

**RTG: electronic Computational Homotopy Theory Research
Community
Year 2 report**

FUNDED PARTICIPANTS

Funded participants in Year 2 were:

- David Mehrle, Kentucky, postdoctoral researcher. The project paid half of his academic year salary and also provided summer support.
- Jack Carlisle, Notre Dame, postdoctoral researcher. The project paid half of his academic year salary and also provided summer support.
- Sarah Petersen, Colorado, postdoctoral researcher. The project paid half of her academic year salary and also provided summer support.
- Scotty Tilton, UC San Diego, graduate student. The project fully supported him during the academic year, including tuition and stipend, and provided summer support.
- Danika Van Niel, Michigan State, graduate student. The project fully supported her during the academic year, including tuition and stipend.
- Hassan Abdallah, Wayne State, graduate student. The project fully supported him during the academic year, including tuition and stipend.
- Millie Rose, Kentucky, graduate student. The project fully supported her during the academic year, including tuition and stipend.
- Irina Bobkova, Texas A&M, faculty. The project will support her for 0.75 months in Summer 2024 to direct the Summer REU.
- Six undergraduate students. The project will support these students for their participation in the Summer 2024 REU.

RESEARCH ACTIVITIES

Reading seminars. We hosted two research-oriented reading seminars. The topics were algebraic vector bundles and Hopf rings.

Algebraic vector bundles seminar. The seminar was organized by postdoctoral researchers Morgan Opie (UCLA) and Thomas Brazelton (Harvard), assisted by funded graduate students Scotty Tilton (UC San Diego) and Millie Rose (Kentucky). The seminar attracted approximately 60 participants, consisting of a mixture of graduate students, postdoctoral researchers, and tenure-track/tenured faculty. About half of the participants were located at U.S. institutions.

The organizers selected participants to give weekly talks on the general subject of algebraic vector bundles. We have had great success with this model of having participants take turns giving presentations.

In this seminar, the organizers experimented with a regular schedule of office hours for informal interaction and collaboration. The organizers invited a series of subject matter experts who were not otherwise involved in

the seminar. The participants were very enthusiastic about this aspect of the seminar, so we will repeat it in future seminars.

Seminar on Hopf rings. The seminar was organized by funded postdoctoral researcher Sarah Petersen (Colorado), assisted by Torgeir Aambø (NTNU) and Danika Van Niel (Michigan State). The seminar attracted approximately 40 participants, consisting of a mixture of graduate students, postdoctoral researchers, and tenure-track/tenured faculty. About half of the participants were located at U.S. institutions.

As for the algebraic vector bundles seminar, participants took turns giving presentations.

Research seminar. We held a regular research seminar that met once per month for two talks. The seminar was managed by Guchuan Li (Peking), co-PI J.D. Quigley (Virginia), funded postdoctoral researcher Jack Carlisle (Notre Dame), funded graduate student Scotty Tilton (UC San Diego), and funded graduate student Hassan Abdallah (Wayne State).

The 16 speakers were nearly evenly split between postdoctoral researchers and tenure-track/tenured faculty. Most speakers were located in the United States, with additional speakers from China, Israel, the Netherlands, and Denmark. Six of the speakers were women.

Video recordings of most seminars are available to the public. Analytics suggest that the videos earn a significant on-going viewership.

We experimented with a Reading Group for graduate students to prepare for some of the talks. The speakers recommended background reading, such as introductions and specific sections of research papers. We announced the suggested readings in advance, and then graduate students met the day before the seminar to discuss the material. The Reading Group was managed primarily by graduate students with only minimal guidance from the PI. This simple management structure makes it sustainable, and we plan to continue to offer Reading Groups in the 2024–2025 academic year.

Mini-courses. Guchuan Li (Peking) and funded postdoctoral researcher Sarah Petersen (Colorado) organized two mini-courses.

In response to current events, Doug Ravenel (Rochester) gave a mini-course in December 2023 on background and context for the Telescope Conjecture. The goal of the mini-course was not to present information about the recent disproof of the conjecture, but rather to give participants the necessary background in order to appreciate the importance of this significant breakthrough in stable homotopy theory.

Julie Bergner (Virginia) gave a mini-course in May 2024 on Segal 2-sets. This topic belongs to abstract homotopy theory, so it falls somewhat outside the main scientific scope of the eCHT project. One benefit was that we attracted a number of participants who had not previously engaged in eCHT activities.

Video recordings and lecture notes for both mini-courses are available to the public. Analytics suggest that the videos earn a significant on-going viewership.

Research workshop. Funded postdoctoral researcher Sarah Petersen (Colorado) will lead a one-week research workshop in June 2024. There will be approximately 20 participants, consisting of a mix of graduate students, postdoctoral researchers, and tenured/tenure-track faculty. The workshop format will be an online version of the format of an American Institute of Mathematics (AIM) workshop. Participants will be introduced to open problems and will work in groups on these problems.

The workshop will occur after the date of this report, so more details will appear in a future report.

INSTRUCTIONAL ACTIVITIES

We offered two synchronous online courses in Winter 2024 that were meant to serve as substitutes for comparable in-person courses. In both courses, students were assigned formal grades. These grades were reported directly to the students' home institution advisors.

We advertised the courses through a variety of channels, including:

- Subject-specific mailing lists such as `algtop-1`.
- The American Mathematical Society's Mathematical Opportunities webpage:
www.ams.org/opportunities.

Algebraic topology: homotopy theory. The Homotopy Theory course was taught by funded postdoctoral researcher Jack Carlisle and assisted by funded graduate student Scotty Tilton. It was intended for first-year graduate students.

Nine students completed the course, although an additional six students withdrew. The attrition rate was higher than expected and represents a concern for the sustainability of online first-year graduate courses. Another concern was that only five of the original fifteen students were from U.S. institutions.

On the other hand, enrollment in the course was significantly better than in the first-year course on Homology and Cohomology that was offered in Winter 2023. The eCHT project is slowly making progress at attracting participants from earlier academic career stages.

Students were required to submit homework assignments on a regular schedule, as well as a video project and a written project on a topic related to the course. They were also required to take traditional written exams.

Stable homotopy theory. The Stable Homotopy Theory course was taught by funded postdoctoral researcher David Mehrle and assisted by funded graduate students Hassan Abdallah and Millie Rose. It was intended for mid-career graduate students.

Fifteen graduate students enrolled in the course. All but one of these students were from U.S. institutions. The applicant pool for the course was particularly strong. We were only able to accept half of the highly qualified applicants. There is very clearly demonstrated demand for online courses in stable homotopy theory. This course could probably be offered every year on a permanent basis.

Each week, the course consisted of:

- A one-hour lecture given by a student, following an outline provided by the instructor.
- A one-hour small group problem session in which students discussed homework problems.
- A written homework assignment to be completed individually.
- A private meeting between the instructor and the student speaker for the following week.
- Two 30-minute office hour sessions with the instructor.
- A variety of office hours with the graduate student assistants.

Office hours with both the instructor and the graduate student assistants were heavily utilized.

While most of the eCHT activities have been successful, we are particularly proud of the success of the Stable homotopy theory course. This course provides a viable model for courses on a variety of topics that are intended for mid-career graduate students. There is great demand for such courses from students because many institutions are unable to offer low-enrollment courses for advanced graduate students. Advanced graduate students are very mature students, and they take ownership for their own learning. This maturity overcomes many of the deficiencies of online instruction.

Kan seminar. The Kan seminar was led by Sarah Petersen, assisted by Hassan Abdallah and Danika Van Niel. Fourteen graduate students participated in the seminar. Each student gave a presentation about a classic paper in algebraic topology. All but one student were enrolled at U.S. institutions. The seminar is an electronic version of the well-known Kan seminar at MIT.

eCHT has offered online Kan seminars every year since 2019. They have been one of our most popular activities. They are well-suited for graduate students who are making the difficult transition from coursework to independent study. We plan to offer Kan seminars yearly in the future.

REU

Summer 2023 REU. The Summer 2023 REU was led by Kyle Ormsby (Reed College) assisted by Christy Hazel (UCLA) and Scotty Tilton (UCSD). The students participated for five hours per day for six weeks. Students engaged in a variety of activities during work hours, including lecture, small group work, and individual work. Students met in various combinations with the REU staff.

The PI Dan Isaksen handled all of the administrative aspects of the REU. This allowed Ormsby, Hazel, and Tilton to focus solely on the scientific aspects of the REU.

We advertised our REU through several channels:

- The American Mathematical Society: www.ams.org/opportunities
- The Institute for Broadening Participation: pathwaystoscience.org
- The Math Alliance: mathalliance.org
- The Math REU Programs website: www.mathreuprograms.org
- NSF's list of REU Sites: Mathematical Sciences:
www.nsf.gov/crssprgm/reu/list_result.jsp?unitid=5044
- Individual emails to administrators at historically black colleges and universities and Hispanic-serving institutions.

Overall, we considered the REU advertising to be a success. We received a large, diverse applicant pool of 87 applications.

Of the six participating undergraduate students, three were women, including one transgender woman. One of the women was married, and one student was disabled. We draw attention to these latter two students because they belong to groups that are often excluded from in-person REUs for non-academic reasons. This is very strong evidence of the social value of offering some REUs in an online format.

The REU work led to a manuscript [BHK⁺23] that has been submitted for publication.

Summer 2024 REU. This report precedes the main activities of the Summer 2024 REU, so we cannot report yet on outcomes.

Based on our experience from the 2023 REUs, we narrowed our advertising efforts to the most effective channels:

- The American Mathematical Society: www.ams.org/opportunities
- The Institute for Broadening Participation: pathwaystoscience.org
- The Math REU Programs website: www.mathreuprograms.org
- NSF's list of REU Sites: Mathematical Sciences:
www.nsf.gov/crssprgm/reu/list_result.jsp?unitid=5044

Overall, we consider the REU advertising to be a success. We received a large, diverse applicant pool of more than 100 applications. All six of our offers were accepted. This is evidence that online REUs are an attractive option for some undergraduate students.

Of the six participating students, two are women.

PROFESSIONAL DEVELOPMENT AND COMMUNITY BUILDING

Office hours. Following a model from the Applied Algebraic Topology Research Network (AATRn), we experimented with a series of faculty office hours. We invited a senior faculty member to hold an online office hour that was open to the public. We held seven of these events over the course of the academic year. Attendance was consistently in the range of 5–10

people, which is nearly ideal for this kind of event. Attendance was high enough to sustain conversation, but small enough that everyone got to participate. Most participants were graduate students, although some senior people stopped by to say hello to their professional acquaintances.

The office hours were organized mostly by funded graduate students with minor assistance from the PI.

Based on the success of our experiment, we plan to continue offering office hours in the future. Our target is to hold 12 office hours during the 2024–2025 academic year.

Writing group. In Fall 2024, we experimented with an online writing group that met on a regular weekly schedule. Attendance was poor, so the project was discontinued.

Zulip. The eCHT community uses the Zulip chat platform. Zulip has features that are similar to the better-known Slack, but it has excellent LaTeX integration. Separate channels are created for the various seminars and courses. There are also channels reserved solely for graduate students.

ASSESSMENT

Course and reading seminar evaluations. We conducted a formal evaluation for each course and reading seminar. Participants were invited to provide anonymous feedback. Response rates were appropriately high. Overall, participants were enthusiastic about the experiences. Some participants offered specific suggestions that we intend to act upon in future years.

Annual report. A draft version of this report was circulated amongst the co-PIs and Senior Personnel. Their feedback was incorporated into the final version of this report.

Interviews with funded participants. The PI conducted individual end-of-year interviews with the three funded postdoctoral researchers. We received valuable feedback that will contribute to minor improvements in the project in future years:

- The funded participants reported a positive impact on their research productivity.
- The reduction in instructional responsibilities was consistently reported as a major benefit.
- The postdoctoral researchers appreciated that they were only 50% committed to eCHT. This allowed them to participate with in-person communities at their home institutions.

REU assessment. We assessed the Summer 2023 REU at its end through:

- an evaluation form, to be submitted by the undergraduate participants.
- individual exit interviews between the PI and each undergraduate participant.

- a group debriefing involving all of the leaders of the program.

Overall, both students and leaders were enthusiastic on the experience. A disabled student was especially appreciative of the opportunity because she felt excluded from REU opportunities that require travel.

Our results point very strongly to the importance of offering both in-person and online REUs to meet the needs of a variety of undergraduate students.

BUDGET AND ADMINISTRATION

The project administration requires cooperation amongst a variety of departments at different institutions, as well as their sponsored programs offices. There was some concern that these complicated interactions could lead to ineffective management. This turned out not to be an issue. Some effort was involved to make sure that all units communicated with each other, but there were no major problems of this nature.

CONDUCT

Unfortunately, many online communities degenerate into unhealthy, negative interactions. We are consciously building a healthy online community. This requires the leaders to take active roles in setting constructive tones. We are pleased with the results of our efforts.

We wrote and posted an official eCHT Code of Conduct:

s.wayne.edu/eht/eht-code-of-conduct.

We offer an online reporting tool, with optional anonymity. We are fortunate that we received no reports.

In the 2023–2024 academic year, one incident was reported verbally to the project director. It was resolved directly between the conflicting parties.

In the 2024–2025 academic year, no incidents were reported.

REFERENCES

- [BHK⁺23] Linus Bao, Christy Hazel, Tia Karkos, Alice Kessler, Austin Nicolas, Kyle Ormsby, Jeremie Park, Cait Schleff, and Scotty Tilton, *Transfer systems for rank two elementary Abelian groups: characteristic functions and matchstick games* (2023), available at [arXiv:2310.13835](https://arxiv.org/abs/2310.13835).