Affordable Learning Georgia Affordable Materials Grants  
Continuous Improvement Grants Final Report

(or Mini-Grants, for R17 and earlier)

# General Information

Date: May 15, 2025

Grant Round: 25

Grant Number: M267

Institution Name: Georgia Institute of Technology

Team Members

* Greg Mayer, Academic Professional, School of Math, greg.mayer@gatech.edu
* Hunter Lehmann, Academic Professional, School of Math, hlehmann3@gatech.edu
* Elizabeth Holdsworth, Head of Academic Engagement, Georgia Tech Library, [liz.holdsworth@library.gatech.edu](mailto:liz.holdsworth@library.gatech.edu)

Project Lead: Greg Mayer

Course Name(s) and Course Numbers: Multivariable Calculus MATH 2551

Final Semester of Project: Spring 2025

Number of Students who Used Course Materials

Webwork sets were used in regular course sections that meet in-person in Fall 2024 and Spring 2025.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Fall 2024 | | Spring 2025 | |
| Number of sections | | 7 | | 9 |
| Average enrollment per section | | 101 | | 110 |
| Total enrollment | | 708 | | 986 |

Webwork sets we also used in an online section that is offered once per year in spring semesters. The enrollment is relatively larger than our in-person sections.

|  |  |  |
| --- | --- | --- |
|  | Fall 2024 | Spring 2025 |
| Number of sections | 0 | 1 |
| Average enrollment per section | 0 | 1,126 |
| Total enrollment | 0 | 1,126 |

# Project Narrative

Describe the course of your revision or ancillary creation project, including

* A summary of your project’s purpose, plan, and timeline.
* The original works which were revised or added to, with links. For example, if you revised an open textbook, give the title, author, and link.
* A narrative description of how the project’s plan was carried out.
* Lessons learned, including anything you would do differently next time.

## Project Context

This project aimed to involve undergraduate students in developing ancillary materials for MATH 2551 at The Georgia Institute of Technology (GT).

MATH 2551 is Multivariable Calculus, and is part of a sequence of calculus and linear algebra courses offered at GT. It is a 4-credit multi-section course that enrolls over 1000 students in the fall, over 800 students in the spring, and over 100 students in the summer. Additionally, Georgia Tech has a large Dual Enrollment program that enrolls Georgia high school students every spring: the Distance Math Program (https://admission.gatech.edu/dual-enrollment/distance-math).

MATH 2551 uses a commercial textbook that is bundled with an online homework system (https://www.pearson.com/en-us/subject-catalog/p/thomas-calculus/P200000007103).

Unfortunately, the commercial textbook and its paired online homework system are inseparable. There are discounted bundles to cover the introductory mathematics courses that many GT students must complete. But switching to an open textbook provides no financial benefit to the student without an online homework system to go with it.

A team of Georgia Tech faculty in the School of Mathematics who regularly teach MATH 2551 have been working on transitioning to no-cost Open Educational Resources (OERs) since Spring 2023. Most of the progress that has been made in transitioning to OERs has focused on developing assessments in two platforms.

* **WeBWorK**: Georgia Tech School of Math faculty have developed a set of homework assignments in WeBWorK (<http://webwork.maa.org>) to replace the publisher online homework system. This platform is an open online homework system that was developed by the Mathematical Association of America with support from the National Science Foundation. WeBWorK allows faculty to create their own problems and can cover a wide range of subjects. The GT Office of Information Technology (OIT) supports WeBWorK for all Georgia Tech courses, and WeBWorK homework sets that we developed are now being used to provide weekly graded homework. They do not, however, offer additional practice beyond their intended purpose: graded homework sets.
* **Canvas Quizzes:** Canvas is the centrally supported LMS at GT. GT School of Math faculty have been developing a set of assessments in [Canvas Quizzes](https://community.canvaslms.com/t5/Canvas-Basics-Guide/What-are-Quizzes/ta-p/68). We use Canvas quizzes for interactive formative assessment (i.e. – extra practice). Having these sets as Canvas Quizzes allows us to make assessments available within the LMS and allows us to make them available to all GT students through an open website that we are developing (https://gatech.instructure.com/courses/353656). However, the quizzes that have been developed so far consist only of a few review sets for exams and so they do not currently cover everything that students are expected to learn in multivariable calculus. But the sets that have been developed so far are available on OER Commons (https://oercommons.org/courseware/lesson/108508).

These assessments have been aligned to the OpenStax Calculus Volume 3 textbook (<https://openstax.org/details/books/calculus-volume-3>).

The Canvas quizzes were developed using funds from a fellowship that provided funding for student assistants to develop a set of Open Courses (<https://cos.gatech.edu/news/cos-inclusive-excellence-faculty-fellowship>). However, these funds could not be used to hire student assistants beyond April 2024 and we did not have enough exercises in the Canvas quizzes to cover the entire course.

In most sections of MATH 2551 the commercial textbook is recommended but no longer required. But at the time we applied for this grant, the section offered for high school students in the Distance Math Program still required the publisher textbook and homework system to meet the specific needs of this program.

## Project Goals

Our project had the following goals.

* Develop roughly 80 webwork exercises that can be used to create four module tests in WeBWorK. These sets will be made for the Distance Mathematics section as graded homework and will be available to the remaining sections of MATH 2551 as extra practice for their exams.
* Develop roughly 170 multivariable calculus exercises aligned to the four chapters of OpenStax Calculus Volume 3 that are covered in MATH 2551 as Canvas Quizzes. We would like to develop around five exercises for each of the 27 sections from these chapters. These exercises can be placed under a Creative Commons BY license and will be developed as Quizzes within the Canvas Learning Management System (LMS).
* Further extend the impact of our work by making our Canvas quizzes available on a website available to the public: <https://gatech.instructure.com/courses/381538>.
* Further extend the impact of our work by sharing our resources on OER repositories (such as OER Commons) and the GT Canvas Commons, which allows any GT instructor to easily import these quizzes into their Canvas site.
* Further extend the impact of our work by sharing our resources on the WeBWorK open problem library (<https://webwork.maa.org/wiki/Open_Problem_Library>).

Our project set out to hire student assistants who have completed MATH 2551 within the last 18 months. We anticipated that having student assistants create learning materials would yield additional benefits, both for the student creators and the learners in this course.

## Project Timeline

### Summer 2024

* Greg Mayer advertised undergraduate student assistant positions within Georgia Tech and reviewed applications.
* Hired six assistants who have completed MATH 2551 within the last 18 months with a final letter grade of A or B.
  + Four assistants were hired to develop assessments in Canvas Quizzes
  + Two assistants were hired to develop assessments in WeBWorK using the ALG grant
* Student assistants were hired for 5 hrs per week for 9 weeks at $15 per hour.
* Greg Mayer met with student assistants on a weekly basis for roughly half an hour each week.
* Mayer was involved in editing and revising materials made by students.
* Assistants developed assessments that are aligned to OpenStax Calculus 3.
* Most WeBWorK assessments were developed by selecting problems from the WeBWorK Open Problem Library (OPL). Assistants adapted the curriculum to our course by refining or added solutions, hints, and additional scaffolding.

### Fall 2024

* Greg Mayer supervised the four assistants hired to create canvas quizzes in the summer to continue creating canvas quizzes in the fall.
* WeBWorK exercises were piloted in the on campus sections of MATH 2551.
* Assistants were hired using other funds to continue developing the webwork sets by adding hints, solutions, and scaffolding.
* Hunter Lehmann addressed any typos in the WeBWorK exercises.
* Canvas quizzes were made available on the Open Course site for multivariable calculus. Surveys and analytics will help us evaluate the Canvas quizzes.
* Greg Mayer presented work on this project along with other related work at the annual Kennesaw SOTL summit in September 2024.

### Spring 2025

* One assistant was hired using other funds to refine the Canvas Quizzes by addressing typos and formatting errors. Greg Mayer supervised them.
* WeBWorK exercises were again used in the on-campus sections of MATH 2551.
* WeBWorK exercises were used in the online section of MATH 2551 for dual enrolled students.
* Canvas Quizzes were also used in the online section of MATH 2551 for dual enrolled students.
* Hunter Lehmann addressed any typos in the WeBWorK exercises.
* Greg Mayer presented work on this project along with other related work at the annual All Things Open conference in April 2025.

# Materials Description

Describe all the materials you have created or revised as part of this project. These descriptions may be used in the [OpenALG](https://alg.manifoldapp.org/) repository description field. Include the [*open license your materials will be shared under*](https://creativecommons.org/share-your-work/)—for most materials, this will be an Attribution 4.0 License (CC BY) as required in the Grants Request for Proposals.

There are two components contained in this resource: 1) a set of Canvas Quizzes, and 2) a set of WeBWorK exercises.

## Canvas Quizzes

* This resource contains assessments that are aligned to the OpenStax Calculus Volume 3 textbook which focuses on multivariable calculus. The assessments are:
  + Four Chapter Tests that are aligned to specific chapters of the OpenStax textbook.
  + 27 Quizzes that are aligned to specific sections of the OpenStax textbook.
  + One Final Exam
* All assessments are in QTI format so they can be imported to platforms that support QTI.
* Most questions in the tests have explanations and alternate versions that are in question banks.
* These assessments have been used to give students additional practice to learn multivariable calculus.
* All questions are open for public use.
* Quiz questions use a mix of true/false, multiple choice, and numeric responses.
  + Test 1 has 16 questions and looks at OpenStax Chapters 2 and 3, covering the following topics: Dot products, cross products, and projections; Equations for lines, planes, and curves; Parametric representations of vector-valued functions; Tangent/normal vectors, arc length, and curvature.
  + Test 2 has 14 questions and looks at OpenStax Chapter 4, covering the following topics: Partial derivatives, tangent planes and linear approximations, critical points and Lagrange multipliers, gradients and directional derivatives.
  + Test 3 has 15 questions and looks at OpenStax Chapter 5, covering the following topics: Double integrals (in Cartesian and polar coordinates), Triple integrals (in Cartesian, cylindrical, and spherical coordinates), order of integration, change of variables using the Jacobian.
  + Test 4 has 13 questions and looks at OpenStax Chapter 6, covering the following topics: Line integrals and vector fields, Green's Theorem, Conservative vector fields and potential functions, Stokes' Theorem, Divergence Theorem.
  + The final exam incorporates questions from all of the above topics.
  + The 27 other quizzes are linked to specific sections of the OpenStax textbook.
* Each assessment uses question banks. In total, there are 552 questions in the question banks.
* Many student assistants contributed to developing these resources. Many thanks to: Sophie Andersen, Neil Dave, Paulo Carey, Claire Haskell, Melissa Leng, Selin Osman, and Kimberly Tsung for their effort.

## WeBWorK Exercises

* This resource contains
  + the exercises developed by this grant,
  + exercises that were sourced from the WeBWorK Open Problem Library and subsequently modified by our team, and
  + set definition files that define the problem sets.
* All exercises sourced from the OPL are under a GNU Free Documentation License 1.2. Further information about WeBWorK copyright is here: <https://webwork.maa.org/wiki/WeBWorK:Copyright>.
* There are 186 exercises in 17 sets. Four of these sets review material from 13 homework sets.
* Two student assistants contributed to developing these resources. Many thanks to Seth Brunner and Sidharth Kolichala for their work.

# Materials Links

If you are hosting your materials in places other than OpenALG, please provide these links in this section. Otherwise, leave blank. Note: we cannot access D2L or Canvas links.

## Canvas Quizzes

* We have placed our Canvas Quizzes on the OER Commons repository: [*https://oercommons.org/courseware/lesson/108508*](https://oercommons.org/courseware/lesson/108508)
* We have also listed our Canvas Quizzes resources on the MERLOT repository: [*https://merlot.org/merlot/viewMaterial.htm?id=773418058*](https://merlot.org/merlot/viewMaterial.htm?id=773418058)
* *Our Canvas quizzes should be accessible to the general public at this website:* <https://gatech.instructure.com/courses/381538>

## WeBWorK Sets

* We have submitted a small portion of our WeBWorK exercises to the Open Problem. They are currently under review.

# Future Plans

* Describe any planned or actual papers, presentations, publications, or other professional activities that you expect to produce that reflect your work on this project.
* Describe any plans to revise or add to these materials in the future.

## Presentations and Conference Proceeding

Two presentations were given that incorporated elements of our work on this project.

* Mayer, G., & Reikes, S. (2025, April). From Barriers to Breakthroughs: Leveraging Undergraduate Teams for Inclusive Open Courses. Presented at the All Things Open Conference. Online conference organized by Kennesaw State University Libraries.
* Mayer, G., & Reikes, S. (2024, September). From the classroom to the community: Guiding undergraduate student teams to create OER-based online courses for inclusive and equitable learning. Presentation at the 31st Annual Scholarship of Teaching and Learning Conference. Online conference organized by Kennesaw State University.

As a result of the more recent All This Open conference, the conference committee invited us to submit an article for their conference proceedings. The submission deadline is May 31, 2025. We are not sure what the anticipated publication date would be. But the committee is working with the Journal of Open Educational Resources in Higher Education (JOERHE) to publish the proceedings. Greg Mayer and Stephanie Reikes are working together to submit their proceedings which would include work funded by this grant.

## Curriculum Implementations

* We plan on using the course materials that were developed with this grant in the fall semester and beyond.
* We plan on no longer requiring the textbook and online homework system for the online section of MATH 2551 that only enrolls dual enrolled students. As per state policy, dual enrolled students cannot be required to pay for course materials, and so the institution was paying for these materials. The textbook with online textbook is currently priced at $106.65 for a 130-day digital rental (other options are available but are less desirable), and our enrollment is projected to be at least 1,110. The total course material savings to the institution are at least $117,000 per year. Likely the savings are greater than this as 1) we would probably have used a bundle at a higher price point and 2) enrollment in Distance Math tends to increase every year. Precise enrollments are not known until
* Canvas quizzes are available on an open course site that is available to the general public. We are planning to keep the site publicly available as long as is possible.

## Future Curriculum Development

* Greg Mayer is currently supervising a student assistant who is further refining the WeBWorK sets over the Summer 2025 semester. This objective of this sub-project is to create more problems to the Module Review sets to better prepare students for formative assessments. We will likely extend this project into the fall semester as well with the current assistant and/or hire another assistant.
* We have submitted our WeBWorK exercises that we developed to the WeBWorK Open Problem Library in March 2025. We are currently waiting on whether they will be approved and adopted into their library for other institutions to use them.