Geoscience Education Research Project: Student Benefits and Effective Design of a Course-Based Undergraduate Research Experience

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ABSTRACT

Undergraduate research has been shown to be an effective practice for learning science. While this is a popular discussion topic, there are few full examples in the literature for introductory-level students. This paper describes the Geoscience Education Research Project, an innovative course-based research experience designed for introductory-level, nonscience majors. Participating students complete all steps of a scientific research project, starting with the research question, "What do college students think about ___?" Students fill in the blank with a geoscience topic of their choosing. Support for the students is ongoing through detailed directions and multiple checkpoint assignments with timely feedback to ensure they are on task. This design and support can be used as a model for other undergraduate research experiences. Student reactions to the benefits of participating in the research project and the effectiveness of its design were analyzed. Students' benefits from this research project included increased content knowledge, improved skills, and positive affective responses, such as interest leading to motivation. In this study, students were also found to have an increased appreciation of science and scientists, without necessarily having the desire to become scientists themselves. Student reactions to the design of the Geoscience Education Research Project emphasized the importance of an appealing topic, careful planning and conveying of project information, frequent deadlines and feedback, and communication by students beyond just the professor. Based on these findings, recommendations for successful implementation of course-based, introductory-level undergraduate research experiences are given. © 2016 National Association of Geoscience Teachers. [DOI: 10.5408/15-11.1]

Key words: undergraduate research, two-year college, interest, course-based undergraduate research experience (CURE), high-impact teaching activity

INTRODUCTION
Purpose

The purpose of this paper is twofold. First, it describes an innovative, course-based undergraduate research project. This project allows introductory-level students to complete all parts of a scientific research project, such as asking a question, collecting and analyzing data, peer review, drawing conclusions, and sharing findings. There are few published examples of projects with a similar scope and audience. The design and scaffolding of the project can be used directly in other courses or as a model for other undergraduate research projects. Second, this paper describes an analysis of the effectiveness of the research project, breaks down the aspects of the project that were particularly effective and beneficial to students, and provides recommendations for their incorporation into other introductory course undergraduate research projects.

Benefits of Undergraduate Research

Undergraduate research is recognized as an effective learning tool and is recommended by the President's Council of Advisors on Science, Technology, Engineering and Mathematics to be incorporated into courses (Presi-

dent's Council of Advisors on Science and Technology [PCAST], 2012). Although it can be defined in many ways, the Council for Undergraduate Research (CUR) defines undergraduate research as "an inquiry or investigation conducted by an undergraduate student that makes an original intellectual or creative contribution to the discipline" (www.cur.org). Similar to the *Vision and Change in Undergraduate Biology Education: A Call to Action* (Brewer and Smith, 2011), the *Summary Report for Summit on Future of Undergraduate Geoscience Education* recommends undergraduate research be an integral part of students' education (Mosher et al., 2014).

Various studies have looked at the benefits of undergraduate research to students. Osborn and Karukstis (2009) categorized the benefits into cognitive growth, personal growth, and professional growth. Cognitive growth is the most widely studied of these divisions and includes gains in knowledge and skills as well as progressing academic achievement and educational attainment. For example, various studies have found that participating in undergraduate research results in students being more able to think and work like a scientist (Lopatto, 2004; Seymour et al., 2004; Harrison et al., 2011), communicate effectively (Bauer and Bennett, 2003; Lopatto, 2004; Seymour et al., 2004), and think analytically and critically (Ishiyama, 2002; Bauer and Bennett, 2003). In addition, studies report an increase in students' retrospective belief of the quality of their undergraduate education experience (Bauer and Bennett, 2003; Lopatto, 2004, 2007) and an increased retention in the course and/or discipline (Nagda et al., 1998; Bauer and

Bennett, 2003; Brandt and Hayes, 2012; Brownell and Kloser, 2015).

In additional to cognitive growth, students also experience personal growth in affective elements and professional growth and advancement (Osborn and Karukstis, 2009). For example, students gain confidence (Lopatto, 2004; Seymour et al., 2004; Russell et al., 2007; Brandt and Hayes, 2012), are more independent in learning, thinking, and working (Ishiyama, 2002; Lopatto, 2004, 2010; Seymour et al., 2004; Shaffer et al., 2010; Brandt and Hayes, 2012), and are more self-motivated (Brandt and Hayes, 2012). Finally, students' interests in a science career are validated or enhanced (Lopatto, 2004; Seymour et al., 2004; Harrison et al., 2011), and they develop ties to the scientific community (Lopatto, 2004; Seymour et al., 2004).

Student interest is a complex and multifaceted construct, but at its essence, it is an important driver of motivation (Hidi et al., 2004; Renninger and Hidi, 2011). Several factors associated with participating in undergraduate research are related to triggering interest. Student interest in science typically does not match what is taught as part of school curriculum (Häussler and Hoffman, 2000; Maltese and Tai, 2010). However, undergraduate research often includes aspects that can trigger, maintain, and support interest, through engaging in authentic scientific inquiry (Palmer, 2009), providing social interactions (Palmer, 2004), and providing opportunities for choice (Maltese and Tai, 2010). Therefore, undergraduate research can cause students to become more interested in a particular aspect of science, which can lead to greater self-identification with science (Hidi and Renninger, 2006).

Students who are more interested are more likely to engage in self-regulated learning (Sansone and Thoman, 2005; Hidi and Ainley, 2008). Self-regulated learning is a student's ability to set goals and monitor emotions, actions, and motivations as they engage in a task (Zimmerman, 2001). Students who are successful self-regulators tend to have a better understanding of the content and employ a deeper set of strategies to be successful in their learning (Zimmerman, 2001). Therefore, self-regulation is an important component of succeeding in science. Undergraduate research can improve self-regulated learning, not only by increasing interest, but also by providing students with options from which they must thoughtfully and consciously choose (Sansone and Smith, 2000).

Undergraduate research appears to particularly benefit first-generation and minority students (Ishiyama, 2002; Russell et al., 2007). Ishiyama (2002) found that early participation in undergraduate research led to perceived improvements in independent analytical thinking skills of first-generation college students. Although Russell et al. (2007) found small but significantly higher positive effects of undergraduate research on minority students compared to nonminority students and Lopatto (2004) did not, both found that the undergraduate research experience is overall a beneficial experience that results in the retention of minority students in the science pathway at least as well as it retains nonminority students.

Course-Based Undergraduate Research Experiences

Traditional undergraduate research experiences typically involve a select few upper-division students working closely with a professor or laboratory leader over the summer as a research intern. Therefore, the many benefits of undergraduate research previously described typically help a few students later in their academic careers due to the limited number of positions available. Undergraduate research tends to include only those students who have self-identified in majors, missing out on the recruiting potential at the critically important introductory level. In addition, faculty cite many barriers to engaging first- and second-year college students in undergraduate research, such as time, resources, institutional support, and for two-year colleges in particular, the short-term nature of the student population (Hewlett, 2009; Brandt and Hayes, 2012).

In spite of these barriers, some faculty have attempted to instill undergraduate research in the first 2 years. One particularly successful approach has been with course-based undergraduate research experiences (CUREs), which have begun to be incorporated into curricula (Auchincloss et al., 2014), especially at two-year colleges (Hensel and Cejda, 2014). CUREs have a goal of teaching students how to do science by having them conduct authentic scientific research (Auchincloss et al., 2014; Brownell and Kloser, 2015). In this way, the research is student- and process-centered rather than solely outcome- or product-centered (Beckman and Hensel, 2009). These courses with research experiences are different than traditional science laboratory courses because undergraduate students conduct research in which the outcome is not known (Buck et al., 2008; Lopatto, 2010; Auchincloss et al., 2014; Ryker and McConnell, 2014; Brownell and Kloser, 2015). This difference is also incorporated in the CURE definition of undergraduate research as an "original" contribution, although tensions arise as to whether "original" needs to mean original to the discipline or original to the student or class (Beckman and Hensel, 2009).

Courses with a significant research component share similar benefits with summer research experiences (Lopatto, 2010). In addition, these experiences expose all students to conducting research, not just a few select ones, and have the additional advantage of potentially broadening the diversity of the scientific community (Bangera and Brownell, 2014). Faculty can also take advantage of the class structure to more easily weave in topics such as guided reflection on how science works, a practice that is necessary for students to have a more comprehensive understanding of the nature of science (Abd-El Khalick and Lederman, 2000). Collaboration, an important part of the research process, is also a component that can be relatively easily integrated in a course setting (Auchincloss et al., 2014). Undergraduate research within a course results in a more student-focused and active learning course, which reflects highly effective teaching and learning practices (Freeman et al., 2014).

There are many published examples of undergraduate research, although there are fewer relating to CUREs in students' first 2 years (e.g., Hopper et al., 2013; Hensel and Cejda, 2014). Geoscience faculty from two- and four-year colleges and universities came together at a recent On the Cutting Edge workshop to share ideas and examples of undergraduate research in the first 2 years (Mogk et al., 2014). The Web site for this workshop contains resources and links to undergraduate research examples, and it was followed up by a topical publication, *In The Trenches*, that focused on undergraduate research in the first 2 years, giving advice and examples (Kraft, 2015). An initial description of

TABLE I: Demographic comparison of research participants to classroom and institution.

Population	% Female	Average Age	% Nonwhite
Research participants	60	27	31
Class as a whole	50	25	29
Institution (Fall 2015)	59	26	37

the Geoscience Education Research Project described here was published in that volume (Kortz, 2015), and this paper expands on that preliminary study by providing details of the project and by analyzing additional student data.

The Geoscience Education Research Project

Despite the benefits of undergraduate research, there are few examples of fully described projects in the geosciences that can be effectively implemented with first- and second-year students, such as those at two-year colleges. In addition, many projects take advantage of particular geologic settings (such as streams on or near campus) or instruments (e.g., Hopper et al., 2013; Mogk et al., 2014; Kraft, 2015). This project was developed to give introductory-level undergraduate students a course-based research opportunity despite the college's lack of approachable local geology or instrumentation.

Although the instructor who implemented this curriculum (first author K.M.K.) has experience with conducting geoscience education research, faculty who wish to implement this assignment do not need to have that experience. Full directions are included on the Science Education Resource Center (SERC) Web site (http://serc.carleton.edu/88777), along with examples of analyses, tips, and best practices. On the continuum between process-centered and product-centered research (Beckman and Hensel, 2009), this project falls closer to the process side. As a result, the goal is not for students to produce publishable results but rather to gain the benefits from experiencing the process of research. Most of the semester-long project is completed by the students outside of class and laboratory time, although the four checkpoint assignments require about 20 min of class or laboratory time each, and time is necessary for the final presentation at the end of the semester.

The description of the Geoscience Education Research Project is also meant to provide a model for how undergraduate research can be done in the first 2 years. Many of the supporting activities can be used and modified to support other research projects. The analysis of the effectiveness of the project and resulting recommendations provides guidance for others developing their own research projects for introductory students to focus on the essential features presented here.

METHODS
Participants

Lead author Kortz implemented this research project in four courses of historical geology taught over two semesters at a large community college in the Northeast United States. There are no prerequisites for the course, and most students enrolled had not taken a previous geology course and were

nonscience majors. Class sizes ranged from 13 to 16 students, and there were no teaching assistants.

All students in the four courses completed the Geoscience Education Research Project, and 54 students (96%) gave permission to use their data. These students were 52% female and 28% racial and ethnic minority (mostly African American and Hispanic). The average age was 25, ranging from 19 to 64. Of these students, 35 responded to the short answer questions used for evaluation. These students had similar demographics to the entire group, with 60% female, 31% minority, and an average age of 27 (Table I).

Instructional Materials and Procedure

For the Geoscience Education Research Project, students complete a scientific project from start to finish, beginning with asking a research question and ending with presenting their results. Students determine how to collect data to answer their research question, collect the data, analyze it, and present their findings. The project requires students to research what other college students think about a particular geoscience topic. They are doing original research, since they are finding out the answer to a question that no one else knows. Students in class are scaffolded through the semester by four checkpoint assignments, forcing them to stay on schedule and giving them the opportunity to receive and provide peer feedback.

The Geoscience Education Research Project prompts students by giving the skeleton of the research question, "What do college students think about _____?" Students fill in the blank with something in the geosciences that interests them. Example research questions students have asked are: "What do college students think about how granite forms?" "What do college students think about whether humans and dinosaurs lived at the same time?" "What are preschool teachers' ideas on how horses evolved?" "How do college students believe the Appalachian Mountains formed?" "What do college students think about when we will run out of fossil fuels?"

The directions then guide students through the steps of conducting research to answer their research questions. Table II summarizes the steps involved and gives abbreviated directions, but the full handout is posted on the SERC Web site (http://serc.carleton.edu/88777). Students are provided the full directions from the beginning of the semester, including an evaluation rubric. In this way, students know the intermediate checkpoint deadlines as well as what they are expected to do at each step. After developing a survey, students collect convenience samples of other students, generally on campus, such as students in the cafeteria, students in the classroom before a class may begin, etc. They then analyze their data to report out to the class. The expectations of what they need to include in their final oral presentation are also included in the directions, and a summary of the required components is given in Table III. Although the directions are written with the end product of an oral presentation in mind, the final communication of the research project can be modified to instead be a written paper or poster presentation.

The four checkpoint assignments are an integral part of scaffolding, or supporting, student learning, so they can successfully complete the Geoscience Education Research Project, and these are summarized in Table IV, with the full assignments also included on the SERC Web site. The

TABLE II: Description of activities and due dates of related checkpoint assignments for the Geoscience Education Research Project.

Week	Description (Abbreviated from What is Given to Students)	Checkpoint Assignment
4	The research question is what you are trying to answer in your research study. It needs to be something you can answer by collecting data. In this project, you will focus on how people conceptualize some aspect of geology, and your question will take the form "What do college students think about _____," where you can fill in the blank with any topic that interests you. The question should not be too open or too narrow. Example research questions are given.	Research question
	Do background research to find out what other scientists have already found out about your topic in general. Scientists do not work in a vacuum, but instead build their ideas on top of the work of other scientists.	
	Create Introduction slides	
6	How you answer your research question depends on what it is, and this is where scientists commonly need to get creative. In general, there are many ways to collect data, but for this study you will use a questionnaire. Your question on your questionnaire will be similar to your research question you are answering with this study, although it will not be exactly the same. Test the one or two questions on your questionnaire on a friend or family member to make sure it is clear. Example formats of questionnaire questions are described, including open-ended, drawing, labeling a time line, labeling a diagram or picture, and multiple choice.	Questionnaire
	Create Methods slides	
	Collect data by distributing your questionnaire to at least 15 other students. Do NOT collect student names, since everything should be anonymous.	
9	Now that you have your data, you will want to analyze it to try to answer your research question. There are different ways to analyze data, depending on the data you collected. Example methods are given. As you analyze your data, determine the best way to present it to answer your question. For example, you can include a bar graph, pie chart, example quotes and drawing, or a table. Remember that you cannot include a lot of words on a slide, so you will need to figure out the most efficient way to tell the story of your data.	Data analysis
	Create Results slides	
	Interpret your data by figuring out what it means. This is the fun part! Think about your research question, and figure out how your results answer your question. Did the student perspective match the scientific perspective? Was there anything that surprised you? Why are your results interesting? Discussing your interpretation of your data should be an important focus of your presentation.	
	Create Discussion slides	
	Create Conclusion slide	
12	Finish creating your slides, keeping in mind best practices for slides (e.g., limited number of words, each slide has a distinct topic).	Slides
13	Give your presentation.	Presentation

reason for including four checkpoint assignments is twofold. First, they require students to spread out the work on the project throughout the semester and not procrastinate the research until the end. Because most students have self-reported not having previously completed a full-scope scientific research project, they do not have a good understanding of the work it entails, and many would not begin until it was too late. This is particularly important for students who are traditionally lower-performing students, as they lack some of the more effective self-regulatory learning strategies that higher-performing students possess (Zusho et al., 2003; Lukes and McConnell, 2014; Sinapuelas and Stacy, 2015). Second, the checkpoint assignments allow for feedback. The instructor gives students direct feedback on two of the assignments (research question and questionnaire; see Table IV), but students give each other feedback on all of the assignments. The checkpoint assignments take about 20 min each to complete. These were implemented at the beginning of four separate laboratory periods, either choosing laboratory classes that consistently were about 20 min short or removing small pieces of the laboratory class to

make time. They could also be implemented during class time. They begin with a "training" activity to get students familiar with what they are expected to do and then direct them to critique each other's assignments.

There are also several assignments incorporated throughout the class that require students to reflect on the nature of science in order to help them better understand how science works. This was intentional because participation in research does not necessarily result in student understanding of the scientific process if it is not made explicit (Abd-El Khalick and Lederman, 2000). Many small assignments require students to complete pieces of the scientific process, such as making observations, analyzing data, and supporting claims with evidence. A modified version of an activity that relates the scientific journey of Alvarez in his work exploring mass extinctions (Farkas et al., 2010) is included as a 1 day class activity, and after completing it, students in the class compare their scientific journey on their research projects to that of Alvarez. At the end of the semester, after the research projects are

TABLE III: Description of components in the final oral presentation.

Section of Presentation	Description of Slides in that Section
Title	Title and student name (1 slide)
Introduction	Scientific perspective (2–5 slides)
	Goal of study (1 slide)
Methods	Study instrument (1 slide)
	Justification (1 slide)
	Study population (1 slide)
Results	Summarize results (1–2 slides)
Discussion	Meaning of results, answer to research question, why it is interesting, bigger picture, recommendations, changes to study, future work (3–5 slides)
Conclusion	Summarize findings, answering research question (1 slide)
References cited	References sources of ideas that are not your own

TABLE IV: Summary of checkpoint assignments to scaffold student learning.[1]

Checkpoint Activity	Description
Research question	Students divide 6 research questions into categories of excellent (e.g., What are the five events that college students think are most important in Earth's history?), okay, and needs improvement (e.g., What do college students think about the history of Earth?). After discussing the reason they made those divisions, students then examine each other's research questions and give constructive feedback.
Questionnaire	Students divide 6 questionnaire questions into categories of excellent (e.g., On the blank time line below, label the following three events: dinosaurs evolve, dinosaurs go extinct, people evolve.), okay, and needs improvement (e.g., What do you think about the history of Earth?). After discussing the characteristics of excellent questionnaire questions, students as a group write 3 questionnaire questions that are different ways to address a given research question. Students then examine each other's questionnaire questions and give constructive feedback, using the guidelines provided.
Data analysis	Students are given 18 short responses to a questionnaire question, and they sort them into piles based on common themes. Students name and define each theme, and then create a graph showing the number of responses for each theme. Students then examine each other's graphs of their data and give constructive feedback, using a series of guiding questions.
Slides	Students are given a set of guiding questions to analyze each other's slides. The questions focus on if the required content is included, how well the slides support the presentation, and whether the presentation is appropriately focused.

[1]Full description of the activity can be found http://serc.carleton.edu/88777.

completed, students also complete a homework assignment asking them to reflect on their research project.

Evaluation Methods

The evaluation of this project seeks to answer two questions: (1) What about the design of the Geoscience Education Research Project was effective? (2) What are the benefits to students from completing the Geoscience Education Research Project? To answer these questions, the first author did a qualitative analysis of an assignment asking students to reflect on the project. The five questions the 35 participating students answered and analyzed were:

1. In what ways did you personally benefit from doing the Geology Research Project?[1]
2. Do you think you would have the same knowledge of science and attitudes about science if, instead of the Geology Research Project and Presentation, the assignment was something along the lines of pick a topic that is interesting to you and present about it to the class? Why or why not?
3. How was completing the Geology Research Project the same as you expected, and how was it different from what you expected?
4. How are your ideas about how science is done different than if you didn't do the Geology Research Project?
5. What are some recommendations you have for changing the Geology Research Project in the future? What advice would you give future students?

These questions were given as an extra credit assignment in the first year ($n = 14$, 52% response rate) and a

[1] It should be noted that we are using the term "Geoscience Education Research Project" to imply to the readers that this can be broadly applied across all domains of the geosciences (e.g., geology, atmospheric sciences, oceanography, etc.), but for the students in these geology classes, it was titled "Geology Research Project."

homework assignment in the second year ($n = 21$, 78% response rate). Question 5 was not given the first year, and in the second year, students had the option of answering between 3 and 5 of the given questions, so not every question was answered by every student.

The lead author analyzed student responses twice, each time addressing one of the two evaluation questions, using constant comparative analysis (Glaser and Strauss, 1967; Lincoln and Guba, 1985) following the methods described by Erlandson et al. (1993). The first analysis answered the question about the effectiveness of the design of the project. The first author read through the full responses and pulled

out segments of student responses that addressed the design of the project and divided these segments into categories. This initial analysis resulted in a series of categories that were then modified, combined, and re-created into new categories to incorporate the new information with further analysis. For example, initially coded segments describing the effectiveness of the project into the categories of "flexible" and "detailed directions" were combined into a single category of "well planned and conveyed." Once the categories captured the variations in the students' ideas, a final list of themes of student reflections about the design was generated. Student responses were analyzed again with the identified themes to verify that they truly represented the student data. In this way, the themes in the evaluation emerged from the data and are a reflection of the students' responses. In order to answer the question about the benefits to students, the first author again read through the full responses, but this time pulled out segments of student responses that addressed the benefits to students. The analysis of these segments followed the same procedure as for the design segments, as described already. The second author read through of all of the student responses to look for counterevidence of the categories and claims of the first author.

Trustworthiness of qualitative research, such as that done for the evaluation of this project, is termed validity and reliability in quantitative research. It demonstrates the truth value and allows for external judgments to be made about the procedures and the neutrality of the findings (Erlandson et al., 1993). Trustworthiness of this study is addressed in several ways. The code–recode process for analysis helps to establish dependability, or whether the findings would be repeated under similar circumstances. Quotes are provided to demonstrate a link between students' words and interpretations to establish credibility and confirmability of the results. A description of the situation in which the developed curricular instruction was applied is provided to improve the transferability of the findings. In addition, in a comparison to less-formal sources of data (classroom observations, informal discussions with students, and student responses to anonymous course evaluations at the end of the semester), those findings match in overall tone and message with the findings from the evaluation, helping to triangulate results from different perspectives.

Finally, to help ensure trustworthiness, the location of the researcher is provided (Feig, 2011). The location helps to make transparent how the researcher fits into the study and provides context for potential bias. In this study, the first author was a researcher–participant (Feig, 2011), since the data were generated from assignments within her own class. The second author served in the role of the peer debriefer (Lincoln and Guba, 1985) in establishing credibility.

RESULTS

Following the procedures described, themes were identified in student responses, and these themes are described next. Because individual students did not answer each question, the percentage of students that respond in a particular way cannot be meaningfully reported. However, even when not directly prompted by a question, all students included at least two benefits of doing the Geoscience

Education Research Project, and all students discussed something about the design of the project.

On the whole, students liked doing the project. There were no overall negative responses towards it, and at worst, a few students felt there was no extra value added over a traditional research report. Some students did offer suggestions for ways to improve the project for future students.

Effectiveness of the Geoscience Education Research Project Design

Student responses pertaining to the effectiveness of the design of the Geoscience Education Research Project were grouped into the following four themes: topic, well-planned and conveyed, frequent deadlines and feedback, and communication by students. Each of these design themes is more fully described in the following sections. The themes are supported by explanations of what students thought in particular was effective and example quotes from students. Student quotes are taken verbatim except in a few cases where minor changes to spelling or grammar were made to improve readability, but these did not change the intent of their response. Pseudonyms were assigned to indicate the variety of students from which these quotes are derived.

Topic

According to the analysis of student responses, it is important to the success of the project that students are interested in the topic. Because they were given the freedom to choose their own topic, students chose one about which they personally wanted to learn. For example, Kirah wrote, "being able to pick our topic benefitted me so much more because I actually wanted to do the research and I learned a lot more." Students were curious, not only about the topic itself, but also what other students thought about their topic. By choosing their own topic, they were invested in it, motivated to learn more, and felt ownership of the research project. Alyssa captures this investment, "Although I knew there would be a lot of work involved, I thought it was going to be very hard to complete. On the contrary, I found that the work was not hard because I was interested in finding out more about my topic." Students also felt the uniqueness of the topic made it more interesting, as illustrated by Courtney, "If the project had been along the lines of picking a topic I found interesting and presenting it [instead of doing research], I probably would not have done the project at all. Not only have I done so many projects like that before, but I actually find it boring."

Students also connected information from their project to what they had learned in class, with the course content and project complementing each other and helping them learn more about each. They found that the presentation helped make the course content more interesting. By finding out how little many other students knew about the geosciences, they gained a sense of appreciation of how much they had learned in the class, as demonstrated by Tori's reflection, "It also gave us some insight as to how much other students at [my college] know about geology and how interesting the course really is."

Students also were excited to create new knowledge and to present "not just what the internet and books say" (Kayla). They appreciated the unique approach to a course project that they had not done before and were pleased to go beyond "book research." Jasmine wrote, "This project made

me feel that I really accomplished something on my own when I was presenting, which regular presentations wouldn't give me the same feeling since they would be not my findings." Mark responded, "[I] created something that was actually useful and not just for the sake of learning."

Well-Planned and Conveyed

Students appreciated the detailed directions and descriptions given. Each step of the process was explained ("all the information was given in the packet" [Mark]), and expectations were given. Students found that the instructions were organized in a way that enabled them to conduct scientific research. Because most students had not done a scientific research project before of this nature, they did not know what was involved, and there was a learning curve. For example, many students were not familiar with different components of scientific research, as illustrated by Mark, "The research project introduced me to the idea of discussion of data. This is the most enjoyable and useful part of the scientific process, yet I was unaware of this step in the past." The detailed descriptions allowed students to have a better understanding of the components and expectations of not only this project, but of scientific research in general. Tanishia wrote, "I did projects before and I did it without any guidelines, only dates when projects should be completed. . . . But now I learned to give myself time to gather background information and [it] helped me to develop confidence to complete my research project." Students found that it was a lot more work and it was more complicated than a "normal" presentation based on book research, which is something with which many did have experience. For example, Megan explained, "There was quite a bit of a learning curve when it came to actually doing scientific research. I thought that the project as a whole would be more clean-cut but it turned out to be far more complicated than I initially assumed." On the other hand, they also felt that the scope and expectations were reasonable. Some students added that as a way to improve the project, it would have helped them to see examples of completed projects.

Students valued the detailed directions given at the beginning of the semester, so they could see where they were going with each component and how it all fit together. They realized that there was a purpose for each of the steps they completed within the project. Troy summed this up by writing, "Everything fit into the puzzle perfectly, which kind of surprised me."

Students also saw purpose in the project in the context of other activities in class and course goals. For example, they did a minipresentation earlier in the semester to give them experience and feedback giving presentations. Many students specifically reflected on the nature of science when discussing their research project, and this was a topic that was emphasized with activities during class. Tanishia described her reaction to the comprehensive approach by writing, "I realized what I learned in class was not just the words, but how to do research and prepare a presentation, were all related to my research project."

Although the project was structured with frequent deadlines, flexibility was also incorporated into the process. For example, students were able to change their research question after it was due if they found that their original question was not the one they really wanted to ask. Emily found that "even when the results of gathering and testing data don't necessarily go as planned, it can inspire curiosity about other new and interesting ideas." Erika commented in a similar manner to the necessity of flexibility when she wrote, "There is a lot of collecting data and going back to do it again when it fails the first time."

Frequent Deadlines and Feedback

The frequent deadlines were necessary for most students to complete a high-quality project, as exemplified by Jamie's comment, "Having due dates from various parts of the project throughout the semester helped me to keep up with it and definitely allowed my project to be that much better in the end. Having all of the different parts of the presentation being worked on for these past couple months made creating my presentation a step by step process that was virtually stress-free." Students described how the deadlines prevented them from procrastinating, made the project less stressful, and prevented overwhelming them at the end, and ultimately helped with time management. Although the Geoscience Education Research Project was an important component of their grade, many students used the words "overwhelmed" and "stressed" to describe how they did NOT feel during the project. For example, Joseph wrote, "the reason I found it to be a lot easier than expected was because of the date deadlines. In the long run the date deadlines I feel made the project a lot easier to complete. I feel having the deadline always kept the project fresh in my mind instead of putting it off until the last minute." Some students found the deadlines helpful but wanted even more components due earlier in the semester. For example, completing the slides throughout the semester (see Tables 1 and 2) was a suggestion followed by some students, but it could have been made a requirement, so it would be followed by all students.

Along with the frequent deadlines, students received timely feedback from the instructor and their peers. They used this feedback to reflect on their project and make changes and adjustments as necessary, as explained by Jasmine, "I benefited from hearing different feedback from students in class which helped me by adding new ideas and fixing some mistakes." Students felt that they learned from their classmates and spent the allotted time consulting with them and working together either to make sure they were on the right track or to solve problems. Although most students reported a positive experience working with their peers, a couple wrote that it was not as helpful as they had wished.

Communication by Students

This project required students to define or refine communication skills relating to the final presentation. Some of the skills they developed were specifically related to an oral presentation with a slide show, such as creating high-quality slides. Other skills would apply to any type of presentation, such as determining what should be included and what should not, organizing the information effectively, and gaining confidence in communicating ideas. By tying everything together in a presentation, they had to reflect on the entire research process. For example, Troy wrote, "Even though my presentations weren't the best, I still learned and experienced standing in front of the class." The final presentation also made students accountable to their peers, not just the professor.

Students also reported that talking to students outside of class while distributing the questionnaires helped increase their communication skills. It got many out of their comfort zone by forcing them to talk to strangers, increasing their confidence by doing so. Although some students stating they were initially uncomfortable doing so, all of those students also reported that they benefited by the experience, and none of them recommended the removal of talking to students outside of class.

Students also described that they benefited from the group work and increased their skills working together. They developed skills of giving and receiving constructive feedback, the value of which was described by Stephanie, "real scientists look [to] others for educated opinions and that can always open a new idea." Groups were given specific directions of what to accomplish during each of the times for feedback to help them stay on task.

Benefits of the Geoscience Education Research Project

Student responses pertaining to the benefit of doing the Geoscience Education Research Project were grouped into the following seven themes: increase knowledge related to class; increase positive affective responses; improve soft skills and confidence; improve presentation skills and confidence; improve science skills; understand and appreciate science and scientists; and carry ideas beyond the class. Each of these themes, along with example quotes from students, is more fully described in the following sections.

Increase Knowledge Related to Class

Students connected the information they researched while doing the Geoscience Education Research Project to information covered in class. As would be expected, nearly all students commented that they learned the topic in more depth than what was covered in class. Mike commented, "[a] nice surprise was how much I learned from doing research on this project. I thought I knew a lot about fossil fuels but I was wrong." Some described themselves as feeling like they were an "expert" on their topic and could teach others. They built on information learned in class to be able to understand their topic. The reverse was also true, where students reported that the information they learned while doing the background research for their project helped them to better understand class content. George noted, "basically, the class prepared me perfectly for this project." He continued by saying, "when I was researching my topic, I already knew the answers. The research just helped increase my knowledge on the subject, which was awesome." He then went on to describe how, "the project gave me an extremely detailed view on multiple geologic concepts. It required me to dig into past knowledge in order to answer my question. I feel that when you do this you only perfect your expertise."

Increase Positive Affective Responses

Most students wrote about a positive affective response to doing the research project. Student affect is an emotional, attitudinal, and motivational response, and research shows that it plays critical role in student learning and interest-development in the geosciences (McConnell and van der Hoeven Kraft, 2011; van der Hoeven Kraft et al., 2011). Many students used the words "fun," "enjoyable," and "exciting" to describe the project, even though many of the same students also reported the large amount of time and effort it took to complete. For example, Sarah wrote, "It was different than I thought it was going to be, it was long, but it was also really fun!" Students wrote that they were interested in and curious about both the topic and other college students' knowledge of the topic. Some students even reported a desire to continue the project based on their findings. Students reported that they like learning. Jamie explained, "The geology research project was a very positive experience. I learned more than I thought I would and I truly enjoyed doing it." They had a sense of ownership of the project and were "proud of" and "pleased with" their end result.

Improve Soft Skills

Students described a large variety of skills that they practiced and developed confidence in, with which they will take beyond this project into future classes and jobs, enhancing their future education. John called these "real-world" skills in his response ("This project really helped me with 'real world' skills. Projects like those are the projects you never forget."), and it is important for nonscience majors to identify that they are developing skills beyond the content. For example, students reported an improvement in their time management and organizational skills. Students reported more confidence in and willingness to talk to other people, both in terms of collaboration in groups and being required to talk to strangers to ask them to fill out their questionnaire. They reported that they had to challenge themselves, stay focused, and use self-discipline. The project also opened their minds to others' opinions and required them to look at things from more than one perspective. Many students responded that they developed more confidence, either in general or in a specific aspect of the project. Troy summed up some of these benefits by writing, "If you just took notes every day, you would get something out of it, but you really wouldn't care; you would . . . move on, but I feel as this course taught a life lesson that gave many benefits to me personally."

Improve Presentation Skills and Confidence

This theme, presentation skills and confidence, could probably be grouped under the theme of soft skills. However, it is a separate category here because it was a topic that was consistently mentioned by most students. For faculty who adopt or adapt the Geoscience Education Research Project and modify the style of presentation (in this case, oral presentation with slide show), some of the benefits described by students may not be as pertinent.

Students reported that the experience they received by preparing for and giving oral presentations resulted in them being more comfortable when presenting in front of their classmates and more confident with the content. For example, Jamie described, "I found myself not being as nervous as I usually am when I do a presentation. This may be because of the dinosaur [practice] presentations that we did before this project that loosened me up or because I felt like I really was almost an expert on my topic." By learning how to communicate ideas during a presentation effectively, they felt they would be better at future presentations, as described by Alyssa, "[It] made me realize that presenting in front of people really isn't so bad when you know what you're talking about. I used to have a lot of anxiety." In

particular, some students commented on the importance of being purposeful in choosing what information to present so they would stay within the time limit without overwhelming the audience with talking fast or busy slides. Alyssa went on to write, "I learned the importance of time restraints … when presenting information to an audience but also in life in general. When it comes to the presentation part, if you are too long people will think it is boring but if it too short, people will not feel as if they got enough information on the topic."

Improve Science Skills

This theme emphasizes skills that are particularly relevant to science, although it is understood that real-world skills and presentation skills are also important in science. Students reported an increased confidence in being able to do science. Many identified themselves as scientists (or "mini-scientists") and reported that to complete the research project, they had to think like a scientist. For example, Erika wrote, "This particular project teaches you to go out and collect data rather than sitting in front of a computer looking up info. It also helps you brainstorm and use your own creativity like a real scientist. When doing this, you are learning … and using your own knowledge to put things together rather than just using info another scientist already put together." They discussed improving skills such as making graphs, problem solving, analyzing and interpreting data, and using creativity to solve problems. They described that there was much more to science than "simply collecting facts and understanding them" (Mark).

Understand and Appreciate Science and Scientists

Many students wrote that through their research project experience, they realized that science is hard work. For example, Mike wrote, "I also got a glimpse into how much work it takes to answer just a simple question. It really gave me a perspective on the amount of work that must go into the harder questions that geologists answer." They have a greater respect for scientists, since they now have a better perception of what goes into research. Students also reported that they have a better understanding of how science works and how geologists think and solve problems.

In terms of the nature of science, the most common aspect students reported is how they learned that science is not linear, which was a theme emphasized during supporting activities in class. They explained that science is not like the step-by-step process they learned in their K–12 education, but instead was a never-ending, iterative complex process where "failures" can inspire curiosity to learn more.

> "This project changed my ideas on how science is done by a lot. I had always imagined science as being this very rigid and formal thing where you just run through the 'scientific method' in order, start to finish. I instead found that it was a very flexible and dynamic thing (at least in my case) where everything from the question you are trying to ask to how you interpret your data is constantly changing. You might find out that data answers question you didn't even think to ask. … This project has really taught me that science is really a very fluid and dynamic process." (Carl)

Carry Ideas Beyond the Class

Students described curiosity, interest, and excitement in learning what people outside of the class thought about topics in geology. Many were surprised that what they thought was common knowledge actually was not.

> "Doing this project and research on other college students that don't take geology classes made me come to a realization that not everyone knows the same information that I know, information that I find to be common knowledge or simple facts is actually not that simple to other students." (Sue)

Interestingly, after analyzing their results, many students emphasized the importance of geology education.

> "I learned that science is such an important thing. Schools systems should try to add more geology to science courses. This will definitely change the amount of knowledge students have about geology, and science as a whole." (John)

Students also reported sharing their knowledge gained with people outside the class. They taught family members their findings and taught fellow students the correct answers to the questionnaire questions after they took the survey.

Student Recommendations and Possible Student Pitfalls

Students provided a few common recommendations to future students who embark on this project and recommendations to the instructor on areas for future improvement. Recommendations to future students were primarily targeted around staying on top of deadlines and not procrastinating. As Tori recommended, "as for tips that I would give future students I would definitely say DO NOT PROCRASTINATE…[the instructor] gives us a guide as to when to have things done for a reason and I wish I had followed that from the beginning." One additional recommendation that may be implemented in future renditions of this project included providing previous student examples for current students to better understand what the final product could look like.

DISCUSSION
Benefits of the Geoscience Education Research Project

Many of the benefits students reported in this study are similar to benefits from undergraduate research experiences reported in the literature. For example, as a result of the Geoscience Education Research Project, students self-reported significant cognitive growth. They described increased content knowledge, a greater ability to think like a scientist, and more effective communication skills; these link back to the themes identified by Osborn and Karukstis (2009) of cognitive growth, personal growth through affective elements, and professional growth and advancement. Cognitive growth includes elements of communication skills development, professional growth includes aspects of collaboration, and lastly personal growth includes affective elements such as interest. These components are so tightly interwoven, it is difficult to separate one element from another in the final outcome of this project.

Many of the benefits stated from students' reflections also match outcomes that employers desire. For example as reported by the Association of American Colleges and Universities (AAC&U) and Hart Research Associates (2013), in a national survey of business and nonprofit leaders, more than 75% of employers say they want more emphasis on the key areas of critical thinking, complex problem-solving, written and oral communication, and applied knowledge in real-world settings. Since most of the students participating in this study of the Geoscience Education Research Project are primarily nonscience majors, these skills, agreed upon by employers in all sectors, are especially pertinent. For those students who want to become geoscience majors, similar nontechnical skills, such as time management, relationship building, and critical thinking, are desired (Houlton and Ricci, 2015). Many of these skills were described by the students as benefits of participating in the Geoscience Education Research Project.

Most students commented that they found the Geoscience Education Research Project interesting. Since students have unique combinations of prior experience and goals that influence what they find interesting, the Geoscience Education Research Project helps to address this divergence by allowing students to choose their own topic. In addition, because students' interest in science typically does not match what is traditionally taught in the classroom (Häussler and Hoffman, 2000; Maltese and Tai, 2010), this project addresses that by adding in the additional dimension of learning what other students think. This nontraditional focus perhaps better aligns to students' individual interests than what they traditionally are expected to learn in a science class. Students also found the project fun, and that "fun" aspect is a recommended component in doing research and modeling scientific inquiry (Jarrett and Burnley, 2010).

Because students were interested in the Geoscience Education Research Project, that interest drove their motivation to complete it and do well on it. Many of their comments coded under the "Topic" theme of the effectiveness of the project design illustrated this. For example, students chose a topic they wanted to learn more about, and the additional twist of researching what other students knew about it increased their interest. Interest also increased in students because they were creating new knowledge. As a result, students reported being motivated to learn more, putting more time and effort into the project than they may have otherwise.

This project triggered students' interest in their own research project, but it also appeared to have created for some students a more general interest and positive affective response in science as a whole.

> "Growing up, I was bored by the idea of doing science. This was specifically because following a set of rules to follow just didn't seem like much fun. Now, I have the complete opposite view, because I personally experienced the truth that after the amount of work that is put in, the outcome is that much more rewarding." (Jamie)

The Geoscience Education Research Project also helped some students develop their self-regulated learning strategies. The design of the project aided them in setting goals and monitoring their actions through the checkpoint assignments and peer review. They were required to make decisions and reflect on their progress throughout the project (especially during checkpoint assignments), such as whether they needed to change their questionnaire or research question and if they needed to change how they analyzed their data. Students described applying some of these self-regulation strategies to other projects and classes, which indicates transfer beyond just this project.

Another aspect in which students' interests were supported and sustained during this project was in working within a context where they were developing a community of learners. This community provided feedback to each other and created a space that allowed them to feel comfortable making mistakes and lessening their performance anxiety. Developing a community of learners is critical for student success and persistence (Tinto, 1997; Barnett, 2011). All of these elements (developing interest, self-regulatory strategies, soft skills, and community building) are examples of why undergraduate research in the first 2 years is seen as a high-impact activity (Kuh, 2008).

In contrast to benefits regarding professional growth seen in other studies, some of the benefits students reported were unique to this project and not reported in the literature. For example, published studies emphasize the reaction of students already interested in majoring in science and their validation or enhancement of their career choice. In this study, students were predominantly nonscience majors, and they instead expressed a much greater appreciation of science and respect for scientists, which is an important benefit for the general public. Students also learned the importance of geoscience education and the surprisingly low levels of understanding (in their opinion) in the student body, so some recommended an increased emphasis on the geosciences in K–12 education.

Limitations

The project was implemented and the data were collected in relatively small historical geology courses for nonscience majors, with an associated laboratory class, at a two-year college. Although four separate sections over two semesters were included in this study, the course environment may be atypical of many introductory-level courses. As with any qualitative analysis, these findings are specific to the institution and students who participated. While these findings are likely similar to those at similar types of institutions with similar types of populations, we urge readers to think critically about the ways to optimize student benefits and design recommendations appropriate for their own school and course setting. While the second author did some aspects of data verification during the qualitative analysis, it was not the full extent in establishing trustworthiness recommended by some researchers (e.g., external audit as described by Lincoln and Guba, 1985).

In addition, the analysis was based on self-reported responses by students. The assignment from which data were collected was extra credit the first year and a homework assignment the second year, and although students were told that their grade was based on effort, not what they wrote, it is possible that students wrote more positively about the assignment than they actually thought. However, the focus of the questions was reflective, and students did offer suggestions for improvement, so students appear to be answering honestly. In addition, student reflections on the assignment matched in overall tone with informal discus-

sions and student responses to anonymous course evaluations at the end of the semester.

Recommendations for Design of Research Experiences

The results of this project examined the beneficial characteristics of the design of the Geoscience Education Research Project as well as the benefits to students. Although the students' comments were specifically directed to the Geoscience Education Research Project, they can be analyzed and applied more broadly. By combining the results of this evaluation, we can make recommendations for other CUREs, especially those for first- and second-year students. These broader recommendations for designing course-based research based on the analysis are:

1. Give students freedom to choose a topic, with guidance.
2. Ensure students see the relationship between the topic and course content.
3. Create the opportunity for students to appreciate how much they learned.
4. Students should discover something new for which they cannot look up the answer.
5. Give detailed and clear directions at the beginning of the research experience.
6. Make clear the purpose of each component within the project and within the course.
7. Build in time for flexibility.
8. Frequent deadlines are necessary and important.
9. Peer review is helpful to provide formative feedback.
10. Students should communicate results beyond the professor.
11. Involve talking to people outside of the class.
12. Incorporate group work.

Suggestions for Modifications

This paper describes how the Geoscience Education Research Project was implemented in relatively small, non-science-major introductory classes at a community college. However, adjustments can be made so the project can be implemented in a variety of different settings.

For example, the Geoscience Education Research Project can be adapted to be used in courses other than introductory nonmajor courses. In upper-level geoscience courses, students could compile more sophisticated background information, or they could potentially compare perspectives of majors compared to nonmajors. For courses focused on preservice teachers, students could perhaps investigate perceptions of younger students and do additional research on common misconceptions. In both cases, the end product can be modified to fit the situation, such as requiring a scientific paper or creating a lesson plan and activity to address misconceptions identified.

Although the project was developed in relatively small classes, the project can be adapted to larger class sizes. Students can work and analyze data in groups instead of individually, reducing the feedback and grading required of the instructor. In addition, the end product of an oral presentation can be modified to be a conference-style poster presentation. If a course has a teaching assistant, the teaching assistant can be involved in providing formative feedback on students' checkpoint assignments.

Another possible application is using this research project to segue into discussing human subjects research (HSR) and the institutional review board (IRB) process of doing research with geoscience education students. IRB approval was obtained for the evaluation research on this project, but it was not something the students themselves were involved in as it was part of an educational classroom learning experience. However, if they were to report outside of the classroom context, IRB approval would need to be obtained, which could be a valuable experience for students hoping to do HSR in the future. There are resources available online for obtaining IRB approval for educational research that could be integrated into this project (National Institutes of Health, 2013; Starting Point, 2015).

CONCLUSIONS

The Geoscience Education Research Project is an effective way for students to get many of the benefits of undergraduate research experiences in an introductory class. Although some of the benefits are unique to this project (such as learning about the current level of geoscience knowledge of peers), many of the benefits emphasize why undergraduate research is a high-impact practice. For example, not only did the students report a cognitive growth, they also had increased interest and motivation, improved communication skills, and supported development of their self-regulation.

Student reactions to the design of the Geoscience Education Research Project emphasize the importance of the topic, the value of careful planning and detailed conveyance of the project, the need for frequent deadlines and feedback, the significance of communication by students and sharing information learned beyond the professor and classroom, and the ability to learn from each other. As a result of this study, we make recommendations that can be integrated into any course-based undergraduate research project, but that are particularly suitable for projects designed for introductory-level students, including nonscience majors. Incorporating these suggestions will help increase the successful implementation of undergraduate research in an increased number of introductory-level courses, which will therefore make undergraduate research more available, approachable, and beneficial to all students.

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