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PUBLISHING EDUCATION RESEARCH

Anne U. Gold
Barbara C. Bruno

Program evaluation is quite different from the rigorous educational research standards required for publication in the peer-reviewed literature. Although not required by NSF, systematically studying and publishing the impacts of your REU program on students and mentors can be highly satisfying, as well as beneficial to REU programs nationwide (as well as to your research career!). To do this, you will need to go beyond the basics and develop a full research design. As many REU PIs may not have a background in education research, this chapter demystifies the process by providing guidelines.

Key Steps

Conduct a Literature Review

A literature review can help you identify:

1. research designs and methods that have been implemented successfully in other REUs;
2. gaps in the knowledge around REU programs; and
3. unique aspects of your REU program which could become the focus of your evaluation.

A list of recommended reading around researching REU programs is provided at the end of the chapter. The National Academies (2017) report on STEM undergraduate research programs is a good place to start. This report summarizes the research around REU programs as measuring their impact on:

- Knowledge, scientific thinking, and skills
- Scientific identity and self-efficacy
- Persistence along the STEM pathway, including retention in STEM majors and enrollment in graduate school.

Construct a Logic Model

A helpful first step in designing your educational research plan is to visualize the connections between what you plan to do and what you hope to accomplish. A "logic model" will map available resources ("*inputs*") and planned activities to outputs (concrete deliverables), and desired *outcomes*.

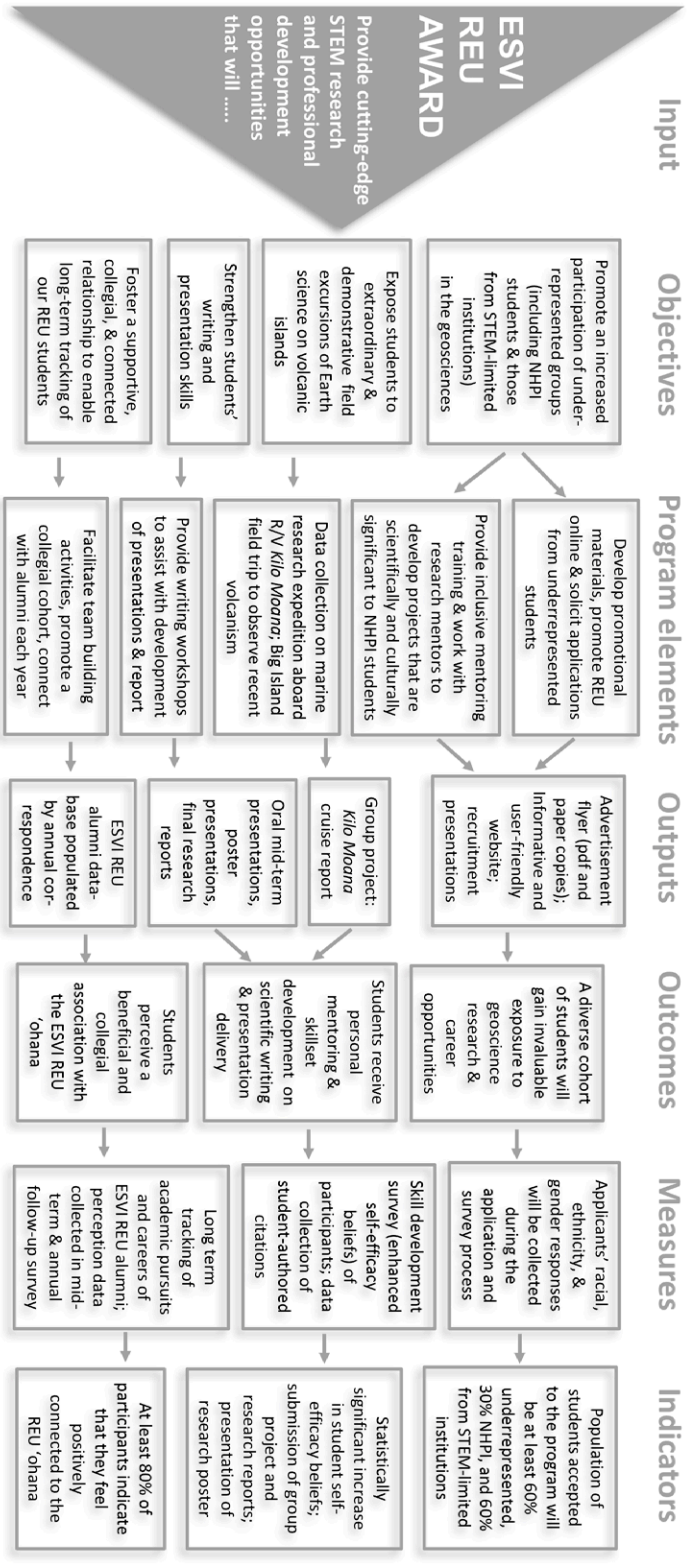


Fig. 1. Logic model example (courtesy of Bridget Smith-Konter, Earth Sciences on Volcanic Islands (ESVI) REU, University of Hawaii).

Develop Your Research Question

Research questions may emerge from your logic model, from knowledge gaps in the literature around REU programs, or from your direct experiences with REU students and mentors.

A research question that could be drawn from the above logic model, for example, might be: “In what ways were recruitment strategies effective in attracting diverse applicants?”

Other research questions might include “In which ways do REU students improve their research skills over the course of the summer?” or “In what ways do mentors benefit from mentoring an REU student?”

Once you decide on one or more research questions, it is helpful to conduct a second, more focused literature review to put your research into context within the existing body of knowledge.

Select the Research Design and Instruments

Educational research at the most rigorous level, such as a randomized control trial, is not feasible within REU programs because of the small participant numbers, non-random participant selection processes, and the challenges in finding appropriate control groups. However, small-scale, quasi-experimental studies provide important insights into program impacts and advance our knowledge on best practices around REUs (National Academy of Sciences, 2017).

Designing the Study

It is not possible to study every aspect of your program. Time and resources are finite, and excessive data collection can result in respondent fatigue. So, it is important to be selective and focused.

To help you focus, ask yourself some key questions:

- What is the purpose of the study?
- Who will use the results and in what way?
- What resources do I have to invest?

Focusing your research design on unique aspects of your REU, using strong measures, is recommended. The small size of most REU programs and/or the lack of control groups can prove challenging. Combining results from multiple years, or from different REU programs, is one possible solution to these challenges.

Choosing Research Instruments or Tools

Based on your research question(s), select the type of data you want to collect, and identify the research methods that align with your intended research outcomes.

Research methods can be *quantitative* (e.g., skills tests, attitude surveys) or *qualitative* (e.g., interviews, focus groups, open-ended survey questions). The former quantifies skills, attitudes, and behaviors with the goal of finding patterns in the data. The latter is exploratory research aimed at understanding why those patterns occur. Often a combination of both ("mixed methods") is necessary to tackle a research question.

The Evaluate handbook (Frechtling Westat, 2010) nicely summarizes advantages and disadvantages of many methods.

Surveys

Due to the small study population in typical REU programs it is usually best to collect a mix of qualitative and quantitative data through surveys. The qualitative data provide important context for the quantitative data that are collected.

Open-ended survey questions will encourage students to broadly reflect on the question. These open-ended responses are usually coded in order to allow for themes to emerge from the student responses (see *Braun & Clarke*, 2006 for a great description of thematic coding). Some of the responses can also be used as direct quotes in publications. Quantitative data are usually collected through closed-ended surveys using either multiple-choice or Likert scales.

Validated instruments are the gold standard for surveys. They have been tested on populations that are large and diverse enough to ensure that they measure what they claim to measure. These instruments are ideally used with the populations for which they have been developed and validated. Shortlidge & Brownell (2016) provide a list of validated research instruments relevant to REU programs. In cases where validated research instruments appropriate to your research questions do not exist, see DeVellis (2016) for guidelines in developing your own instruments.

Interviews

In addition to surveys, a tool that is often used in REU programs are interviews. The Evaluate handbook (*Frechtling Westat*, 2010) summarizes the many pros and cons for conducting interviews.

Advantages of interviews:

- Usually yield richest data, details, new insights
- Permit face-to-face contact with respondents
- Provide opportunity to explore topics in depth
- Allow interviewer to experience the affective as well as cognitive aspects of responses
- Allow interviewer to explain or help clarify questions, increasing the likelihood of useful responses
- Allow interviewer to be flexible in administering interview to particular individuals or in particular circumstances
- Effective data collection for small study populations

Disadvantages of interviews:

- Expensive and time-consuming
- Need well-qualified, trained interviewers
- Interviewee may distort information through recall error, selective perceptions, desire to please interviewer
- Flexibility can result in inconsistencies across interviews
- Volume of information very large; may be difficult to transcribe and reduce data

Collecting Data

Your research question, research design, and research tools drive how, what, and when you collect data. Data can be collected before the REU begins, at any point during the program, and/or after the program ends. For example, demographic data collected at the time of REU application will enable a demographic comparison of the applicant pool with the selected pool, while longitudinal data collected long after the REU program ends can measure long-term program impacts on participants. Here are some tips:

Don't oversurvey your students. Only collect data that are necessary to answer your research question and, if relevant, to improve the program. To avoid survey fatigue, limit each survey to 15 questions or 20 minutes.

Collect data anonymously or, in cases where you will need to pair survey responses (e.g., pre-post) to measure change, replace names with unique codes and then de-identify the data for analysis to avoid any bias in the analysis.

Consider timing. For example, avoid surveying students prior to a presentation, when feelings of insecurity or presentation anxiety may affect their answers.

Be careful when generalizing your research findings (e.g., to other programs, other student populations).

Measuring Change and Avoiding Bias

If your research question involves changes that may occur in students (e.g., in skills, attitudes, behaviors), one common approach is a *pre-post* study design, in which the same questions are asked in surveys administered before and after the REU.

As you design your survey, consider that students' baselines might change.

If for example the survey asks students to self-report their ability to interpret graphs or write Python code before the REU program, they might rate themselves highly, largely due to past success with simple examples.

If during the program they realize how much they have yet to learn, they could rate themselves lower in the post-survey, even though their skills may have increased.

To avoid this bias, we propose several work-arounds:

- Use a retrospective pre-post survey design. That is, at the end of the program, ask students to rate themselves in various areas at two different time points (before and after program participation) or, alternatively, ask students to report the changes in the parameter you are exploring (e.g., skill, confidence, science identity) they experienced over the course of the program. One widely used validated survey instrument is the online Undergraduate Research Student Self-Assessment (URSSA), hosted on the Student Assessment of their Learning Gains (SALG) website.
- If there is a goal to measure the change in a specific skill (e.g., science literacy), try to measure that skill directly (as objectively as possible), rather than asking students to report self-perceptions.

Benefits and Challenges of Longitudinal Studies

Collecting data well after an REU program ends can help you measure long-term program impacts. Moreover, longitudinal studies can reveal whether, in the months or years following REU program participation, alumni develop a greater appreciation of what they learned. However, conducting a longitudinal survey long after the program ends can be challenging, due to funding limitations and difficulties tracking down the students and getting them to respond. Given the value of post-program data collected once students have gained a greater perspective about their experience, it would be worth considering conducting an online survey one year after the REU ends. Tip: Gift Cards as rewards greatly increase the response rate!

Get Feedback

Presenting your research methodology at geoscience education conferences (e.g., Earth Educators Rendezvous) or at education sessions at geoscience meetings (e.g., American

Geophysical Union or Geological Society of America) can be a useful way of getting constructive feedback on your research study. You can also reach out to a community member, either directly or through the GEO REU email listserv, and ask for a review of your research design.

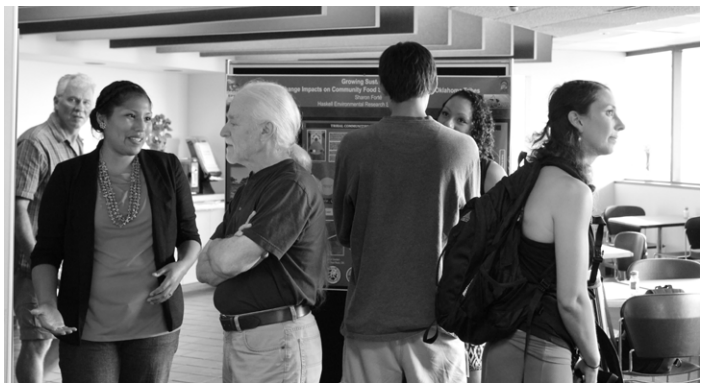
Obtain Institutional Review Board Approval

Educational research involving human subjects always requires consent of the study subjects and approval by your institutional review board (IRB), to ensure that your research is ethical and that program participants are protected. This requirement holds true regardless of whether or not you plan to publish your results, and even if your study is exempt from federal regulations. Check with your local IRB office for guidance on the details for the application, as they vary from institution to institution.

IRB approval must be obtained before you begin your research study. If you plan to use any of the information from the REU applications in your study, IRB approval must be obtained before the application is opened to students.

Analyze the Data

Quantitative data are suhmmarized using descriptive and inferential statistics. Published descriptions of the research instruments usually suggest paths for analysis.



It is possible to convert qualitative data into quantitative data by quantifying the number of times certain themes show up in survey responses.

Qualitative data including interview and focus transcripts as well as open-ended survey responses require coding in order for findings to be reported.

Coding involves matching words or statements with codes that represent meanings or concepts.

Many qualitative analytical methods exist; one intuitive one is thematic analysis (see *Braun & Clarke*, 2006 for a helpful description).

Depending on the methodology, there are variations in the way coding is conducted. Many analytical techniques include these steps:

1. In the first step, read through all transcribed data and outline broad themes in a code book. The list of codes can be informed by work from others or it can emerge from your research question or data.
2. In a second iteration, the responses will be coded using your list of codes.
3. In a third step, a second person will use the same list of codes and data sets to code the responses.
4. Next, compare the results of the coding (interrater reliability).
5. After coding has been completed, you can summarize the prevalence of themes in each data source. This process allows synthesis of the qualitative data.

Make sure to note the absence of certain themes or ideas as you review your data.

Select an Appropriate Publication Venue

Both disciplinary science journals (e.g., *Oceanography, Climatic Change*) and science education journals (e.g., *Journal of Geoscience Education, Scholarship and Practice of Undergraduate Research (SPUR)*) are appropriate venues for publishing geoscience education research. There are also non-peer-reviewed publications (e.g., *In the Trenches* from National Association of Geoscience Teachers) to consider.

The appendix provides an extensive (although not complete) list of relevant journals. When choosing a journal, aim to find a good fit to both your research topic (e.g., geoscience discipline, type of data you are collecting) and your intended audience (e.g., geoscientists, education researchers). For example, the *Journal of Geoscience Education* accepts submissions in four categories: Curriculum & Instruction, Research, Literature Review, and Commentary. Each journal has different submission guidelines, review processes and timelines, and some offer special issues on particular topics.

Summary & Checklist

- o Review the literature on REU program findings
- o Construct a logic model to guide your evaluation plan
- o Develop your research question
- o Select your research design and instruments
- o Get feedback
- o Obtain Institutional Review Board (IRB) approval before beginning your research study
- o Collect and analyze your data
- o Select a journal based on your research topic and intended audience

Further Reading

Brownell, J.E., and L.E. Swaner, 2010. Five High-Impact Practices: Research on Learning, Outcomes, Completion, and Quality; Chapter 4 in Undergraduate Research. Washington, DC: Association of American Colleges and Universities.

DeVellis, R, 2016. Scale Development: Theory and Applications. 4th Edition. University of North Carolina. Chapel Hill, N.C.

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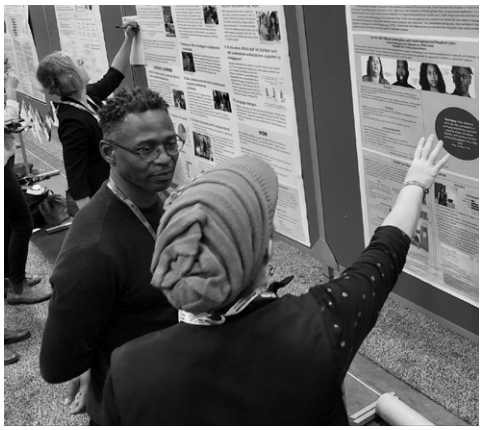
Russell, S.H., M.P. Hancock, and J. McCullough, 2007. Benefits of Undergraduate Research Experiences. Science, Vol. 316, Issue 5824. DOI: 10.1126/science.1140384.

Shortlidge, E.E. and S.E. Brownell, 2016. How to Assess Your CURE: A Practical Guide for Instructors of Course-Based Undergraduate Research Experiences. Journal of microbiology & biology education, 17(3), 399–408. https://doi.org/10.1128/jmbe.v17i3.1103.

Appendix

Journals Relevant to Education Research on Geoscience REUs

In addition to journals in your geoscience discipline, consider publishing in the following:



Geoscience Education Journals

- Journal of Geoscience Education
- Journal of Earth System Science Education
- Journal of Environmental Education

STEM Education Journals

- Journal of College Science Teaching
- Scholarship and Practice of Undergraduate Research
- Science Education
- Journal of College Student Development
- Journal of Women and Minorities in Science and Engineering
- Scholarship and Practice of Undergraduate Research (SPUR)

Geoscience Newsletters & Bulletins

- Bulletin of the American Meteorological Society
- *Limnology & Oceanography Bulletin
- EOS (from American Geophysical Union)
- The Earth Scientist (from National Earth Science Teachers Association)
- *In the Trenches (National Association of Geoscience Teachers)

* = not peer reviewed