Affordable Learning Georgia

Affordable Materials Grants, Round 25: Transformation Grants (Spring 2024-Spring 2025)

Proposal Form and Narrative

Applicant and Team Information

Requested information	Answer
Institution(s)	University of Georgia
Applicant name	Inseok Song
Applicant email	song@uga.edu
Applicant position/title	Associate Professor & Assoc. Head of the Department
Submitter name	Same as the Applicant
Submitter email	
Submitter position/title	

Please provide the first/last names and email addresses of all team members within the proposed project. Include the applicant (Project Lead) in this list. Do not include prefixes or suffixes such as Ms., Dr., Ph.D., etc.

Team member	Name	Email address
Team member 1	Inseok Song	song@uga.edu
Team member 2	Nandana Weliweriya	nandanaw@uga.edu
Team member 3	Cassandra Hall*	cassandra.hall@uga.edu
Team member 4	Loris Magnani*	loris@uga.edu
Team member 5	Nicolas Young*	nicholas.young@uga.edu
Team member 6	Robin Allen**	robin.allen@uga.edu

'*' denotes unfunded co-I and '**' graduate student.

More team members

About a dozen (N~11) undergraduate students.

Project Information

Priority Category / Categories	***Student Participation in Materials Evaluation and/or Development.*** However, this project contains components that can also be identified as ***"Collaborative Projects with Professional Support" or "Departmental Scaling Projects"***
Requested Total Amount of Funding	***$29,996***
Final Semester of Project	*Spring 2025*
Using OpenStax Textbook?	*Yes*

Impact Data

Three astronomy courses (ASTR 1010, 1110, & 1420 [and its online version 1420E]) will benefit through the usage of open education resources created by our project which will enable the full adaptation of a no-cost OpenStax textbook. The total cost saving by students is expected to be **$50,600 per academic year**.

Course 1

Row #	Requested information	Answer
N/A	Course title and number	*Astronomy of the Solar System* ASTR 1010
N/A	Course instructors	Cassandra Hall
1	Average number of students enrolled in the affected course per year	180
2	Average number of affected enrollments in a summer semester	0
3	Average number of affected enrollments in a fall semester	130
4	Average number of affected enrollments in a spring semester	50
5	Original required commercial materials *Include each title, author, price for a new copy purchased from either your campus*	21st Century Astronomy, published by W.W. Norton, $177.50 ISBN13: 9780393539134

Row #	Requested information	Answer
	bookstore, the publisher, or Amazon, and a URL to the book showing the price.	Link to the book
6	Original cost per student section enrollment *Add up the cost of all required materials in row 5.*	$177.50
7	Average post-project cost per student section enrollment	$0
8	Average post-project savings per student section enrollment *Subtract row 7 from row 6.*	$177.50
9	Projected total annual student savings per academic year *Multiply row 1 and row 8.*	$31,950

Course 2

Row #	Requested information	Answer
N/A	Course title and number	*Introductory Astronomy for Majors I* ASTR 1110
N/A	Course instructors	Inseok Song
1	Average number of students enrolled in the affected course per year	40
2	Average number of affected enrollments in a summer semester	0
3	Average number of affected enrollments in a fall semester	40
4	Average number of affected enrollments in a spring semester	0

Row #	Requested information	Answer
5	Original required commercial materials *Include each title, author, price for a new copy purchased from either your campus bookstore, the publisher, or Amazon, and a URL to the book showing the price.*	21st Century Astronomy, published by W.W. Norton, $177.50 ISBN13: 9780393539134 Link to the book
6	Original cost per student section enrollment *Add up the cost of all required materials in row 5.*	$177.50
7	Average post-project cost per student section enrollment	$0
8	Average post-project savings per student section enrollment *Subtract row 7 from row 6.*	$177.50
9	Projected total annual student savings per academic year *Multiply row 1 and row 8.*	$7,100

Course 3

Row #	Requested information	Answer
N/A	Course title and number	*Life in the Universe* ASTR 1420/E
N/A	Course instructors	Inseok Song
1	Average number of students enrolled in the affected course per year	70
2	Average number of affected enrollments in a summer semester	30
3	Average number of affected enrollments in a fall semester	40

Row #	Requested information	Answer
4	Average number of affected enrollments in a spring semester	This course is offered once in AY either in Fall or Spring in addition to a summer semester.
5	Original required commercial materials *Include each title, author, price for a new copy purchased from either your campus bookstore, the publisher, or Amazon, and a URL to the book showing the price.*	Origins of Life in the Universe, published by Cambridge Univ. Press, $165.00 ISBN: 9780521825764 Link to the Book
6	Original cost per student section enrollment *Add up the cost of all required materials in row 5.*	$165
7	Average post-project cost per student section enrollment	$0
8	Average post-project savings per student section enrollment *Subtract row 7 from row 6.*	$165
9	Projected total annual student savings per academic year *Multiply row 1 and row 8.*	$11,550

The total cost saving by students from the three courses is expected to be **$50,600**/AY.

Narrative Section

1. Project Goals

Enhancing Student Understanding through Immersive Astronomy Open Education Resources
While offering no/low-cost courses to students is important, it is also critical to keep students excited and engaged in the course through high-quality open education resources. ASTR1010 (and ASTR1110; Astronomy of the Solar System) is one of University System of Georgia (USG) Core Curriculum Courses and ASTR1420 is a USG General Curriculum course. In every academic year, about 300 students are taking these courses.

Under the Round 25 Transformation Grant project, we plan to achieve the following goals:

- Develop a set of “Scientifically correct, Immersive, Engaging, Visually stunning, Modular” 3-D astronomical simulations to enhance students’ understanding of fundamental astrophysical concepts.
- Merge the newly developed 3-D simulations with OpenStax textbook and measure success
- Assess the effect of immersive 3-D (including virtual reality and augmented reality) simulations on student learning and course satisfaction.

2. Statement of Transformation

Through the previously accepted Round14 Affordable Learning Georgia project (PI: I. Song), we investigated the possibility of adopting a no-cost open textbook from OpenStax (“Astronomy” ISBN-13: 978-1-951693-50-3) for ASTR1010. A new set of lecture notes, online quizzes, homework, and exams were developed and implemented in UGA’s *eLearning Commons*. Then the new course structure was offered during 2019 Fall and 2020 Spring semesters. The adaptation of no-cost textbook was well received by students. However, the disparity between textbook concepts, problem representations, and real-world applications could lead to growing frustration among students. The OpenStax astronomy textbook came with a limited set of illustrations compared to commercial textbooks in terms of abundance and quality.

Current astronomy education resources, especially illustrations and figures, are generally limited in 2-D that falls short in providing chances to students to grasp the underlying concepts of fundamentally 3-D phenomena. In addition, one of the main reasons that students are interested in astronomy in the first place is the awe-inspiring beauties of celestial objects. 2-D static figures are not enough to meet the expectations of students and instructors, failing to provide motivation to continue in astronomy. Almost all available illustrations were 2-D figures inadequate to depict complex 3-D real-world scenarios accurately, often hindering student’s comprehensive understanding and even contributing to misconceptions. The case for 3-D simulations is worse because there are only a few freely available 3-D simulations, and they are rudimentary with solid geometrical objects. Moreover, limited opportunities to engage with and solve real-world problems, either individually or collaboratively, can diminish students' general interest in the STEM fields. To address these challenges, our Round25 ALG project aims to bridge the gap by providing essential connections to real-life scenarios and enhancing the representation of 3-D concepts frequently overlooked in traditional textbooks. With our on-going developments of 3-D open education resources, the full adaptation of the no-cost textbook can be fulfilled sooner and the achievement of our goal to provide high-quality educational materials for our students can be accelerated.

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 extended reality including but not limited to VR as education resources. Currently, nine USG faculty members including one member from Georgia State University are actively engaged in the education project called *STEMin3D*[1] with the aim of developing immersive education resources by adopting the 3-D, VR, and/or augmented reality technologies. All investigators of the current proposal are active members of the STEMin3D project.

[1] https://STEMin3D.net

To overcome the aforementioned limitations of the current 2-D education resources, we propose to develop a set of visually stunning, astrophysically correct, modular 3D simulations. These simulations can be projected on traditional 2-D displays or projected into a virtual reality (VR) headset. Simulations can also be ported easily as separate augmented reality (AR) versions that can be viewed with smartphones or tablets (see this AR example from the project website).

With the intended creation of astronomical simulations, all future 1000-level astronomy courses offered by the Department can fully utilize the no-cost OpenStax textbook. Furthermore, in-depth involvement by students in developing, adopting, and evaluating simulations provide invaluable experiential learning opportunities to student team members. They can learn details of real time programming while contributing to the project as paid student programmers. Currently, there are eleven undergraduate students and four graduate students involved in the project.

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

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

3. Action Plan

The new immersive education resources can increase the student motivation (e.g., Atta et al. 2022, Educ. Sci., 12, 890; Blanco et al. 2018, ASP conf. 524). However, improving students' understanding of the related scientific concepts is critically dependent on the appropriateness of selected topics (Blanco et al. 2018) emphasizing the importance of identifying suitable astronomical topics for simulations. We have already identified about two dozen relevant topics (Table 1 and Table 2) where 3D simulations can immensely enhance students' comprehension of core concepts and ignite a heightened interest in those core concepts. Under the scope of this Round25 Affordable Learning Georgia project, we will create simulations for all topics in Table 1 and implemented in classrooms. Simulations for topics in Table 2 will be created in the near future with supports from other grants including future ALG rounds.

Table 1 3-D simulations to be created under the scope of Round24 Affordable Learning Georgia.

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

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

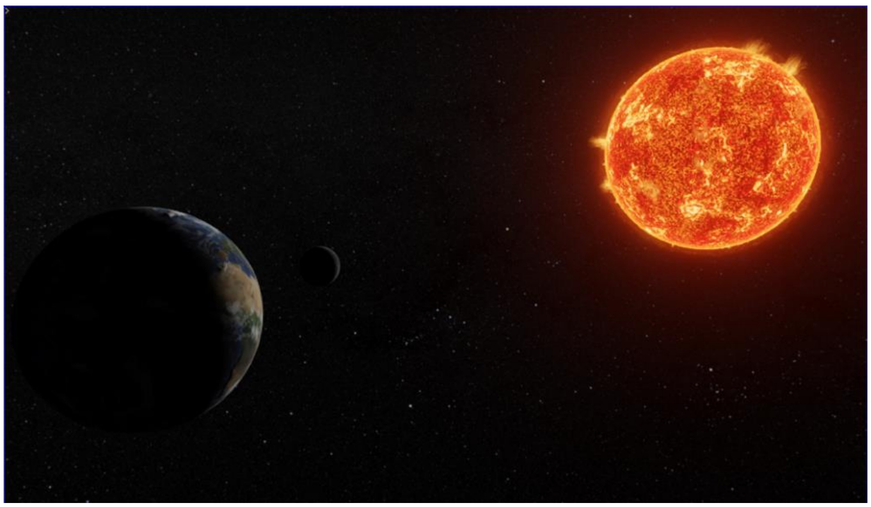

Figure 1 A snapshot image rendered from a 3-D simulation of the Sun-Earth-Moon system created by Blender V3.6.2. This simulation was created by two freshmen UGA students.

Table 2 Additional astronomy topics for future simulation creations.

No.	Topic	Note
7	Precession and change of zodiacs	
8	Light pollution	weather-free public outreach events
9	Solar System Overview	
10	Doppler Effect	can use the audio capability of a VR headset
11	Motions at the Galactic Center	
12	Gravity and Orbits	
13	Retrograde motion of Mars	time-lapse animation of real Sun images
14	Stellar evolution on the HRD	different evolution speed for each mass
15	Telescope (diffraction), atmosphere effect, etc.	
16	Star formation	or the simulation of Turbulent Gas
17	Latitude-dependent Shape change of the Moon	suitable for upper-level astronomy courses
18	Parallax and proper motions	

19	Blackbody radiation: color and temp	Types of spectra: Emission & absorption spectra
20	Cosmic scale	From Earth to the known Universe
21	Hubble Expansion	
22	Binary orbit: Orbital motion (and reflex motions)	Link to the exoplanet discovery through Doppler Shift
23	Asteroids, NEA, PHA.	Good public outreach topic
24	Landing on surfaces of planets	different landscape of each Solar System planet

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

Three astronomy faculty members (Drs. Song, Hall, & Magnani) will create a detailed simulation requirement document for each topic in Table 1 so that student programmers can be guided during the actual development of the simulations. By the time of the announcement of the accepted R25 ALG projects, we will have identified the most suitable technology platform for each topic. Simulation requirement documents will be later transformed to "storyboard" files by non-programming undergraduate students under the guidance of faculty members and these documents will be reviewed and evaluated in regular group meetings. Storyboard files are similar to lesson plans but with modern technology components such as animatics. Drs. Weliweriya and Young, science education experts, will lead efforts in implementing developed simulations into actual courses. This includes: (1) coordinating with astronomy course instructors (Song/Hall/Magnani) for securing IRB approvals, (2) developing student surveys, and (3) analyzing collected data.

Created simulations will be provided through the project webpage, published reports, the ALG portal, and the OpenStax OER common. All results including the resultant simulations, script files, relevant documents will be openly accessible under Creative Commons Attribution License (CC-BY).

Financial supports for this project will not only be limited to R25 ALG. We have already applied for several internal and external grants. The financial support from the R25 ALG will cover efforts in the creation of simulation of six topics. R25 ALG will ensure the timely creation of simulation requirement documents and storyboard files by astronomy faculty members and support undergraduate student programmers. With the support of the R25 ALG, we aim to (1) create simulation requirement documents and storyboard files for 6 selected topics in Table 1, (2) create simulations for the 6 topics, (3) use simulations in AY24-25 courses, (4) perform surveys to assess effectiveness, and (5) analyze the effectiveness of new OERs. We will likely propose for continued support under ALG rounds in the future. By then, we can officially adopt the OpenStax astronomy textbook for all departmental introductory astronomy courses and the adaptation can be sustained over the foreseeable future. Even if external grants are not secured soon, the project can continue with already secured UGA internal grants for this project. The R25 ALG grant will expedite the completion of our project goals.

Three critical tasks from the support of R25 are:

- Create simulation requirement documents and storyboard files: This effort will be carried out by Song/Hall/Magnani. 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. We anticipate about 2 weeks of total efforts (~60 hours) per single topic.
- Develop actual simulations: This will be done by undergraduate programmers under the close mentoring by Song and Weliweriya. As has been done already, we will continue announcing opportunities and recruiting capable undergraduate students among physics/astrophysics majors and engineering students. Involved undergraduate project team members can receive UGA's experiential learning program credits and they are encouraged to register for faculty mentored research courses (PHYS 4960/4970/4980/4990 or ASTR 4960/4970/4980/4990). Although the range of scope and depth for each simulation varies extensively, we anticipate about 15-20 students' hours to create one draft simulation. Experienced students can teach the next group of new students through hand-on interactive sessions and/or detailed tutorials and act as UGA's *Peer Learning Assistant*s.
- Use the created simulations in actual classroom lectures, perform prepared surveys, analyze data, and present the result.

4. Quantitative and Qualitative Measures

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

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

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

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

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

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

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

5. Timeline

- Attending Kickoff Meeting for the Round25 (May 3, 2024)
- Finalize the choice of software and VR Interface for each topic (by Jun 1, 2024): Song/Weliweriya/Hall/Magnani, along with our graduate and undergraduate students, will finish the on-going investigation of assessing the shortcomings of current astronomy education resources and embark on the creation simulations tailored for spring 2025 Astronomy courses.
- Simulation requirement documents and storyboard files for 6 selected topics (by Jul 1, 2024): Song/Hall/Magnani
- Attending Midpoint Check-in meeting (Jan 10, 2025)
- External Funding Initiative (Jul 2024): seek external funding by submitting a grant proposal to the National Science Foundation's Improving Undergraduate STEM Education Program (NSF: IUSE). Also submit a proposal for the Unreal Engine's Epic Megagrant opportunity.
- Finish the development of simulations by student programmers (by Jan 1, 2025): Song/Weliweriya and undergrad students.
- Adopt new simulations in 2025 Spring semesters: Song/Hall
- Student surveys: Weliweriya/Young and graduate students obtain data from the initial in-class trials and initiate the analysis (during 2025 Spring).
- Submission of the Final Report and OERs to ALG (June 2025).
- Data Analysis and Publication (Summer 2025): Finish the analysis of the data obtained in 2025 Spring trials. We will prepare and present articles at prominent conferences, including AAPT (American Association of Physics Teachers) and PERC (Physics Education Research Conference). Undergraduate students will be encouraged to participate in UGA's Center for Undergraduate Research Opportunities (CURO) and present the results at CURO Symposium. Five undergrad student team members applied for the AY2024 CURO Research Awards and all of them were selected.

6. Budget

Dr. Inseok Song will oversee the project. He will create simulation requirement documents for four selected topics and create matching storyboard files. With co-I Weliweriya, he will guide undergraduate student programmers in the development of simulations. $5,000 is requested for 2024 summer salary support and fringe.

Dr. Nandana Weliweriya will lead the effort in creating student surveys, securing relevant IRB approvals, obtaining classroom data, and analyzing data. He will also co-mentor undergraduate programmers with the PI. $5,000 is requested for 2024 summer salary support and fringe.

Drs. Cassandra Hall and Loris Magnani will create a simulation requirement document for one selected topic each. They will mentor undergraduate programmers for the selected topic via regular scheduled meetings. No summer salary is requested.

Dr. Nicolas Young will participate in the project as an unfunded collaborator. He will work closely with Dr. Weliweriya in classroom implementation of the created simulations and subsequent analysis.

Graduate students (Robin Allen): He is co-advised by Drs. Song and Weliweriya, and will lead the classroom data acquisition, analysis, and presentation. His RA support of $10,000 is requested from this grant.

Undergraduate student programmers: We anticipate hiring about 10 students total as paid programmers to develop 3-D simulations for 6 topics for a total of about 1,000 hours. The total amount of hourly pay throughout the project duration is anticipated to be $10,000.

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

7. Sustainability Plan

The eventual transformed astronomy courses (ASTR1010, ASTR110, and ASTR1420) will be offered in every academic year as have been in the past. The newly created 3-D astronomy open education resources will expedite the full adaptation of the OpenStax astronomy textbook which began 2019 under the support of ALG Round 14. Already created lecture notes, homework, and assessment materials in conjunction with the newly created initial batch of astronomical 3-D simulations can solidify the continued adaptation of the OpenStax textbook. This transformation is a department-wide transformation and the listed investigators in this proposal represent the whole group of instructors in the department for ASTR1010, ASTR 1110, and ASTR1420. Under future ALG round (e.g., Round 26 or 27) and other fundings, we will continue create more simulations for topics listed in Table 2, and such continued updates will make the transformation expand into upper-level astronomy courses such as ASTR3010 (Observational Astronomy) and ASTR4010 (Stellar Astronomy).

Through the project webpage, published reports, ALG portal, and the OpenStax OER common[2], all created simulations will be shared with the broad STEM education community under CC-BY resulting in a boarder impact. A handful of research papers will be created as graduate student thesis works and other external fundings will be actively sought after. This project is to be continued over a foreseeable future hence the effort can be sustained for a long time at the department.

Creative Commons Terms

I understand that any new materials or revisions created with ALG funding will, by default, be made available to the public under a Creative Commons Attribution License (CC-BY), with exceptions for modifications of pre-existing resources with a more restrictive license.

Accessibility Terms

I understand that any new materials or revisions created with Affordable Learning Georgia funding must be developed in compliance with the specific accessibility standards defined in the Request for Proposals.

[2] https://oercommons.org/groups/openstax-astronomy/1283/

Letter of Support

Please provide the name and title of the department chair (or other administrator) who provided you with the Letter of Support.

Craig Wiegert (cwiegert@uga.edu) *Head of the Physics and Astronomy*

UNIVERSITY OF GEORGIA

Franklin College of Arts & Sciences
Department of Physics & Astronomy

28 February 2024

Dear Proposal Committee:

This letter is to express my support for Dr. Inseok Song's application for Round 25 of the Affordable Materials Grant. Dr. Song and his colleagues have been steadily working to increase the affordability of course materials for introductory astronomy courses at the University of Georgia, and this proposal is the next step in that transformation. Once this grant work is completed, the resources will be available for use every subsequent semester in ASTR 1010, ASTR 1110, and other introductory astronomy courses. The faculty who regularly teach these courses are committed to continued use of these resources.

If funded, Dr. Song will work with our dedicated grants management and business services staff in the Franklin College of Arts and Sciences.

Sincerely,

Craig C. Wiegert

Craig C. Wiegert
Department Head
Associate Professor of Physics

Grants or Business Office Acknowledgment Form

Please provide the name and title of the grants or business office representative who provided you with the acknowledgement form.

Ginger Williams, ginger33@uga.edu
Franklin College of Arts and Sciences | Research Administrator
214 Old College | Athens, GA 30602-1588 | 762-499-0484

Grants/Business Office Acknowledgement Form

The Grants or Business Office signature below indicates the following:

- ☐ The Grants/Business Office is aware of this applicant's intent to apply for an Affordable Materials Grant.
- ☐ The applicant has contacted the institution's appropriate Grants/Business Office to discuss application and funding procedures.

Inseok Song
____
Applicant Name

Ginger Williams
____
Grants/Business Office Representative Name

____
Grants/Business Office Representative Signature