Creating a collaborative undergraduate geoscience research community

Lon Abbott and Jennifer Stempien, Department of Geological Sciences

Introduction to the Project and its Objectives

Research shows that undergraduate student participation in authentic research opportunities (ARO) enhances persistence in STEM fields by strengthening student perceptions of themselves as scientists (e.g. Singer et al., 2005; Graham et al., 2013; Linn et al., 2015). Longitudinal studies show that students who participated in an ARO, including members of underrepresented groups, were 14-17% more likely to persist in STEM fields on to graduate school compared with their colleagues who did not (Thiry et al., 2011; Fechheimer et al., 2011). However, these same studies pointed out that, despite the benefits of undergraduate research, the designs of many such research programs have shortcomings that can inhibit wider student participation or even reduce student persistence in the sciences.

Currently there are two ARO models: 1) the individual undergraduate research experience (URE), which typically involves one student working alongside a graduate student or faculty member, and 2) the course–based undergraduate research experience (CURE), which involves a group of students who work on a pre-set project with guided exploration. Most AROs are designed to be either a URE or a CURE, not both together (Linn et al., 2015) and few occur at large research universities (Fechheimer et al., 2011; Thiry et al., 2011).

Linn et al. (2015) concluded, based on a meta-analysis of AROs in the literature, that UREs are typically student initiated and highly competitive, meaning that most participants already intend to persist in the sciences. That makes assessment of the URE's role in enhancing persistence speculative. Thiry et al. (2011) demonstrated that CUREs, thanks to their guided exploration of the relevant literature, are appropriate for students who are still deciding whether or not to pursue science. Students benefit most when they grasp the underlying theories and concepts in the scientific discipline, and CUREs are more effective than UREs for establishing that foundation (Thiry et al., 2011; 2012). Despite these many benefits, CUREs also have some drawbacks. The emphasis of most CUREs on a short-term project can give students an unrealistic impression of the scientific process. Furthermore, many students lack ownership of the research project, due, in part, to the absence of one-on-one faculty mentoring. Regardless of which model is used, to be successful the research experience must be integrated with the student's expectations and beliefs and it must be of sufficient duration for students to build their identities as scientists. Linn et al. (2015) found that one- or even two-semester-long research experiences did not foster the desired student progression from data collection to scientific interpretation.

We propose to pilot a unique ARO design within the Department of Geological Sciences that combines the benefits of the faculty-student mentoring and apprenticeship characteristics of an URE with the peer mentoring and guided literature discussion of a CURE. This project will create a collaborative multi-semester undergraduate research community. Undergraduate students participating in the ARO will: 1) conduct independent but interrelated research projects, each exploring one facet of the geologically recent evolution of the American Southwest; 2) participate in a 1-credit research seminar that will place each student's project into a broader scientific context by exploring the scientific literature and that will promote each student's role as a peer mentor and collaborator in answering a larger research question.

We will recruit students who are at different stages of their career so that the younger students can benefit not only from faculty mentoring, but can also learn from their undergraduate 'elders'. Research shows that such peer mentoring effectively orients and informs students participating in UREs. Today's neophytes will, in subsequent semesters, become the elders who mentor a new group of undergraduate researchers, thereby making the research community self-sustaining.

Model attributes that will encourage students from a wide range of backgrounds to consider a research experience and that will make implementation practical at an R1 university include:

1) Increased faculty mentorship: Mentoring of students will be shared between the research seminar directors and the mentors of the individual projects. This will make it possible for students to interact frequently with faculty mentors without placing an undue time burden on the tenure-track faculty participants, who are eager to work with many undergraduate researchers but who face serious time constraints. It is this faculty mentoring that produces the most meaningful and effective discussions about what it means to do science, but such interactions are a "scarce resource" in most ARO designs, according to Linn et al. (2015).

2) Multi-level mentoring structure: Abundant peer mentoring, a significant benefit of the CURE model (Strawn and Livelybrooks, 2012), is built into the program, along with faculty-to-student mentoring. Because all students will be working on projects that examine one aspect of a larger question, and that question, students will actively share their ideas and discoveries with each other.

3) Inclusive excellence through community research: The model is an effort to develop a research community that involves undergraduate students, graduate students, and faculty, all of whom share the common goal of answering a fundamental research question. Participating students will develop connections with each other and with the department that transcend the classroom experience, furthering the goal of achieving inclusive excellence within Geological Sciences. Students for whom participation in a STEM discipline might at first seem intimidating will see that they aren't alone, they are part of a supportive community.

4) Engaging students in research at different stages in their undergraduate career: Students we select will be at different stages of their career. That way, younger students can benefit not only from faculty mentoring, but can also learn from their undergraduate 'elders' and older students will refine their communication and mentoring skills. Today's neophytes will, in subsequent semesters, become the elders who mentor a new group of undergraduate researchers, thereby making the research community self-sustaining.

Creating the Research Community

Both components of the proposed research experience will contribute to fostering a self-sustaining research community that will endure long after this seed grant has expired.

Research Seminar

The fall and spring research seminar, which will be team-taught by Abbott and Stempien, will educate students about how their specific research project fits into the regional geologic picture and provide a platform for students to share their experiences in research with each other. In so doing, the seminar will help knit the students and their mentors into a research community, with everyone's individual projects all contributing to exciting shared discovery. Abbott will lead

seminar content discussions and do the grading. Stempien will design the tools used to assess the program's educational effectiveness and will lead that analysis.

Exploration of the American Southwest's recent geologic history is a fertile topic for this collaborative effort because that history is steeped in controversy. A nearly unlimited set of projects, most that involve a field component and many the perfect size for an undergraduate thesis, lie on CU's doorstep just waiting to be tackled. Students in the research seminar will explore what facts are established, what issues are controversial, and what tools geoscientists employ in their attempts to resolve those controversies.

As part of the research seminar, students will create a research portfolio that contains all of their project materials. The portfolio will include items such as literature reviews, grant applications (both internal and external to CU), public presentations they've made about their research (such as posters or talks at professional societies), a research journal, and their answers to reflective questions about their process and their goals. Evaluation of these portfolios will comprise an important benchmark by which to gauge the project's relative level of success and the effectiveness of the research community design.

We will organize several field trips associated with the research seminar. As noted by Boyle et al (2007), Whitmeyer et al, (2009), and Durrant and Hartman (2015), during field trips students engage in active learning and develop a more acute sense of place, both of which help to further develop their conceptual understanding and fuel their enthusiasm for the scientific enterprise. Some trips will involve only seminar participants and their faculty mentors, thereby allowing our research community to grapple with sophisticated concepts and build camaraderie and esprit de corps. All CU students will be welcome to participate in other, widely advertised trips, with students from our research community leading these tours of discovery. The assumption of leadership roles on these trips will further strengthen our students' self-identification as scientists, cement their understanding of relevant underlying concepts and theories, and improve their communication skills to non-experts. Of equal importance, we expect the trips to inspire scientific curiosity amongst a broad student population and fuel the aspirations of a new generation of geoscience students to become involved in our research community.

Individual Research Projects

Six participating students will embark on an interdisciplinary research project, each of which explores a facet of the American Southwest's complex recent evolution. Projects will employ tools ranging from apatite (U-Th)/He thermochronometry (AHe) to geomorphic modeling and from clumped isotope paleoaltimetry to cosmogenic radionuclide dating. Faculty experts in those fields who have longstanding research interests in the evolution of the American Southwest will mentor the individual projects. Distinguished Professor Robert Anderson, Professor Greg Tucker, Associate Professor Rebecca Flowers, and Assistant Professor Kathyrn Snell are all eager to work with students on these projects (see the letters of support appended to this proposal).

Natalie Tanski and Coleman Hiett, both of whom have already begun research projects for their honors theses, have agreed to comprise the initial group of undergraduate elders. Ms. Tanski, under the mentorship of Tucker and Anderson, is currently constructing a numerical model of river incision in Grand Canyon. This summer, Mr. Hiett will collect AHe samples near Crested Butte. His age analysis of those samples, with guidance from Flowers, will constrain the incision history for a tributary of the Colorado River.

We know of several younger students who are excellent candidates to fill the remaining four program slots based on their interest in gaining research experience, as expressed through classwork and in academic advising sessions. These students will conduct projects that include: 1) clumped isotope analysis of Colorado's Florissant and Antero Formations, under the supervision of Snell); 2) a geomorphic modeling study, guided by Tucker and Anderson, of the upper Colorado River basin's incision history; 3) cosmogenic radionuclide dating of river gravels in Black Canyon of the Gunnison National Park to constrain the Gunnison River's incision history (under the supervision of Anderson) and; 4) an AHe study of the Whitehorn granite near Salida, Colorado (supervised by Flowers).

The results obtained by this first class of undergraduate researchers will point the way to many new projects that can be tackled by the students who will join the program in subsequent years. These new students will learn from their peer mentors how important the project they are about to embark upon is to our scientific understanding of the geologic story behind the Southwest's breathtaking landscape.

Evaluation of the Project

The innovative design of the collaborative undergraduate research community is based on the strong departmental desire to nurture student identification as geoscientists and foster their persistence in science, strengthen students' analytical and communication skills, promote interdisciplinary collaboration, and to afford a greater number of department-based undergraduate research opportunities by having the research seminar directors and the students' peers assume some of the mentoring responsibility that would normally fall exclusively on one faculty member. We will use multiple measures to evaluate the benefits and areas for improvement of our proposed ARO design. We will ask students to complete a survey three times throughout the year: once at the beginning of the fall semester, once at the beginning of January, and once at the end of the Spring semester, to capture changes in students' affect towards research. This survey will consist of items from the Survey of Undergraduate Research (Weston and Laursen, 2015) to capture their self-reported learning gains and attitudes about research. Assessment of student growth in analytical and communication skills will be via analysis of the student portfolio. Classroom observations and interviews with participating faculty members will capture the frequency and level of collaboration between the students themselves and with their faculty mentors. Finally, open feedback from students and faculty will capture participants' perceived outcomes of the multiple-mentor model (Laursen, 2015).

Timeline

Table 1: Project Timeline by Phase

Summer 2016: Phase 1 Prepare material	• Prepare readings and course outline for Fall research seminar and initial phase of field trip organization • Recruit and enroll the remaining students • Prepare course effectiveness assessment material and obtain IRB approval
Fall 2016-Spring 2017: Phase 2 – Implementation	• Fall 2016 and Spring 2017 – conduct research seminar • Fall 2016 – most students begin their research project • Fall 2016 and Spring 2017 – conduct two field trips each

	semester, one for the research seminar students and the other led by those students intended for a broader audience • Spring 2017 – students who have not started the research/lab component of their project will begin it • Use of Fall semester feedback from students and faculty mentors to modify the research community structure • New students who are considering research opportunities begin their literature review for the Spring 2017 semester
Summer 2017: Phase 3 Analysis and Dissemination	• Survey analysis and qualitative analysis of research journals, classroom observations, and research portfolio evaluation • Final interviews with research faculty members regarding their experiences with the model, identifying pros and cons. • Write up and disseminations, applications for further funding opportunities. • Students write up project, submit presentation abstracts

Impact Beyond the Award Timeframe

We believe that our proposed AGO can rapidly become a model for undergraduate research because it creates a high impact *sustained* research experience that combines the invaluable *one-on-one faculty mentoring* of a URE with the guided concept discovery of a *research seminar* (a CURE) (see Linn et al. (2015)). Once established, we plan to actively recruit the participation of students who belong to groups that are underrepresented in STEM disciplines and students at different stages of their academic career. The impacts of this will be to attract a more diverse student body to departmental undergraduate research opportunities, strengthen the sense of community of STEM students with each other and with the department, and promote ownership and control over their education. Creation of this undergraduate research community will contribute to achieving two important University of Colorado goals: 1) to increase student retention and six-year graduation rates and, 2) to achieve inclusive excellence.

Beyond the benefits to CU students, this ARO model has the potential to provide great insight to the design of undergraduate research programs nationwide. Authentic research experiences are comparatively rare at Research 1 universities (Fechheimer et al., 2011; Thiry et al., 2011) and little pre-existing data on their effectiveness exists, even more so for geoscience undergraduate programs. Furthermore, Linn et al. (2015) and Laursen (2015) highlighted the need to rigorously test via multiple measures which aspects of a given program, regardless of the institution type that houses it, are the most effective for achieving desired outcomes.

We are committed to subjecting the proposed program's results to this type of rigorous testing from its inception, thereby contributing to this critical need for analysis of program effectiveness. Because of the program's expected longevity and its mixed modalities, we will be able to contribute significant new insights into which aspects (e.g. URE, CURE, peer-mentoring, field component, duration) affect desired outcomes more significantly than others. We believe the strong appeal of developing undergraduate research communities to promote retention and innovation in the science, combined with the lack of understanding on the effectiveness of undergraduate research opportunities in the geosciences, will make this program competitive in applications to NSF and private foundations seeking funds to continue the work whose seeds were sewn by this Chancellor's STEM Grant.

Budget

We request $10,000 for this project. Of that amount, $8000 will be allocated to summer salary so as to pay for the time Abbott ($4000) and Stempien ($4000) devote to teaching the research seminar, mentoring student research activities, organizing and promoting field trips, and conducting educational research to document program effectiveness. The remaining $2000 will be used to pay for: 1) transportation expenses and camping fees associated with field trips, both those associated with the research seminar and with field campaigns for individual research projects; 2) research supplies; 3) salary to hire an undergraduate student who will assist Stempien to analyze the written materials used to evaluate program success; 4) costs of materials consumed during the research in the participating research labs.

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April 13, 2016

To Award Selection:

This letter is to express my strong support for the proposal by Dr. Abbott and Dr. Stempien for a Chancellor's Award to build a new learning experience through research for our undergraduates in the Department of Geological Sciences. The proposed research seminar is innovative and refreshing in engaging the students at a higher yet achievable level. While this type of engagement will undoubtedly enrich students' academic experience and foster their intellectual growth, potentially helping improve retention could be another value-added.

Through the proposed research seminar, individual students will be well connected to specific research and faculty of varying expertise. Dr. Abbott and Dr. Stempien are at a unique position to play such a catalyst role, as they are involved in both faculty research and student mentoring and advising. Their in-depth knowledge on the subject matter, geology of the US Southwest, will help ensure the prospect of project success. The proposed seminar and mentoring activities are well thought-out. As we continue to strive for enhancing the learning environment for our students, this proposal is an exciting endeavor for our department and we are eager to have the opportunity to participate.

Sincerely,

Shemin Ge

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April 8, 2016

Dr. Lon Abbott
Department of Geological Sciences
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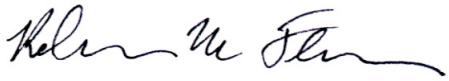
Dear Lon,

I enthusiastically support your proposal for a CU Chancellor's award to create an undergraduate research community in the Department of Geological Sciences. You and I are already engaged in collaborative research involving two Geological Sciences majors. I routinely have 3-5 undergraduates working in my lab, and would love to expand these invaluable research opportunities to more undergraduates. These experiences were key in my own undergraduate education and in shaping my subsequent path. Your proposed seminar and mentoring activities are well-designed to provide the necessary broader project and mentoring framework while capitalizing on the interests and expertise of the faculty. I expect that this effort will also foster additional collaborations among us. There is an abundance of local projects that undergraduates can become involved in. I have a strong interest in and ongoing research aimed at understanding the Cenozoic evolution of the western U.S., and so will be invested in the project outcomes.

Please let me know if there is anything else I can assist with to make this excellent idea become reality.

Sincerely,



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April 15, 2016

Dr. Lon Abbott
Department of Geological Sciences
University of Colorado Boulder

Dear Lon,

I write in enthusiastic support of your proposal for a Chancellors Award for excellence in STEM Education. I love the idea of the proposed research-based curriculum in which students engage in research problems related to the fascinating and enigmatic evolution of the landscapes of the American Southwest in the last 65 million years. These are world-class landscapes with such iconic features as the Grand Canyon and the staircase-like landscape beside it, Colorado's own high mountains that form the repeatedly glaciated spine of the state, and many of the state and national parks that dot the west. These landscapes and the geologic stories behind them remain in many ways mysterious, or at the very least contentious, and form the perfect target for a sustainable undergraduate research effort.

The team of faculty to be engaged in the enterprise cuts a broad swatch across the geology discipline, and includes both older and younger members of the department. The toolkit the students will have available to employ in teasing out the geologic history is on the cutting edge, as it includes the means of extracting timing of geologic events that spans the last 65 million years. This includes thermochronology in Becky Flowers' lab, cosmogenic radionuclides ^{10}Be and ^{26}Al in my own lab, clumped isotopes capable of constraining past temperatures and hence elevations in Katie Snell's lab, and numerical modeling of landscape evolution that forms the cornerstone of both Greg Tucker and my research efforts. That the stories are so sweeping, and the landscapes so attractive, makes this proposal to form a small and self-sustaining team of engaged undergraduates both viable and attractive to those of us who would serve as advisors. Greg and I are already mentoring one of the "elder" students described in the proposal, and I very much look forward to mentoring more. But most exciting to me is the chance to engage with a team, with cross-cutting interests and projects. As stated in the proposal, it is quite easy to design undergraduate-sized projects that fit into the jigsaw puzzle we are attempting to assemble.

Finally, I look forward to having an explicit excuse to work with Lon and Jennifer. I have worked on and off with Lon over the last 30 years, and it is no understatement that there are few who know better the geologic stories of the America West.

I therefore fully support the idea, and commit to helping to guide one or more undergraduates on a project that serves as a part of this enterprise.

Sincerely,

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14 April 2016

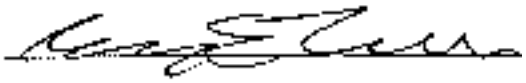
Dr. Lon Abbott
Department of Geological Sciences

Dear Lon,

I write to express my strong support for your proposal for a Chancellors Award for Excellence in STEM Education. The concept of a research-based curriculum is very appealing, and takes great advantage of CU's stature as a leading research university. The proposed focus on the geology of the American west over the past 65 million years is a wonderful idea: it provides a theme that knits together the interests of quite a few of our faculty members, including myself. I see this as a nice opportunity to provide our best undergraduates with a meaningful research experience while also helping to enhance collaboration among the faculty. As you know well, sharing advisory responsibility for students is one of the most effective ways to bring busy faculty members together.

I would be happy to serve as a conduit between this program and the Community Surface Dynamics Modeling System (CSDMS), for which I serve as Deputy Director. CSDMS is an NSF-supported research enterprise that fosters computational modeling in those branches of earth and environmental sciences that deal with the earth's changing surface. CSDMS' >1100 members represent some 60 different countries. In the context of this project, CSDMS maintains and distributes computational modeling software and related educational materials, provides technology for coupling different models, and hosts a supercomputing facility that is designed in part to help newcomers learn the ropes of high-performance computing. I'm excited about the potential to provide undergraduates in the program with early-career training in these technologies.

Sincerely yours,



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Dr. Lon Abbott
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April 14th, 2016

Dear Lon,

I'm writing to state my very keen interest and strong support for your excellent proposal for a CU Chancellor's award for excellence in STEM education. The focus on the development of the western US Cordillera as both a seminar and research platform for undergraduates is a fantastic idea that is sure to inspire engaged undergraduates; this region and the many climatic and tectonic forces that have shaped the area have long been of interest to geologists and yet still have many remaining mysteries. It will provide a very unique opportunity to be able to involve these students in the kind of truly interdisciplinary science that makes for challenging and rewarding research, and provide unprecedented opportunities in and exposure to a range of exciting and fundamental science questions and techniques. I particularly like that it will build a cohort of students working together on these projects, which will likely provide a formative and positive experience as they learn to support each other and learn from each other as their projects progress.

I am extremely excited to be a part of this project, and to have the opportunity to work with a fantastic group of students and faculty alike on projects so well connected to many of my own research efforts. I would be thrilled to advise students on individual projects that arise as a part of this program and to make my lab and instrumentation available for the students and train them to make their own measurements. I have no doubt that this will foster a great research community for our undergraduates and promote some new collaboration among the faculty, both of which will also be a tremendous opportunity to me as a new member of the faculty.

Please let me know if there is any thing else I can do to help support your proposal!

Sincerely,

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