ApJS, 225, 15
14. J. Lee & Inseok Song, "Evaluation of nearby young moving groups based on unsupervised machine learning", 2019, MNRAS, 489, 2198
15. J. Lee & Inseok Song, "Development of models for nearby young stellar moving groups: creation, revision, and finalisation of the models", 2019, MNRAS, 486, 3434
16. J. Lee, Inseok Song, & S. Murphy, "2MASS J15460752−6258042: a mid-M dwarf hosting a prolonged accretion disc", 2020, MNRAS, 494, 62
17. L. Sgro & Inseok Song, "The infrared excess emission from nearby Gaia DR2 M dwarfs", 2021, MNRAS, 508, 3084
18. J. Lee, Inseok Song, & S. Murphy, "Low-mass members of nearby young stellar moving groups from Gaia EDR3", 2022, MNRAS, 511, 6179

12 Grant Proposal Submission History (past 3 years)

Title: Empowering Experiential Learning: A Hands-On Game Engine Programming Initiative for Engineering Majors
Project Period: 02/01/2024 – 06/31/2024
Funder name: UGA
Proposed award amount: $4,000 Status:
funded (co-PI)

Title: Adoption of the free OpenStax textbook for multiple astronomy courses
Project Period: 02/01/2024 – 06/30/2024
Funder name: UGA
Proposed award amount: $5,000 Status:
funded (PI)

Title: Teaching Enhancement and Innovation Fund for FY24
Project Period: 02/01/2024 – 06/30/2024
Funder name: UGA
Proposed award amount: $2,000
Status: funded (co-PI)

Title: Exploring Virtual Reality in Astronomy Education: Enhancing Student Understanding through Immersive Learning Environments
Project Period: 07/01/2023 – 06/30/2024
Funder name: UGA

Proposed award amount: $25,000
Status: funded (co-PI)

Title: Exploring Virtual Reality in Astronomy Education: Enhancing Student Understanding through Immersive Learning Environments
Project Period: 07/01/2023 – 06/30/2024
Funder name: UGA
Proposed award amount: $25,000 Status:
funded (co-PI)

Title: Enhancing ASTR 1420 Course with an OpenStax textbook
Project Period: 02/01/2022 – 06/30/2022
Funder name: UGA
Proposed award amount: $5,000 Status:
funded (PI)

Title: Presidential Interdisciplinary SEED grants
Submitted date: July 2023
Funder name: UGA
Proposed award amount: $100,000
Status: Not funded (co-PI)

Title: SEarch for Nearby Stars with Extreme Excess Emission: SENSE3
Start date: 1 September 2023
End date: 31 August 2025
Funder name: NATIONAL AERO & SPACE ADMIN
Proposed award amount: USD 191,857
Status: Not funded (PI)

Title: Building the Nearby Young Stars ARChive: NYSARC
Start date: 1 September 2023
End date: 31 August 2026
Funder name: NATIONAL AERO & SPACE ADMIN
Proposed award amount: USD 458,450 Status:
Not funded (PI)

Title: SED/Emcee Characterization of transiting exoplanet host stars
Start date: 1 January 2023
End date: 31 December 2025
Funder name: NATIONAL AERO & SPACE ADMIN
Proposed award amount: USD 306,641 Status:
Not funded (PI)

Title: Building or destroying? Distinguishing between models for the origin of material orbiting the dustiest main sequence stars
Start date: 1 January 2022
End date: 31 December 2024
Funder name: NATIONAL AERO & SPACE ADMIN

Proposed award amount: USD 207,952 Status:
Not funded (PI)

Title: Building or destroying? Distinguishing between models for the origin of material orbiting the dustiest main sequence stars
Start date: 1 July 2021
End date: 30 June 2024
Funder name: NATIONAL SCIENCE FOUNDATION
Proposed award amount: USD 207,952
Status: Not funded (PI)

Budget for Faculty Seed Grant Proposal

PI Name: Inseok Song
Proposal Title: Improving STEM Education with Immersive 3-D Simulations

A. Personnel	Item	Amount
1.	1 Grad Student @ 19.58% FTE	$14,424.00
2.	Grad Student Benefits @ 4%	$576.00
3.	10 Undergrads @ $10.50/hr, 10 hours per week, 9.52 weeks/yr	$9,996.00
4.		
5.		
	Category Total:	**$24,996.00**

B. Equipment		Amount
1.		
2.		
3.		
4.		
	Category Total:	**$0.00**

C. Supplies/Expenses		Amount
1.		
2.		
3.		
4.		
5.		
6.		
7.		
	Category Total:	**$0.00**

D. Travel		Amount
1.		
2.		
3.		
	Category Total:	**$0.00**

	TOTAL	**$24,996.00**

BUDGET JUSTIFICATION – UNIVERSITY OF GEORGIA

A. Personnel

Graduate Student Research Assistant: Salary support is requested for 1 PhD graduate research assistant at 19.58% FTE for 12 months for the duration of the project. The graduate student under the direction of the PI will lead the effort in implementing developed simulations into actual courses. This includes: (1) coordinating with astronomy course instructors for securing IRB approvals, (2) developing student surveys, and (3) analyzing collected data.

Undergraduate Student Research Assistants: Salary support is requested for 10 undergraduate research assistants (salary estimated at $10.50 per hour). Support is requested for the following estimated hours of undergraduate work on this project: ~10hrs per week for 9.52 weeks per student for the duration of this project. The undergraduate research assistants will develop 3-D simulations guided by the faculty-created simulation requirement documents for seven selected topics. Non-programming undergraduate students will work on creating “storyboard” files that guide how the simulation will be used in the classroom.

Fringe Benefits

Fringe rates are estimated at: 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.

Indirect Costs

Indirect costs are not included due as this is an internal proposal.

UNIVERSITY OF
GEORGIA

Franklin College of Arts & Sciences
Department of Physics & Astronomy

28 February 2024

Dear Proposal Committee:

This letter is to express my strong support for Dr. Inseok Song's application for a UGA Faculty Seed Grant. Dr. Song and his collaborators have been working for several years to develop and deploy new, innovative instructional resources for introductory astronomy courses.

Astronomy is a very visually oriented subject that holds a great deal of fascination among students and the general public. However, the static diagrams in textbooks and non-interactive, flat animations on web sites do little to excite the learner and contribute to persistent misunderstandings of fundamental concepts. Dr. Song's team is addressing this problem by creating immersive AR/VR astronomical simulations, designed to address students' misconceptions and conceptual struggles, and refining these simulations in an evidence-based iterative cycle.

Dr. Song and his collaborators have a well demonstrated capability for carrying out this project, both the design and the educational research components. They have attracted funding for earlier stages of this work through Affordable Course Materials Grants, Learning Technologies Grants, and Engineering Education Transformations Institute Research and Innovation Grants. This seed grant, if funded, will position the team to attract additional research collaborators and to be competitive for federal (NSF) and private research funding.

Sincerely,

Craig C. Wiegert

Craig C. Wiegert
Department Head
Associate Professor of Physics

201 Cedar Street | Athens, Georgia 30602-2451 U.S.A. | Telephone (706) 542-2485 | Fax (706) 542-2492

Proposed Research Question When highly motivated first-year students enter their introductory-level Science, Technology, Engineering and Mathematics (STEM) courses, the material and traditional instruction methods play a destructive role in students' interest in remaining in the STEM areas. In traditional STEM education, conveying complex 3-D real-world scenarios often relies on imagination or static 2-D textbook illustrations, presenting significant challenges to student comprehension. Current astronomy education resources, especially illustrations and figures available in textbooks, are mostly limited in 2-D that falls short in providing chances to students to grasp the underlying concepts of fundamentally 3-D astronomical phenomena. This limit not only hinders students' comprehensive understanding of the underlying astrophysical concepts but also diminishing students' motivation to persist in astronomy.

Unique and Innovative Features Over the years, educators and researchers looked for solutions to incorporate technology to overcome the abovementioned barrier. In an effort to address the issue, we started a project, STEMin3D, adopting the new, immersive, extended reality (XR) technology to enhance the quality of STEM education. Within the scope of this Faculty Seed Grant (FSG) proposal, we proposes to develop an XR astronomical immersive technology platform with specific modules to evaluate the effectiveness of the platform for enhancing the quality of astronomy instruction and research, broadly STEM. The proposed platform will include specific 3-D modules like Virtual Night Sky, Eclipses, Tides, and Solar rotation, which will be assessed for effectiveness in enhancing student understanding.

Significance of the Research The result of our proposed research project will not only improve students' understanding of fundamental astronomy concepts but also refine their critical thinking and problem-solving abilities. Furthermore, it also comes with a research component of measuring the impact. Our project will revolutionize astronomy education, liberating it from traditional limitations and ushering in a new era of exploration and comprehension for all. Therefore, we can trigger a paradigm shift in general STEM education with the new immersive technology hence motivating more students into the STEM fields. We will share publicly all developed simulations, documentation, underlying platform for further development of modules across the entire STEM disciplines so that educators in underprivileged communities, especially minority serving institutions, can utilize the high-quality education resources from our project to stimulate young minds toward the STEM field.

Future Direction Strengthening STEM education nationwide is a high national priority as emphasized in the various strategic goals, mission statements, and reports of the Depart 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*." Our proposed work is a change in thinking in the STEM education dovetailed with these national priorities. Therefore, there are several available external funding opportunities that we can tap to expand the current project beyond the scope of the FSG supported project.

Using the pilot project result obtained through the support of this FSG proposal, we will build a strong case for several external grants that include (1) NSF Improving Undergraduate STEM Education (IUSE), (2) NSF Advancing Informal STEM Learning (AISL), (3) NSF Inclusion across the Nation of Communities of Learners of Underrepresented Discoverers in Engineering and Science (INCLUDES). Even a commercial sector funding possibility such as Unreal Engine Epic Mega Grants exists that we will apply for a grant. Within a few years, we (UGA) can serve as the lead institution of the multi-million-dollar STEM education research hub. Faculty Seed Grants in Science & Engineering will be a timely fertilizer in this rapidly growing, crucial project.

Introduction: Current astronomy education resources, especially illustrations and figures, are mostly limited to 2-D that falls short in providing chances to students to grasp the underlying concepts of fundamentally 3-D phenomena. In addition, one of the main reasons that students are interested in astronomy in the first place is the beautiful appearances of celestial objects. 2-D static figures, oftentimes with simple collections of geometrical objects, are not enough to meet the expectations of students and instructors, failing to provide motivation to continue in astronomy. The case for 3-D simulations is worse because there are only a few freely available 3-D simulations, and they are rudimentary with solid geometrical objects. Inadequate illustrations to depict complex 3-D real-world scenarios accurately often hinders students' comprehensive understanding of the underlying astrophysical concepts. Moreover, limited opportunities to engage with and solve real-world problems, either individually or collaboratively, can diminish students' motivation to persist in astronomy. To address these challenges, we aims to bridge the gap by providing essential connections to real-world scenarios and enhancing the representation of 3-D concepts frequently overlooked in traditional textbooks. Several faculty members in the Department of Physics and Astronomy have been actively working in enhancing the STEM undergraduate education by adopting the great potential of immersive technology such as extended reality (XR) as education resources with the aim of developing immersive education resources by adopting the 3-D, VR, and/or augmented reality technologies. All investigators of the current proposal are active members of this STEMin3D project.

Importance of Proposed Work: Our project can revolutionize astronomy education and greatly contribute to the open education resource community, liberating it from traditional limitations and ushering in a new era of exploration and comprehension for all. The result of our proposed research project will not only improve students' understanding of fundamental astronomy concepts but also refine their critical thinking and problem-solving abilities. Our project results can be easily applied to other STEM disciplines. Therefore, we can trigger a paradigm shift in general STEM education with the new immersive technology hence motivating more students into the STEM fields. Furthermore, in-depth involvement by students in developing and evaluating simulations provide invaluable experiential learning opportunities to student team members. They can learn details of real-time programming while contributing to the project as paid student programmers. Currently, there are eleven undergraduate students and four graduate students involved in the project.

Specific Aims/Objectives: In traditional STEM education, conveying complex 3-D real-world scenarios often relies on imagination or static 2-D textbook illustrations, presenting significant challenges to student comprehension. Our project is dedicated to addressing this issue by developing a series of "Scientifically Correct, Immersive, Engaging, Visually Stunning, and Modular" 3-D simulations aimed at enhancing student understanding and engagement. These simulations can be projected on traditional 2-D displays or projected into a virtual reality (VR) headset. Simulations can also be ported easily as separate augmented reality (AR) versions that can be viewed with smartphones or tablets (see this AR example from the project website). These new platforms of education can increase the student motivation (e.g., Atta et al. 2022, Educ. Sci., 12, 890; Blanco et al. 2018, ASP conf. 524). However, improving students' understanding of the related scientific concepts is critically dependent on the appropriateness of selected topics (Blanco et al. 2018) emphasizing the importance of identifying suitable astronomical topics for simulations.

Table 1 *3-D simulations to be created under the scope of FY25 UGA Faculty Seed Grant.*

No.	Topic	Note
1	Virtual Night Sky	A platform development that can be used in other simulations
2	Diurnal Motion of Celestial bodies	Add to "Virtual Night Sky". Similar to Dr. Hall's Stellarium-based video: here
3	Origin of Seasonal Constellations	Build upon "Virtual Night Sky".
4	Time & Calendar	Add to "Virtual Night Sky". Similar to Dr. Hall's Stellarium-based video: here
5	Eclipses	Accurately reproduce/predict/simulate solar or lunar eclipse
6	Solar rotation and cycle	Rotating Sun showing differential rotation and activity cycle

Approach: We have already identified about two dozen relevant topics where 3-D simulations can immensely enhance students' comprehension of core concepts and ignite a heightened interest in those core concepts. Under the scope of this proposal, we will create simulations for six selected topics shown in Table 1 and the created simulations can be used as showcases in future external grant proposals. Simulations for other remaining topics will be created with the support of forthcoming external grants (see following sections). Leveraging leading 3-D software tools such as Unity, Blender, Unreal Engine, Maya, and A-Frame, we are creating user-interactive simulations tailored to educational needs. To identify the most suitable software for our objectives, we have already started comprehensive research into each platform, evaluating factors including Benefits, Limitations, Capabilities, Costs, System Requirements, and VR/Mobile AR Capabilities.

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

Created simulations can be used in several different ways including an interactive 3-D simulation projected into a VR headset. For example, using realistically created Sun, Earth, and Moon in accurate orbits, we can simulate solar/lunar eclipses or even predict future ones. This simulation creates a previously infeasible scenario with which students interact to get the in-depth knowledge through activities. By interactively adjusting camera viewing angles, object sizes, orbital inclinations, time of observations, etc., students will have a chance to grasp the fundamental principles that govern the eclipse phenomenon. These simulations not only improve students' understanding of fundamental astronomy concepts but also refine their critical thinking and problem-solving abilities. Two freshman computer science majors already started the creation of the eclipse simulation module with Blender (see Figure 1).

Three astronomy faculty members (Drs. Song, Hall, & Magnani) will create a detailed simulation requirement document for each topic in Table 1 so that student programmers can be guided during the actual development of the simulations. Simulation requirement documents will be later transformed to “storyboard” files by non-programming undergraduate students under the guidance of faculty members and these documents can be used as lesson plans. Dr. Weliweriya will guide a graduate student who will lead efforts in implementing developed simulations into actual courses and measuring the student learning. This includes: (1) coordinating with astronomy course instructors (Song/Hall/Magnani) for securing IRB approvals, (2) developing student surveys, and (3) analyzing collected data.

Created simulations will be shared through the project webpage, published reports, and the OpenStax open education resource (OER) common. All results including the resultant simulations, script files, relevant documents will be openly accessible under Creative Commons Attribution License (CC-BY). In addition to developing six 3-D simulations as OERs, this project includes research components as well to study the effectiveness of these OERs. These include:

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

Quantitative and qualitative measures of the new OERs will be measured during the first implementations in 2025 ASTR 1010, 1110, & 1420 courses with more specifics as follows.

Testing Conceptual Mastery:
Method 1: collect pre- and post-test scores from students using established astronomical assessments such as the Test of Astronomy Standards (TOAST), Astronomy Diagnostic Test 2.0 (ADT2), and Star Properties Concept Inventory (SPCI).
Method 2: collect data using individuals or groups of students in think-aloud interviews. These interviews will be follow-ups to the user surveys we collect after each session.

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

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

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

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.*

Expected Outcomes: With the six created astronomical 3-D immersive simulations and pilot classroom data, we can make a strong case for several major external grants. Improving the STEM education is a high national priority and there are many funding opportunities that dovetail with the scope of our project. We plan to submit grant proposals to programs summarized in Table 2 during the 2024/2025 grant proposal cycles, and we expect the project will progress rapidly in 2025 with one or more of these external grants. We are in the midst of forming an interdisciplinary group with investigators from engineering, veterinary medicine, etc. to expand our effort beyond the astronomy field. This interdisciplinary STEM group can strengthen our chances of securing significant external grants even more.

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

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

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

References

Detailed reference information were directly embedded in the proposal documents.