DEVELOPING EFFECTIVE K-16 GEOSCIENCE RESEARCH PARTNERSHIPS

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CONSENSUS STATEMENT

Research partnerships between scientists and K-16 students, teachers, and the general public can increase our collective understanding of the Earth system while making the science by which we understand the Earth accessible to all. Partnerships promoting authentic research integrate inquiry-based educational approaches with innovative research questions. Such partnerships serve as effective vehicles for teaching scientific logic, processes, and content, while allowing students to participate fully in scientific investigations. Benefits to the scientists include data collection and analysis that may be difficult to gather with limited human resources, and an opportunity to engage the next generation of scientists. Benefits to the students and teachers include a learning process that fosters creativity, sets high standards, teaches problem solving, and is highly motivating. When closely aligned with the National Science Education Standards, research partnerships should be an integral component of science education reform at all levels. This potential will be achieved only if partnerships are effectively evaluated from both pedagogical and scientific perspectives, and best practices are widely disseminated and supported by both scientific and educational communities.

This statement has been reviewed and agreed upon by all contributors to this issue.

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INTEGRATING RESEARCH AND EDUCATION THROUGH GEOSCIENCE PARTNERSHIPS

There is growing awareness that the way science is experienced in the K-16 classroom deviates greatly from the experiences of practicing researchers. Whereas researchers are immersed in more open-ended observation and inquiry, many K-16 students find themselves cramming to memorize core scientific content in preparation for standardized examinations. The National Science Education Standards (NRC, 1996) are, in part, a response to this disconnect, and outline an inquiry-based approach to learning science in the precollege classroom. This educational shift towards more active engagement in scientific processes is essential in order to adequately train future scientists and, more importantly, foster a general public able to make informed decisions from scientific information. Several key challenges, however, hinder widespread acceptance and implementation of the Standards. Firstly, adherence to fact-based learning continues to be the norm, as many who teach precollege science do not have formal training in their content area, may never have experienced science as a process of inquiry, and may feel unprepared to teach in such a way; this is especially the case for Earth science, in which relatively few teachers are certified (CCSSO, 1999). Secondly, many teachers may be unaware of programs and enrichment opportunities that would support inquiry in their classrooms. Thirdly, there is general concern that inquiry-based activities can be time-intensive and do not allow adequate time to cover necessary scientific content. A great need exists for structured experiences with inquiry at multiple education levels: professional development opportunities for pre- and in-service teachers, inquiry-based classroom modules, and programs for the general public. Access to these experiences would provide a bridge to the recommendations outlined in the National Science Education Standards, and from that, a general population more engaged in, and aware of, the process of science.

This issue of the *Journal of Geoscience Education* focuses on one powerful strategy for meeting these challenges: the integration of science research and education through geoscience research partnerships. In order to teach science as a process of understanding our world we must engage students, teachers, and the general public directly in the inquiry that characterizes scientific research. Research partnerships provide a structure in which to engage these audiences in both scientific content and inquiry processes. The creation of new knowledge through direct involvement in research is exhilarating for teachers and students, and as such can be a catalyst for learning (Project Kaleidoscope, 1991). While research partnerships may be effective at covering certain components of classroom curricula, their greatest strength lies in their ability to empower participants to see themselves as scientists. For students or teachers who may otherwise feel unable, and/or uninterested in science, understanding they can 'do' science is an incredibly powerful lesson. Research partnerships may also benefit collaborating researchers by providing access to data that would otherwise have been unavailable due to the sheer human labor necessary for its collection or analysis.

There are a growing number of research partnerships in the biological and geological sciences, and it has been widely assumed that student participation has strong educational benefits. However, the educational evaluation supporting these claims is often anecdotal, making it difficult to discern the true impact of participation on student and teacher learning. In addition, while involving students in research is often presented as a primary focus, few projects discuss how student data is used in ongoing research, leaving questions about data accuracy and the use of data beyond the classroom context. As the scale of research partnerships continues to grow, both in numbers of projects and participants, it is critical that we grapple with how to effectively evaluate learning outcomes and data quality. If these partnerships are to play a broader role in Earth science education reform (e.g., Barstow et al., 2001), well documented models need to be made available to the greater education community. Facilitating a dialogue on these topics is a primary motivation for this issue of the *Journal of Geoscience Education*.

AUTHENTIC RESEARCH COLLABORATIONS IN CONTRAST TO INQUIRY-BASED CLASSROOM PROJECTS: WHY THE EMPHASIS ON AUTHENTIC RESEARCH?

The focus of this issue is on programs that engage K-16 students, teachers, and the general public, in research collaborations with geoscientists. The emphasis is on projects that integrate authentic research and authentic education (Barstow, 1996). The relevance of authentic research involvement for geoscience education is an issue with which we have wrestled while organizing symposia on research partnerships at the 2001 and 2002 annual meetings of the Geological Society of America, and in the process of editing this issue. Many programs exist that engage students and teachers in inquiry processes that simulate scientific research, with well-documented educational benefit (e.g., Mayborn et al., 2000; Yuretich et al., 2001; to name just a couple). If students are posing questions, gathering and analyzing data, and testing hypotheses, does it matter whether their research relates to a question of interest to the broader scientific community or whether their data is sufficiently accurate to shed light on these questions? In other words, does student research occurring in collaboration with other students and geoscientists have a different suite of experiences and learning outcomes than research occurring solely as a class project? We think the answer is yes, and supporting evidence for the unique outcomes of research partnerships may be seen within the content of this issue. As noted by Jarrett et al., Harnik et al., and others in this issue, collaborating with scientists may empower students and teachers to take inquiry-based explorations seriously, to consider themselves entrusted and worthy of doing high quality work, and can result in greater interest in science. An example of this can be seen in the following comment made by a participating teacher (Hansen et al.): “The moonsnail workshop actually involved us in your research. It is real science. You folks allowed us in. Into your part of the game. You trusted us with something valuable to you. You allowed us to invest in the task. We bought in so we really want our part to be done well.” Seeing one’s contributions in a broader context is an important part of research and research partnerships, and may differ from strictly classroom- based lab exercises.

GENERAL MODERL FOR EFFECTIVE RESEARCH PARTNERSHIPS

A great variety of audiences, approaches, and content areas may be found within the partnerships described in this issue. A number of papers approach professional development through research collaboration (Buck, Butler et al., Field et al., Gosselin et al., Hall-Wallace et al., Hansen et al., Jarrett et al., O’Neal), others look at K-16 classroom partnerships (Blackwell et al., Bowman et al., Buck, Butler et al., Hall-Wallace et al., Hansen et al., Harnik et al., Jarrett et al., Ledley et al.) and still others describe engaging the general public in collaboration with museums (Barreto et al., Ross et al.). Several of these projects incorporate both professional development and classroom programming. The research topics presented are as varied as the audiences they engage, with topics ranging from dinosaur extinction patterns (Barreto et al.) to NASA rover technology (Bowman et al.) and land cover maps (Butler et al.). Arising from this great diversity, however, is a collective vision for geoscience research partnerships presented in the consensus statement that introduces this paper. This vision statement emerged from the perspectives and agreement of all contributing authors.

The consensus statement emphasizes the integral role evaluation plays in the partnering process. Assessments of participant data quality, and evaluation of pedagogy and learning outcomes, assure that both research and educational goals may be met within a partnership. In the development of a partnership, respect and communication among all partners is paramount (e.g., Committee on Science, 1998). Collaborators need recognize, and respect, that each partner may have additional goals in their research involvement. In a partnership, each collaborator must achieve meaningful results from their involvement in research. For students and teachers, this means that participation must go beyond data collection to include data analysis and hypothesis testing, and for scientists, participation should provide meaningful results for their research. Dr. Joseph Bordogna, Deputy Director of NSF, has suggested several characteristics essential in “making a collaboration ‘sing’” (Bordogna, 2000):

- Trust amond partners
- A diversity of perspectives
- Every partner brings something of value to the table
- Every partner has something to gain
- Recruit the best people
- All parties are present on the first day

In their broadest sense, research partnerships create communities of scholars, at a variety of learning levels, working collaboratively on scientific questions. As such, achieving the outcomes defined within the consensus statement hinge upon the process in which partnerships are established and fostered.

UNIFYING THEMES

Generation of scientific data - A strength of research partnerships is their ability to provide researchers with access to large spatio-temporal datasets that may otherwise have been difficult to generate due to limited human resources. A number of papers in this issue present ways in which students and teachers contribute data towards specific research questions. For example, Barreto et al. document how the involvement of the general public in dinosaur fieldwork helped overcome sampling biases in the upper Cretaceous Hell Creek Formation. Butler et al. present selected GLOBE programs that engage large numbers of geographically distributed participants in collecting environmental data usable in creating a global compendium to test the validity of landsat maps and GAPS models. Field et al. describe partnerships between teachers and resource managers to monitor local environmental conditions for which resources would not typically be allocated. Hansen et al. engage classes distributed over a broad geographic area to gather data on modern moonsnail predation that would otherwise prove difficult for a small group of researchers to collect.

Scientific Data Quality - In order to assure that authentic research can occur, the quality of student-generated data must be assessed and constrained. Harnik et al. discuss this topic in their description of formative assessments of taxonomic data generated by students in the Devonian Seas research partnership. Butler et al. and Blackwell et al. compare student results with comparable reference data generated by collaborating scientists in order to identify anomalous student results (i.e., outlier values). The core of the argument for utility of student-generated data is that although it will generally be less accurate than data from professional scientists, large amounts of data permit patterns to emerge that may not have been evident otherwise. Interestingly, Barreto et al. note that the involvement of 'non-specialists' can increase data quality when it "shields data from preconceived [scientist] bias".

Educational Evaluation - Educational evaluation is an essential part of effective research partnerships. Evaluation helps to document learning outcomes, and identify content areas or approaches needing modification. Educational evaluation has proven challenging, however, as one of the primary issues that these partnerships affect are attitudinal variables that may at times be hard to quantify or assess directly. Buck and O'Neal use formative and summative program evaluation tools to determine attitudinal changes and content knowledge resulting from project participation. Bowman et al. discuss 'empowerment evaluation' as an ongoing evaluation tool that feeds back into project development. Butler et al. present the results of six annual external reviews of GLOBE. Hall-Wallace et al. discuss the use of reflective tools (e.g., notebooks) in evaluating the impact of K-16 partnerships on student teachers and in-service teachers. Jarrett et al. employ pre- and post-program questionnaires and make use of existing education metrics (e.g., Likert scale) that may be new to some JGE readers.

Effective Partnerships - In developing effective research partnerships issues of data quality and educational assessment are paramount. There are, however, other details that need be considered for a program to succeed. For example, Ross et al. discuss participant demographics in the context of balancing research goals with large-scale collaboration. Ledley et al. present a template of issues (e.g., required background information and project logistics, among others) for project developers to consider in developing meaningful partnerships that benefit all collaborators. Gosselin et al. and Hall-Wallace et al. tackle the subject of differing cultures of science and science education, and the issues that need to be taken into account when developing collaborations between scientists and teachers. Hall-Wallace et al. raises the importance of incentives and rewards in encouraging participation of all partners.

SUPPORT FOR GEOSCIENCE RESEARCH PARTNERSHIPS

There is growing emphasis on the role of scientific inquiry in precollege and undergraduate science education (AAAS, 1993; NRC, 1996; NSF, 1996;). Coincident with this new emphasis is a push for education reform within the Earth sciences (Barstow et al., 2001). Geoscience research partnerships have the potential to play an integral part in these reforms, as they integrate research and education in a very hands-on approach, and provide experiences with, and training in, inquiry at all educational levels. If these partnerships are to play a role in these reforms we must find and disseminate effective models that are readily usable by the broader geoscience community. Dissemination and dialogue are critical in order to insure that best practices are employed, that time is not wasted reinventing tools, and that partnerships are accessible to a wider audience. Currently available support systems may allow for the large-scale development of effective partnerships. Developing science digital libraries are ideal forums for sharing project models and data. Funding initiatives at the National Science Foundation also support the integration of research and education through research partnerships.

Both the Digital Library for Earth System Education (www.dlese.org) and the National Science Digital Library (www.nsdl.org) provide a forum where model programs, evaluation tools, and data sets can be catalogued as resources and made available to a wide variety of users. Information on how to use data in the classroom and effective approaches to partnering can be accessed through the DLESE community center based at Carleton College (www.dlesecommunity.carleton.edu). Both DLESE and NSDL provide environments where researchers and K-16 students and teachers can access and contribute data. Through DLESE, the opportunity also exists to communicate with colleagues through several listserv-based working groups, including one focused on 'linking research and education'. DLESE community groups exist to support dialogue among users, and if there is sufficient interest new groups can be proposed and established.

The integration of research and education is now encouraged for all projects requesting funding from the National Science Foundation. In addition, several directorates oversee specific programs that financially support aspects of research partnerships. The NSF Directorate for Geosciences offers two programs that support the integration of research and education through partnerships: Geoscience Education and Opportunities for Enhancing Diversity in the Geosciences. The latter focuses on increasing diversity in the geosciences profession and uses the integration of research and education as a strategy for reaching this goal. Supplements to research awards are also available through the Directorate for Geosciences to facilitate the integration of research and education. Three relevant programs offered through the Division of Elementary, Secondary, and Informal Science Education include Instructional Materials Development, Informal Science Education, and the Teacher Enhancement Program. The

Course, Curriculum, and Laboratory Improvement program managed by the Division of Undergraduate Education provides opportunities to integrate research findings and methodology into the curriculum. The GK-12 Fellowship program in the Division of Graduate Education, supports partnerships between graduate students and K-12 classrooms. Much of the work described in this issue has been supported through these programs.

To achieve a national impact, research partnerships must grow in number, size, and quality. It is our hope that the articles in this issue will provide models of project development, implementation, and evaluation, and will be a source of inspiration to JGE readers.

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