JOURNAL OF GEOSCIENCE EDUCATION **64**, 303–313 (2016)

A Mixed Methods Approach to Determining the Impact of a Geoscience Field Research Program Upon Science Teachers' Knowledge, Beliefs, and Instructional Practices

Gail Luera,[1,a] and Kent Murray[2]

ABSTRACT

A mixed methods research approach was used to investigate the impact of a geosciences research institute upon 62 science teachers' knowledge, beliefs, and teaching practices related to teaching the geosciences. Pre- and postinstitute quantitative and qualitative assessments revealed mixed results. Results of a quantitative measure found a statistically significant increase in the teachers' self-reported overall knowledge of the geosciences, knowledge of watersheds, and knowledge of brownfield sites. However, a more specific quantitative instrument that measured watershed knowledge indicated no change except in the teachers' awareness that the water quality in different towns is related. In addition, their science teaching self-efficacy, which was used as a quantitative measure of the teachers' beliefs about teaching science in general, showed a statistically significant decrease. Focus group discussions provided an indication as to why the teachers' self-efficacy decreased, as teachers described numerous barriers that limited their capacity to engage their students in field-based research projects even while noting the benefits of such an experience. Although the study was limited in the ability to measure direct impact on instructional practices, the teachers' perception of their confidence in their capability to use inquiry-based instruction in the classroom showed a statistically significant increase. The discrepant results provide useful information about the complex impact of a professional development experience upon teachers, while identifying possible limitations of the experience and of the assessment measures, as well as providing recommendations for future research. *© 2016 National Association of Geoscience Teachers*. [DOI: 10.5408/14-064.1]

Key words: classroom teacher, field research, inquiry-based instruction

INTRODUCTION

The lackluster performance of U.S. students on state, national, and international science assessments has prompted movement towards reforming the science curriculum and pedagogy in many public schools (Duncan, 2010; NGSS Lead States, 2013a). Among the goals of national science education reform is to address the needs of a national student audience while simultaneously making the content relevant to a specific context (Hollweg and Hill, 2003; NGSS Lead States, 2013b). One way to do this is by linking the content to a particular community or local issue through a pedagogy called place-based education (Dentzau, 2014; Hackworth, 2015). Placed-based education is commonly defined as the process of using the local cultural, historical, and physical environment to teach subjects across the curriculum in a way that emphasizes one's connection and responsibility to the community (Woodhouse and Knapp, 2000; Smith, 2002; Sobel, 2004; Semkin, 2005). It also includes the emotional connection one has to a place (Williams and Semken, 2011). Although this pedagogy has its roots in environmental education, it is currently being implemented in a wide variety of settings, including geoscience education (e.g., LaSage et al., 2006; Semkin, 2005; Monet and Greene, 2012; DeFelice et al., 2014; Hougham et al., 2015).

Given place-based education's focus on the development of the whole individual in relation to their environment, it is not surprising that this pedagogy has been demonstrated to have a positive impact on students and teachers. Place-based education has been shown to increase students' social responsibility and knowledge of the local community while building their content knowledge in a way that is relevant and engaging (State Education and Environment Roundtable, 2000; Athman and Monroe, 2004; Jennings et al., 2005). Teachers who use a local context for their instruction experience increased satisfaction in teaching, in part because there are fewer student discipline problems (Meichtry and Smith, 2007).

Local environments and their inhabitants are complex and dynamic settings that often have their own distinct characteristics. In order to capture the impact of an educational experience that implements place-based pedagogy, it is important to employ a correspondingly complex research methodology such as the mixed methods approach. This research methodology is well suited to capture both the cognitive and affective impact of a place-based geoscience program, since a wide variety of quantitative as well as qualitative measures can be used to illuminate program impact in a way that one type of measure alone is not able to do (Johnson and Turner, 2003; Ponce and Pagan-Maldonado, 2015). Quantitative measures are designed to investigate researcher-defined constructs (Patton, 1990), such as knowledge of the water cycle. In addition, they can even measure likelihood to engage in a future behavior, such as proper disposal of hazardous wastes. In contrast, qualitative data

Received 17 November 2014; revised 28 March 2016, 20 September 2016; accepted 21 September 2016; published online 02 November 2016.
[1]College of Education, Health and Human Services, University of Michigan–Dearborn, 19000 Hubbard Drive, Dearborn, Michigan 48128, USA
[2]College of Arts, Sciences and Letters, University of Michigan–Dearborn, Dearborn, Michigan 48128, USA
[a]Author to whom correspondence should be addressed. Electronic mail: grl@umich.edu. Tel.: 313-593-3762.

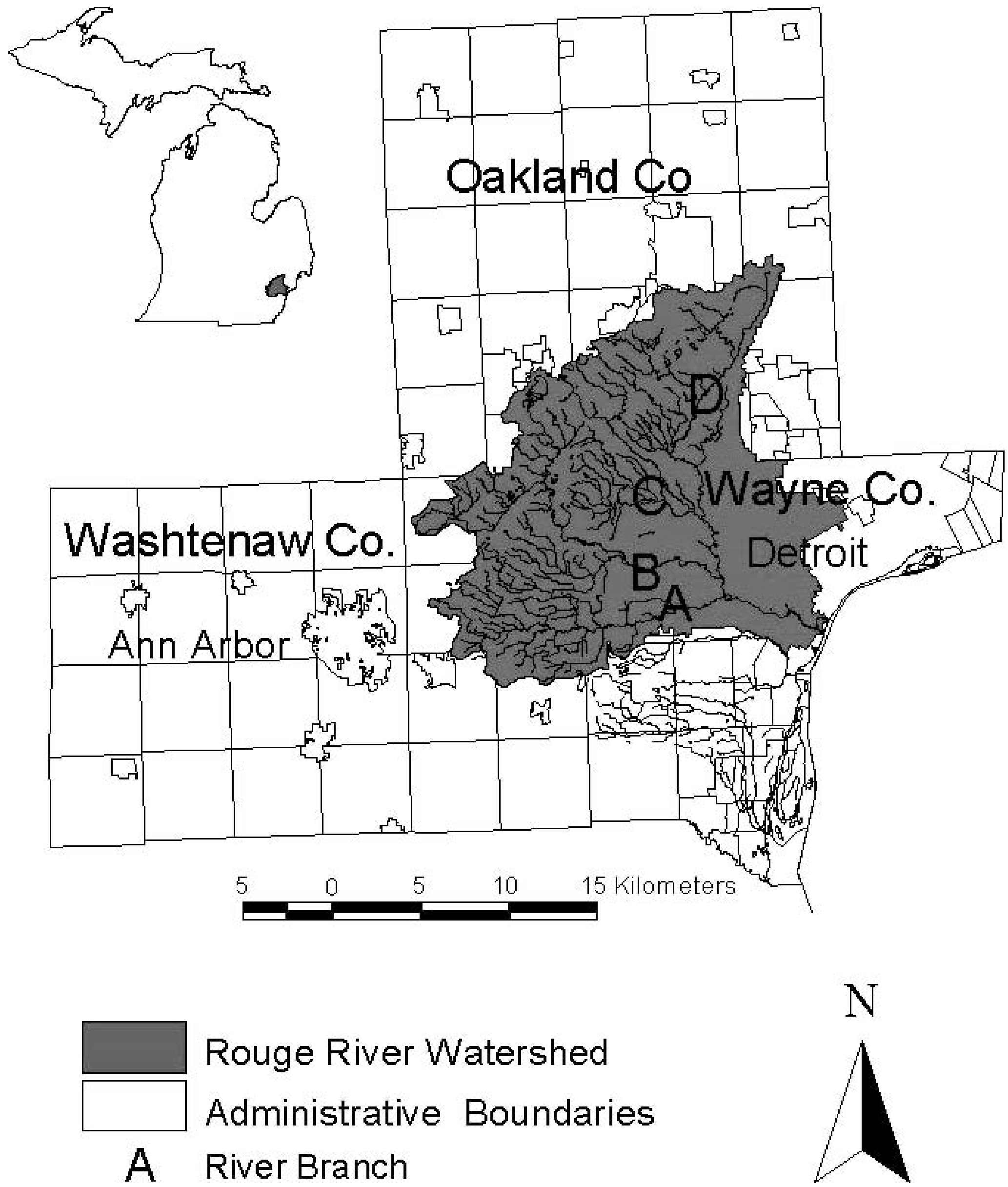

FIGURE 1: Map of Rouge watershed.

allow participants to describe their own experience and how it fits into their unique context. Mixed methods research has the ability to capture the complicated and potentially contradictory impacts of educational programs (Phillips, 2009).

Program Description

In 2006, the University of Michigan–Dearborn (UMD) created a Geosciences Institute for Research and Education (GIRE). The GIRE is a consortium of faculty, UMD graduate and undergraduate students, and local geologists who have worked with local Earth Science teachers and their students in a 3 week, field-based program each summer for 7 y. The funding for the summer institutes came from two grants from the National Science Foundation's Opportunities for Enhancing Diversity in the Geosciences (OEDG) Program. The basis of the program was a hands-on research experience in the geosciences that demonstrated how knowledge of geology can be used to solve community-based environmental problems.

A field research experience was included because these have been demonstrated to increase both teacher and student content knowledge and interest in the sciences (Barab and Hay, 2001; Buck, 2003; Pop et al., 2010), especially if placed in a local context such as a local river or watershed (O'Connell et al., 2004; Meichtry and Smith, 2007). Since the university personnel, teachers, and their students all lived within the same Rouge watershed (Fig. 1), the watershed was used as the local context for the program.

The overall goals of the GIRE were:

- to provide an awareness of opportunities in the geosciences to groups of underrepresented minority students;
- to improve teacher knowledge of geology;
- to stimulate student interest in science; and

- to increase enrollment and retention of groups of underrepresented minority students in the geosciences at UMD.

Each summer, the GIRE workshops consisted of three 5 d sessions. Each session consisted of 1.5 d of interactive workshops where participants learned how to use field/laboratory instrumentation and went on field trips to gain a local perspective, and 3.5 d of hands-on field and laboratory activities. Session leaders, who were often working professionals, emphasized during the field trips and activities how the geosciences are uniquely positioned to help solve many local environmental problems. The goal was to not have the teachers and their students complete research projects, but rather to involve them in active, ongoing research taking place in their community. This was achieved, as participants were introduced to the different field and laboratory activities necessary to solve the problems.

The field research projects focused on watershed issues, since the watershed, or catchment basin, is an excellent unit for the integration of geoscience research, and it is consistent with a geoscience theme, i.e., solving environmental problems (Murray et al., 2004; Kaufman et al., 2011). The watershed approach is appropriate because it focuses on efforts to address solutions to environmental problems within hydrologically defined geographic areas (U.S. Environmental Protection Agency, 1996). During the GIRE, the teachers and students conducted research within the geological features of the Rouge watershed as they learned about the history of the region and the environmental issues located within the watershed.

The geoscience research projects at UMD in which the teachers and students participated included an investigation of soil-lead contamination in Delray, an impoverished community in southwest Detroit that has a history of pollution by industries (Graham, 2015). The teachers and student participants collected soil samples from residential properties throughout the Delray community following Environmental Protection Agency (EPA) protocol.

In a second project, the participants investigated the impact of land use on groundwater and surface-water quality by installing groundwater monitoring wells along the lower branch of the Rouge River. The students and teachers then collected groundwater, sediment, and surface-water samples for subsequent chemical analysis. This project indicated that the use of road salt as a de-icer in winter is having a profound effect on the chemistry and ecology of the Rouge River.

A third project early in the GIRE focused on the transport and fallout of heavy metals from a municipal incinerator. These field research activities provided opportunities for the teachers to deepen their knowledge of the geosciences as they performed research tasks that were focused on a local environmental problem.

This study focuses on investigating the impact of the GIRE during the last 5 y of the project on the classroom teachers' knowledge, beliefs, and teaching practices related to teaching the geosciences.

RESEARCH METHOD

A mixed methods research approach was used to investigate the effect of the institute on the teachers. Using Onwuegbuzie and Leech's (2006) system for presenting mixed methods research questions, each question in this study has both a quantitative (QUAN) and qualitative (QUAL) component. The dominant research methodology used is capitalized, while the other method is shown in lowercase. Three mixed methods research questions were investigated:

(1) What is the relationship between participation in the GIRE and teachers' *knowledge* of geoscience content (QUAN/qual)?
(2) What is the relationship between participation in the GIRE and teachers' *beliefs* about teaching the geosciences (QUAN/qual)?
(3) How are teaching *practices* impacted by participation in the GIRE (QUAL/quan)?

To begin the study, the evaluator reviewed a wide variety of research and survey items related to the professional development of science teachers (e.g., Riggs and Enochs, 1990; Loucks-Horsley et al., 2009), teacher characteristics leading to student interest in the geosciences (e.g., Levine et al., 2002; Sherman-Morris et al., 2013), and established geoscience content knowledge assessments (e.g., Wagenet et al., 1999) when creating the pre- and post-institute survey instruments. All survey instruments were submitted to the University of Michigan–Dearborn Human Subjects Committee and received Institutional Review Board approval. The initial survey instrument was given to the teachers at the beginning of the GIRE and consisted of items from this literature base as well as additional items that were created to focus on specific goals of the study. These additional items gathered information about the educational background of the teachers, their preferred teaching style, their perceived geoscience knowledge, and their familiarity with different science careers. See an online supplement (available in the online journal and at http://dx.doi.org/10.5408/14-064s1) for the initial teacher survey.

Several questions were included on the survey that dealt with geoscience concepts that were addressed during the GIRE, since one of the goals of the study was to improve teacher knowledge of geology, and specifically watershed issues. The survey also included 24 items from Wagenet et al. (1999) relating to watersheds. These questions focused on three of the six levels of Bloom's taxonomy of the cognitive domain: knowledge, application, and evaluation (Bloom et al., 1956). The nine knowledge questions required the teachers to recall discrete facts about watersheds, while the ten application questions assessed their ability to link different watershed features to watershed protection. Participants rated statements on these two levels as either correct or incorrect. The five evaluation level statements were measured with five-point Likert scale items (strongly agree, agree, neither agree nor disagree, disagree, strongly disagree) because there are elements of value or judgement for this cognitive level (Bloom et al., 1956). Issues relating to the validity and reliability of the watershed questions are described in Wagenet et al. (1999). Content validity was determined by having two GIRE geologists review each item. Any suggestions they made to improve an item were incorporated into the survey before it was administered to the teachers.

One of the goals of the research was to determine if the GIRE had an impact on teaching practices. Because it was beyond the scope of the grant project to measure the teachers' instruction in the classroom, an instrument was selected to measure the teachers' belief in their likelihood to teach the geosciences. The belief in one's ability to engage in a particular behavior is called self-efficacy and was first developed by Bandura (1977) as part of his social cognitive theory.

The Science Teaching Efficacy Behavior Protocol (STEBI; Riggs and Enochs, 1990) was determined to be a suitable measure of self-efficacy and was included at the end of the survey. The STEBI is based upon Bandura's (1977) social cognitive theory, which states that self-efficacy beliefs motivate people towards specific actions and can be used to predict future behavior. A limitation is that the STEBI measures general science self-efficacy rather than geoscience self-efficacy, although it has been used in other studies relating to geoscience teaching self-efficacy (e.g., D'Alessio, 2012; Posnanski, 2007). The STEBI includes 25 Likert-scaled statements relating to personal beliefs about teaching science, and it contains two subscales, personal science teaching self-efficacy beliefs (PSTEB) and science teaching outcome expectancy (STOES). The first subscale measures teachers' beliefs in their ability to teach science, while the outcome expectancy measures their beliefs that their teaching will make a difference in their students' understanding of science. Riggs and Enochs (1990) provided a complete description of the reliability and validity measures for STEBI.

A final measure of program impact and the primary source of qualitative data was the focus groups conducted on the last day of each summer's workshop. The focus groups for the teachers and the students were conducted separately by the project evaluator and other School of Education faculty experienced in this method of data collection. Over the length of the project, each focus group session lasted for an average of 45 min. Focus group methodology was appropriate in this evaluation research because it facilitated the exploration of diverse program impact by creating a collective conversation among participants. Focus groups also revealed the rich experiences of the participants in their own words and provided a depth of understanding about the GIRE experience that could not be determined using quantitative methods. The semistructured focus groups allowed for the exploration of issues such as content, program structure, personal meaning, social implications, and recommendations for improvement (Kamberelis and Dimitriadis, 2005). Sample questions included asking the teachers to describe what new geoscience content was learned and how they anticipated that the knowledge gained about their local environment would impact their professional and personal behaviors. The focus group questions remained constant each year, so that the discussion group responses could be compared across groups (Stewart et al., 2007).

The quantitative measures were administered on the first and last days of the GIRE in order to measure change. The qualitative measure, the focus group, was held on the last day of the program.

Participants

A diverse set of teachers was recruited primarily through two channels: Information was sent to local urban school districts with high percentages of minority students and was posted on the Michigan Earth Sciences Teachers Association Web site. The selection process was conducted by the project director. First priority was given to teachers who were responsible for teaching Earth Science and did not have any college education in the geosciences. Second priority was for teachers who taught Earth Science or environmental science and had minimal geosciences coursework in college. There was also an attempt to balance the number of middle school and high school teachers selected as well as male and female participants. An average of 40 teachers applied each year. Twelve teachers were selected to attend each institute, and while each teacher had the option of bringing one or two of their students to the GIRE, the total number of institute participants (teachers plus students) could not exceed 18 due to the space limitations of the field research projects. This limited the teachers' ability to bring students to the institute. As the project progressed, fewer middle school science teachers and students were able to be recruited because the university incentive to offer college credit to students was extended solely to high school students. Conceptually, it also made sense to focus on the high school level because that is often when students are able to make the decision to enroll in science elective courses. Despite these constraints, by the end of the fifth year of the GIRE, 62 teachers and 36 students had participated in the project. Demographic characteristics are presented in Table I for the participating teachers and in Table II for the students.

RESULTS

The quantitative data were analyzed using the Statistical Package for Social Science (SPSS), version 22, to compute the difference between the scores on the pre- and postassessments. Before the tests were conducted, a preliminary analysis was conducted to test the assumption for normality. This was checked using both statistical (Shapiro-Wilk) and visual methods (Q-Q plots). In the cases where the assumption was not met, a nonparametric test was used, since both the preliminary analysis and the relatively small sample size indicated that this type of statistical text was most appropriate (Wells and Hintze, 2007).

The qualitative data, the focus group discussions, were analyzed using a content analysis approach and NVivo software. The focus group data were analyzed by transcribing the discussions, reviewing the transcripts for accuracy, and manually coding the content into themes. Six themes were identified: knowledge of local community, change in teaching, change in personal behavior, impact on participating students, geoscience content (watershed, groundwater, brownfields), and suggestions for improvement of the GIRE. After this process of coding was completed by the program evaluator, a project staff member read over the transcripts and code labels and coded the text. This was done to establish the reliability of the coding system and is commonly used when analyzing focus group data (Stewart et al., 2007). There were only three coding differences (out of a total of 423 sections of coded text) between the two researchers. The final codes for these discrepancies were resolved by consensus after a discussion. See Fig. 1 for a graph of the total number of references for each of these themes. Totals for coding values exceed 100% because

TABLE I: Demographics of participating teachers.

Demographic	No. Teachers
Gender	
Male	15
Female	47
Race	
African American	16
White	46
Educational Level	
Bachelor's degree	17
Master's degree	43
Doctorate	2
Number of College Level Geoscience Courses	
None	6
One	20
Two	16
Three	7
More than four	13
Classroom Teaching Experience	
1–5 years	11
6–10 years	20
11–20 years	27
21+ years	4
Grade Level	
Elementary	4
Middle school	34
High school	24
% Student Population Members of Underrepresented Minority Groups	
Less than 50%	18
50%	18
More than 50%	26

comments may have been coded for more than one theme. To prepare for reporting the findings of this analysis, exemplars for each theme were identified from the data (Hsieh and Shannon, 2005) and linked to one of the three research questions.

The type of statistical tests performed and the results from the quantitative and qualitative analysis relating to each research question were compared, and areas of similarity as well as divergence were noted and are described next.

Research Question #1: What Is the Relationship Between Participation in the GIRE and Teacher *Knowledge* of Geoscience Content?

The teachers self-reported their general knowledge of the geosciences, watersheds, and brownfield sites using a five-point Likert scale (1 = no knowledge, 5 = excellent knowledge). Since the results of these three items were not normally distributed, a Wilcoxon matched-pairs signed-rank test was conducted to determine where there was a difference in the pre- and postreports of geosciences, watershed, and brownfield sites knowledge. Results of that analysis indicated that there was a statistically significant difference in the teachers' perceived knowledge in each of these areas (Table III).

TABLE II: Demographics of participating students.

Demographic	No. Students
Gender	
Male	20
Female	16
Race	
African American	13
White	23
Highest Grade Completed	
7th	3
8th	11
9th	4
10th	5
11th	5
12th	8
Intend to Attend College	
Yes	35
No	1
At Least One Parent College Graduate	
Yes	19
No	17

A McNemar test (Adedokun and Burgess, 2012) was used to determine if there was a difference in the pre- and postinstitute scores for the watershed issue questions at the knowledge and application levels, and it revealed no statistically significant difference in the scores for these 19 questions. A test for normality indicated that the evaluation level questions were not normally distributed, so the Wilcoxon signed-rank test was used. There was no difference in the pre- and postinstitute scores at the evaluation level, with the exception of question 24, which asked the teachers to rank the level to which they agreed with the statement, "The quality of my drinking water doesn't have anything to do with drinking water quality in another town" (Table III). Therefore, the analysis illustrates that after the GIRE, the teachers were more likely to recognize that the quality of drinking water in different towns is related.

A content analysis of the transcripts from the focus groups revealed four themes that were directly related to specific geoscience content knowledge (watershed, groundwater, brownfields, deep wells). Although the number of references to these specific topics was relatively low (Fig. 2), the comments made by the teachers indicated that they had gained knowledge of these geoscience concepts, which supports the results of the quantitative analysis. For instance, the teachers mentioned frequently that while they may have had a basic understanding of the concept of a watershed, they did not know how important a watershed was. One

TABLE III: Pre/postinstitute perceived knowledge.

Survey Item	Pretest	Posttest	Z Score[1]
Knowledge of geosciences	3.0 (.78)	3.8 (.61)	−5.6***
Knowledge of watersheds	2.7 (.83)	4.1 (.61)	−6.4***
Knowledge of brownfield sites	1.9 (.81)	3.9 (.71)	−6.6***
"The quality of my drinking water doesn't have anything to do with drinking water quality in another town."	4.6 (.55)	4.9 (.28)	−2.8**

[1]Mean (standard deviation) difference between pre- and post-GIRE Z score: ** = $P \leq 0.01$, *** = $P \leq 0.001$.

teacher expressed it this way, "I didn't realize how important the watershed is and what the area was until I came to this Geoscience Institute." Similarly, the teachers often commented that they had known about groundwater, but they did not think about it often, especially in terms of how easily it is polluted.

The teachers mentioned that they had learned about the concept of brownfield sites in the context of their community, noting, for example, "all the different businesses that were located on these brownfield sites and how they have impacted the watershed, the Rouge River, and how businesses today are even impacting it in terms of polluting it or keeping it clean."

While the teachers said their understanding of deep wells had increased, several mentioned that it would have furthered their understanding even more, as one teacher stated, to "see test wells, or using the purging system to clean up the site."

Research Question #2: What Is the Relationship Between Participation in the GIRE and *Belief* in Ability to Teach the Geosciences?

The relationship between participation in the institute and the teachers' beliefs in their ability to teach the geosciences was measured in part through a quantitative analysis of the STEBI scores. Neither the overall STEBI scores nor the two subscores were normally distributed, so again a nonparametric test was used to determine if there was a difference between the pre- and postinstitute scores. A Wilcoxon matched-pairs signed-rank test indicated that there was a difference in both the overall STEBI score and the PSTEB subscore. The overall STEBI as well as the PSTEB subscore decreased from pre- to postinstitute assessment (Table IV). There was no difference in the pre- and postinstitute STOES scores. While it may be surprising that the teachers' overall self-efficacy towards teaching science and their personal science teaching self-efficacy beliefs in general science teaching decreased, self-efficacy has been repeatedly demonstrated to be difficult to change. This is especially true for experienced teachers who have an initial STEBI score above 50 (Roberts et al., 2001). The institute teachers entered the program with an average STEBI score of 52.1. In fact, Roberts et al. (2001) determined that a 4 week, activity-based professional development experience resulted in the largest gain in science teaching self-efficacy, especially for teachers who came into the professional development experience with low self-efficacy (<50 on their overall STEBI score) towards teaching science. One explanation for the decrease in scores can be found in the focus group transcripts. While the theme of changes in teaching the geosciences was most prevalent, a subtheme within it was barriers to teaching. While the institute experiences had an overall positive impact on the teachers, it may have also made them more aware of the barriers that would make it challenging to take their students out in the field. Frequently mentioned barriers were limited time for field trips or hands-on activities and lack of resources to transport the students to sites in the community.

Two questions on the survey directly asked the teachers about their ability to teach the geosciences and their confidence in their ability to implement geoscience concepts in their classroom. For the first question, the teachers rated their ability to teach the geoscience using a five-point Likert scale in which 1 = no confidence, and 5 = excellent confidence. The second question asked teachers to rate how

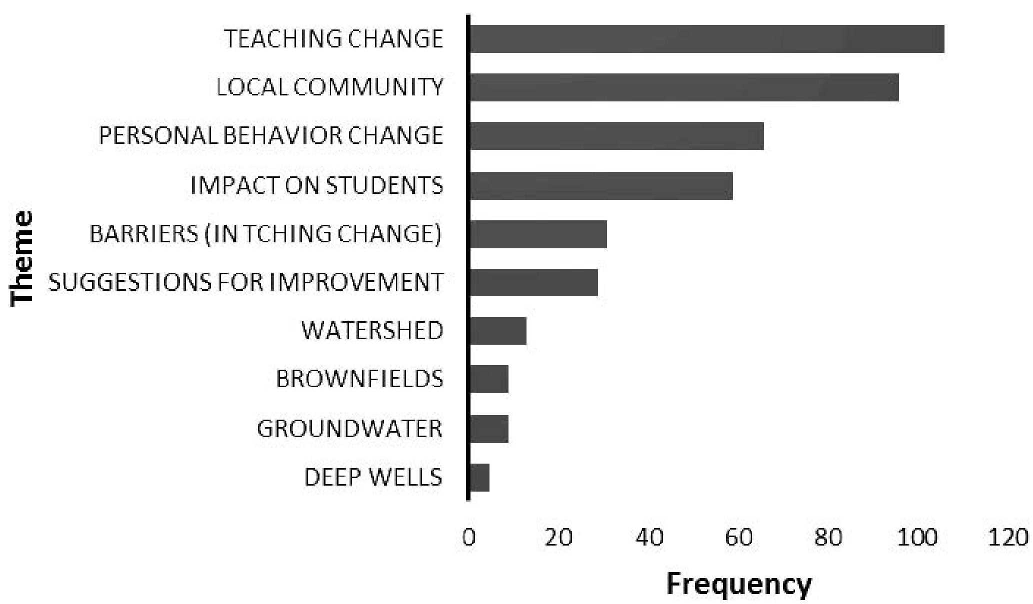

FIGURE 2: Frequency with which each theme was mentioned in focus groups.

TABLE IV: Pre/postinstitute perceived beliefs.

Item	Pretest	Posttest	*Z* Score[1]
Overall STEBI score	52.1 (11.6)	50.5 (9.1)	-3.0^{**}
STOES subscore	30.0 (7.3)	29.6 (6.1)	-1.4^{ns}
PSTEB subscore	22.1 (5.7)	20.9 (4.4)	-3.1^{***}
Ability to teach geoscience concepts	3.0 (.8)	3.9 (.7)	-5.5^{***}
"I currently feel confident that I can incorporate geoscience concepts into my classroom."	3.0 (.8)	3.6 (.5)	-4.6^{***}

[1]Mean (standard deviation) difference between pre- and post-GIRE Z score: ns = $P > 0.05$, ** = $P \leq 0.01$, *** = $P \leq 0.001$).

well they agreed with the statement, "I currently feel confident I can implement geoscience concepts in my classroom setting," using a four-point Likert scale (1 = strongly disagree, 4 = strongly agree). While the two questions may appear similar, they were worded to assess different constructs. The first question is more abstract and general, whereas the second question asks teachers to rate their confidence in their ability to implement geoscience concepts *in their classroom setting*. That is, the question takes into account the dynamics of their present classroom environment. The results of a Wilcoxon signed-rank test showed the GIRE increased the teachers' confidence in their ability to teach geoscience in general and specifically in their classroom (Table IV). Although the GIRE had a positive effect on the teachers' belief in their ability to teach geoscience concepts, this contrasts with the lower post-GIRE science self-efficacy scores. These two disparate results raise the question of what other or additional types of professional development activities could increase the teachers' self-efficacy towards teaching science.

The content analysis of the focus group transcripts revealed a subtheme within the "teaching changes" theme that provided support to the quantitative analysis that the teachers' confidence in their ability to teach geoscience concepts in their classroom had increased. A typical response within this subtheme was that the institute had provided them with specific content knowledge and local contexts in which to teach the geosciences. The teachers noted that they were able to connect their new knowledge and awareness of local issues to a passion for teaching the geosciences. One teacher expressed it this way: "We have a better background and a better understanding of things so we can lay the groundwork."

Research Question #3: How Are Teaching *Practices* Impacted by Participation in the GIRE?

The primary means of answering this research question was through the content analysis of the transcripts from the teachers' focus groups. Teachers were asked to self-report how the institute experience would impact their teaching practices, which was an intentionally broad construct and is historically viewed as a weaker measure of teacher behavior (Desimone, 2009). The analysis of focus group transcripts revealed a related theme of teaching changes. This theme was mentioned most frequently (Fig. 2) and occupied the largest percentage of the focus group time. In fact, nearly 23% of the focus group discussion was related to how teachers anticipated their teaching would change as a result of participating in the GIRE. Three subthemes emerged related to *what, how*, and *why* the teachers would teach the geosciences to their students.

What Geoscience Would Be Taught

Numerous teachers spoke of feeling more comfortable by the end of the institute with the geoscience concepts and an ability to make them more relevant to the students because they had learned about specific community-environmental issues. One teacher noted, "I was trying to think what can I do to make geology important [to the students]. Now I can remind them that geoscience is a connection to everything."

How Geoscience Would Be Taught

Along with relating the geosciences to local issues, the teachers also described the importance of getting the students out in the field for hands-on learning. As one teacher reflected, "The fieldtrips were so important. They were such an eye-opening experience for us as teachers. It would have the same impact and even more on our students."

Often teachers mentioned that there were resources right outside their classroom they could use to make the geosciences real. "Our school's right on the Clinton River watershed and it's literally a tenth of a mile away from our school. And now I'm going to have that time to do exactly what we did in the river. I'm just, really excited to be able to go into our backyard again and to incorporate all this knowledge."

Although a number of teachers described within the subtheme of barriers why they were not able to take students outside, they did mention that the activity modules they participated in at the GIRE would be used in their classrooms. The teachers repeatedly mentioned the practicality of the modules, the easy obtainability of the needed supplies, and the benefit of having already done the module activities before attempting them with their students.

Several teachers mentioned that after participating in the GIRE research projects, they now knew how to test for pollutants in their environment. One teacher mentioned these new research skills in terms of how she would teach her urban students, "I teach in Detroit where lead poisoning is significant. I will be able to tell them if they have contaminated soil at the home now. I can now not just teach science for the sake of these content standards but for real issues in their lives."

The teachers stated that the field experience demonstrated the importance of understanding basic geoscience in order to make environmentally responsible decisions. This relates directly to the next theme—how the GIRE impacted the teachers' reasons for teaching the geosciences.

Why Geoscience Would Be Taught

Teachers reported that as they learned about the interconnectedness of the different parts of the local watershed, they realized that their individual actions do affect local water quality. This motivated the teachers to teach their students what they had learned at the GIRE because the information had relevance for more than standardized test scores. It was important for the students to learn on a very personal level. One teacher described

TABLE V: Pre/postinstitute perceived teaching practices.

Item	Pretest	Posttest	Z Score[1]
Ability to use inquiry-based instruction in the classroom	3.6 (.8)	4.0 (.8)	3.8^{***}
Using hands-on science modules is the best way for students to learn science.	3.7 (.5)	3.7 (.5)	-0.0^{ns}
It is important for students to have fieldwork experience.	3.7 (.5)	3.8 (.5)	-1.4^{ns}

[1]Mean (standard deviation) difference between pre- and post-GIRE Z score: ns = $P > 0.05$, ** = $P \leq 0.01$, *** = $P \leq 0.001$).

powerfully how she realized the importance of learning about local geoscience-related issues and how her thinking had changed, "seeing first hand, how a certain contaminant is transferring through groundwater or surface water, it's a scary thing to think about. This is going to affect us."

There were three questions on the pre- and postsurveys that also focused on teaching practices. These questions were intended to assess how closely the participating teachers' confidence and future pedagogical techniques mirrored the instructional techniques modeled in the GIRE. The first question asked the teachers to rate their confidence in their ability to use inquiry-based instruction in the classroom, using a five-point Likert scale (1 = no confidence, 5 = excellent confidence). The other two questions asked teachers to rate their level of agreement, on a four-point Likert scale (1 = strongly disagree, 4 = strongly agree), with these statements: (1) Using hands-on science modules is the best way for students to learn science. (2) It is important for students to have fieldwork experience. None of the data for these three questions met the assumption of normality, so a Wilcoxon signed-rank test was used to analyze the data. Results indicated that the only change in the teachers' pre- and postinstitute responses was an increase in their confidence in their ability to use inquiry instruction in the classroom (Table V).

This increase in confidence could be a reflection of the inquiry activities that both the teachers and students engaged in at the GIRE. Because there were middle and high school students participating in the activities alongside the teachers, the teachers were able to view the activities from the perspective of both the instructor and the student. The lack of statistically significant differences in the other two areas of teaching practices could be due to limitations within the institute, or it could be a reflection of the ceiling effect, as the teachers had agreed with the value of hands-on science modules and that it was important for students to have fieldwork experience even before they participated in the GIRE.

DISCUSSION

Overall, both the quantitative and qualitative data indicate that there is a positive relationship between the GIRE and increases in the teachers' perception of their knowledge, beliefs in their ability to teach the geosciences, and anticipated changes in teaching practices, although the relationship was not always definitive. This is indicated by the disparate results between the quantitative and qualitative data and is not conclusive due to research limitations.

Nearly all of the teachers expressed how they had gained new knowledge and a corresponding increase in their commitment to make the science curriculum relevant to their students as they learned about pollution occurring on specific research sites in their local community. Teachers mentioned that after the institute, they had the knowledge and skills to use place-based pedagogy by making links to similar sites in their students' local environment. In contrast, the quantitative results were mixed; the teachers' self-report of increases in geoscience knowledge contradicted the results from the watershed survey, which did not indicate a change in knowledge. The lack of change in knowledge could be a result of the geoscience and watershed knowledge survey items being instructionally insensitive to the GIRE activities even though the assessment items were validated by participating geoscience faculty. Instructional sensitivity can be loosely defined as the degree to which scores on an assessment reflect the quality of the instruction (Popham, 2013). This represents a limitation of the research. In the future it would be useful to develop quantitative assessments based upon the professional development activities. The findings from the qualitative measures could provide guidance in developing specific items to measure knowledge and beliefs.

The qualitative data and the results of a quantitative self-report instrument indicated that the teachers did increase their belief in their ability to teach geoscience content in general, as well as to the students in their classroom. In contrast, results using an instrument designed to measure teacher self-efficacy towards teaching general science (the STEBI) and the teachers' personal science teaching self-efficacy beliefs (PSTEB) *decreased*. The PSTEB subscale reflects teachers' confidence in their ability to teach science. There was no change in the STOES subscale score, which reflects teachers' beliefs that student learning can be influenced by their effective teaching. It would be interesting to investigate further why the participating teachers believed less in their ability to teach science after the institute than they had before. Perhaps the teachers overestimated their ability to teach science at the beginning of the institute and once exposed to the large quantity of geoscience information presented at the GIRE, they realized how much more there was to know. Alternatively, the measure itself may need to be reevaluated given the current emphasis on inquiry-based science teaching (Wheatley, 2005). Other studies have reported similar decreases in STEBI scores after professional development activities (e.g., Holden et al., 2011). It has also been argued that self-efficacy is context-specific (Bandura, 1977), and the STEBI is not focused solely on teaching the geosciences. A third explanation for the decrease in scores relates to a limitation of the study—that the STEBI does not target beliefs towards teaching the geosciences specifically.

Teachers reported qualitatively that their teaching practices were positively impacted by the institute in terms of what aspect of the geosciences would be taught, how they would teach it, and why they believed it was important for their students to understand. The quantitative data revealed that the teachers came into the institute possessing confidence to use inquiry-based teaching approaches and positive beliefs that students should learn science through hands-on and field experiences. Not surprisingly, given the initial high scores on these survey items, the postinstitute scores were not higher than the pre-institute scores. The reliance on teacher self-report of future classroom behavior represents a limitation of the study. Although self-reporting is often used in evaluation research, the accuracy of self-reports data is open to debate, especially if it relates to pro-environmental behaviors such as water conservation or energy usage (Corral-Verdugo, 1997; Steg and Vlek, 2009). Classroom observation of teaching behavior and the geoscience content being taught would be a more direct measure of program impact, although, like self-reported behavior, it is difficult to measure objectively (Desimone, 2009). The study would be further strengthened if the teachers' geoscience teaching behaviors were observed before and after the GIRE and compared to the teacher's self-reported behavior.

While the results of the mixed methods research approach do not point directly to one clear conclusion concerning the relationship between teacher participation in the institute and positive changes in their knowledge, beliefs, and teaching practices related to teaching the geosciences, they do illuminate and reflect the complex impacts that a geoscience professional development activity that focuses on environmental research in the local community can have upon science teachers. Both the quantitative and qualitative data provide important information about the effect of the institute upon the teachers. For instance, the quantitative data provide an indicator of teacher knowledge of specific geoscience content, while the qualitative data provide a more personal perspective of the impact of the GIRE upon the teachers in their own words. The profound effect of the institute was evident during the focus group sessions, in which several teachers described the GIRE experience as "life-changing."

IMPLICATIONS AND RECOMMENDATIONS FOR FURTHER RESEARCH

The mixed methods approach used in the study represents an initial attempt at understanding the relationship between placed-based geoscience professional development activities and teacher content knowledge, beliefs, and teaching practices. Mixed methods research is an appropriate first step in evaluating the effectiveness of the GIRE, as the inconclusive results indicate that further research is needed to more rigorously understand program impact upon the teachers. In particular, instruments need to be developed or selected based on their instructional sensitivity and linkage to the professional development activities. The themes identified in the focus group discussion can be used to develop quantitative measures to assess beliefs about teaching the geosciences or about teaching practices. If the ultimate goal of the professional development is to improve student learning and interest in the geosciences, particularly for underrepresented groups, then a conceptual framework such as the one advocated by Desimone (2009) would be useful to implement in later research. The model is based upon an extensive review of impact studies of teachers' professional development. It allows for the investigation of the relationship between the proven features of professional development (content focus, active learning, coherence, duration, and collective participation), increased teacher knowledge and skills, change in attitudes and beliefs, changes in instruction, and changes that foster increased student learning (Desimone, 2009). Use of this model would provide a common framework that would be helpful when designing individual studies that research the impact of teacher professional development programs, and it would also facilitate the comparison of research studies by using a common language.

Despite being a preliminary study, the results of this research can be useful to geoscience educators designing professional development programs for teachers and for those interested in environmental education because they indicate that the GIRE motivated teachers to become environmental stewards, even when that was not the predominant goal of the professional development experience. That result again weaves back to the importance of placing the geoscience content in a local context in which the teachers and students have a personal connection, which is important for all program developers to be mindful of as they create geoscience education programs.

Acknowledgments

The authors thank the classroom teachers, university faculty, and students for their enthusiastic participation in the GIRE. The project was funded by two National Science Foundation Opportunities for Enhancing Diversity in the Geosciences Program grants (#0302424 and #0703712). All research was conducted after receiving approval from the University of Michigan Institutional Review Board, #HUM00016769 Geosciences Institute for Research and Education. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation. Finally, the comments from the reviewers and editors of the *Journal of Geoscience Education* were appreciated as they significantly improved this manuscript.

REFERENCES

Adedokun, O., and Burgess, W. 2012. Analysis of paired dichotomous data: A gentle introduction to the McNemar tests in SPSS. *Journal of MultiDisciplinary Evaluation*, 8:125–131.

Athman, J., and Monroe, M. 2004. The effects of environment-based education on students' achievement motivation. *Journal of Interpretive Research*, 9:9–25.

Bandura, A. 1977. Self-efficacy: Toward a unifying theory of behavior change. *Psychological Review*, 84:191–215.

Barab, S., and Hay, K. 2001. Doing science at the elbows of experts: Issues related to the science apprenticeship camp. *Journal of Research in Science Teaching*, 38:72–102.

Bloom, B., Englehart, M., Furst, E., Hill, W., and Krathwohl, D. 1956. The classification of objectives. *In* Bloom, B., ed., Taxonomy of educational objectives: Handbook I: Cognitive domain. New York: Longmans, Green, p. 45–49.

Buck, P. 2003. Authentic research experiences for Nevada high school teachers and students. *Journal of Geoscience Education*, 51:48–53.

Corral-Verdugo, V. 1997. Dual 'realities' of conservation behavior: Self-reports vs observations of re-use and recycling behavior. *Journal of Environmental Psychology*, 17:135–145.

D'Alessio, M. 2012. Learning by teaching: Microteaching in geoscience content courses for preservice elementary teachers. *Geological Society of America Abstracts with Programs*, 44(7): 574. Poster available at http://www.csun.edu/~mdalessio/files/GSA2012_microteaching.pdf (accessed 14 September 2016).

DeFelice, A., Adams, J., Branco, B., and Pieroni, P. 2014. Engaging underrepresented high school students in an urban environmental and geoscience place-based curriculum. *Journal of Geoscience Education*, 62:49–60.

Dentzau, M. 2014. The value of place. *Cultural Studies of Science Education*, 9:165–171.

Desimone, L. 2009. Improving studies of teachers' professional development: Toward better conceptualizations and measures. *Educational Researcher*, 38:181–199.

Duncan, A. 2010. The vision of education reform in the United States: Secretary Arne Duncan's remarks to United Nations Educational, Scientific and Cultural Organization (UNESCO), Paris, France. Available at http://www.ed.gov/news/speeches/vision-education-reform-united-states-secretary-arne-duncans-remarks-united-nations-educational-scientific-and-cultural-organization-unesco-paris-france (accessed 10 March 2016).

Graham, L. 2015. New international bridge to bring more pollution to already polluted neighborhood. Michigan radio: WUOMFM: Here and Now. Available at http://michiganradio.org/post/new-international-bridge-bring-more-pollution-already-polluted-neighborhood (accessed 15 September 2016).

Hackworth, S. 2015. Next Generation Science Standards and place-based education: An intrinsic case study of teacher experience. Available at http://repository.uwyo.edu/cgi/viewcontent.cgi?article=1042&context=plan_b (accessed 14 September 2016).

Holden, M., Groulx, J., Bloom, M., and Weinburgh, M. 2011. Assessing teacher self-efficacy through an outdoor professional development experience. *Electronic Journal of Science Education*, 12:1–25. Available at ejse.southwestern.edu/article/download/7385/6890 (accessed 11 March 2016).

Hollweg, K., and Hill, D. 2003. What is the influence of the National Science Education Standards? Reviewing the evidence: A workshop summary. Washington, DC: The National Academies Press. Available at https://www.nap.edu/catalog/10618/what-is-the-influence-of-the-national-science-education-standards (accessed 14 September 2016).

Hougham, R., Eitel, K. and Miller, B. 2015. Technology-enriched STEM investigations of place: Using technology to extend the senses and build connections to and between places in science education. *Journal of Geoscience Education*, 63:90–97.

Hsieh, H., and Shannon, S. 2005. Three approaches to qualitative content analysis. *Qualitative Health Research*, 15:1277–1288.

Jennings, N., Swidler, S. and Koliba, C. 2005. Place-based education in the standards-based reform era—Conflict or complement? *American Journal of Education*, 112:44–65.

Johnson, R., and Turner, L. 2003. Data collection strategies in mixed methods research. *In* Tashakkori, A., and Teddlie, C., eds., Handbook of mixed methods in social and behavioral research. Thousand Oaks, CA: Sage Publications, p. 297–319.

Kamberelis, G., and Dimitriadis, G. 2005. On qualitative inquiry. New York: Columbia University, Teachers College Press.

Kaufman, M., Rogers, D., and Murray, K. 2011. Urban watersheds: Geology, contamination, and sustainable development. Boca Raton, FL: CRC Press.

LaSage, D., Jones, A., and Edwards, T. 2006. The evolution of a field-based research learning collaborative. *Journal of Geoscience Education*, 53:109–115.

Levine, R., Gonzalez, R., Fuhrman, M., and LeFloch, K. 2002. The geoscience pipeline: A conceptual framework. Palo Alto, CA: American Institutes for Research.

Loucks-Horsley, S., Stiles, K., Mundry, S., Love, N., and Hewson, P. 2009. Designing professional development for teachers of science and mathematics. Thousand Oaks, CA: Corwin Press.

Meichtry, Y., and Smith, J. 2007. The impact of a place-based professional development program on teachers' confidence, attitudes and classroom practices. *Journal of Environmental Education*, 38:15–31.

Monet, J., and Greene, T. 2012. Using Google Earth and satellite imagery to foster place-based teaching in an introductory physical geology course. *Journal of Geoscience Education*, 60:10–20.

Murray, K., Rogers, D., and Kaufman, M. 2004. Heavy metals in an urban watershed in southeastern Michigan. *Journal of Environmental Quality*, 33:163–172.

Next Generation Science Standards (NGSS) Lead States. 2013a. Next Generation Science Standards: For states, by states (the need for new science standards). Available at http://www.nextgenscience.org/news/states-lead-effort-write-new-science-standards (accessed 12 March 2016).

Next Generation Science Standards (NGSS) Lead States. 2013b. Next Generation Science Standards: For states, by states. Appendix D: All standards, all students: Making the Next Generation Science Standards accessible to all students. Available at http://www.nextgenscience.org/sites/default/files/Appendix%20D%20Diversity%20and%20Equity%206-14-13.pdf (accessed 14 September 2016).

O'Connell, S., Ortiz, J., and Morrison, J. 2004. Connecting urban students with their rivers generates interest and skills in the geosciences. *Journal of Geoscience Education*, 52:462–471.

Onwuegbuzie, A., and Leech, N. 2006. Linking research questions to mixed methods data analysis procedures. *The Qualitative Report*, 11:474–498.

Patton, M. 1990. Qualitative evaluation and research methods, 2nd ed. Thousand Oaks, CA: Sage Publications.

Phillips, D. 2009. A quixotix quest? Philosophical issues in assessing the quality of educational research. *In* Walter, P., Lareau, A., and Ranis, S., eds., Education research on trial: Policy reform and the call for scientific rigor. New York: Routledge, p. 163–195.

Ponce, O., and Pagan-Maldonado, N. 2015. Mixed methods research in education: Capturing the complexity of the profession. *International Journal of Educational Excellence*, 1(1):111–135.

Pop, M., Dixon, P., and Grove, C. 2010. Research experiences for teachers (RET): Motivation, expectations, and changes to teaching practices due to professional program involvement. *Journal of Science Teacher Education*, 21:127–147.

Popham, W. 2013. Classroom assessment: What teachers need to know, 7th ed. New York: Pearson Education.

Posnanski, T. 2007. A redesigned geoscience content course's impact on science teaching self-efficacy beliefs. *Journal of Geoscience Education*, 55:152–157.

Riggs, I., and Enochs, L. 1990. Toward the development of an elementary teacher's science teaching efficacy belief instrument. *Science Education*, 74:625–637.

Roberts, J., Henson, R., Tharp, B., and Moreno, N. 2001. An examination of change in teacher self-efficacy beliefs in science education based on the duration of inservice activities. *Journal of Science Teacher Education*, 12:199–213.

Semkin, S. 2005. Sense of place and place-based introductory geoscience teaching for American Indian and Alaska native undergraduates. *Journal of Geoscience Education*, 53:149–157.

Sherman-Morris, K., Brown, M., Dyer, J., McNeal, K., and Rodgers, J., III. 2013. Teachers' geoscience career knowledge and implications for enhancing diversity in the geosciences. *Journal of Geoscience Education*, 61:326–333.

Sobel, D. 2004. Place-based education: Connecting classrooms and communities. Great Barrington, MA: The Orion Society.

Smith, G. 2002. Place-based education. *Phi Delta Kappan*, 83:584–594.

State Education and Environment Roundtable (SEER). 2000. California student assessment project: The effect of environmental education on student achievement. San Diego, CA:

SEER. Available at http://www.seer.org/pages/research/CSAP2000.pdf (accessed 12 September 2016).

Steg, L., and Vlek, C. 2009. Encouraging pro-environmental behavior: An integrative review and research agenda. *Journal of Environmental Psychology*, 29:309–317.

Stewart, D., Shamdasani, P., and Rook, D. 2007. Focus Groups (2nd ed.). Thousand Oaks, CA: Sage Publications.

U.S. Environmental Protection Agency. 1996. Watershed approach framework. Available at https://www.epa.gov/sites/production/files/2015-06/documents/watershed-approach-framework.pdf (accessed 14 September 2016).

Wagenet, L., Pfeffer, M. Sutphin, H., and Stycos, J. 1999. Adult education and watershed knowledge in upstate New York. *Journal of the American Water Resources Association*, 35:609–621.

Wells, C., and Hintze, J. 2007. Dealing with assumptions underlying statistical tests. *Psychology in the Schools*, 45:495–502.

Wheatley, K. 2005. The case for re-conceptualizing teacher efficacy research. *Teaching and Teacher Education*, 21:747–766.

Williams, D., and Semken, S. 2011. Ethnographic methods in analysis of place-based geoscience curriculum and pedagogy. *In* Feig, A., and Stokes, A., eds. Qualitative inquiry in geoscience education research. Boulder, CO: Geological Society of America, Special Paper 474, p. 49–62. Available at http://semken.asu.edu/pubs/williams11_ethnopbe.pdf (accessed 19 September 2016).

Woodhouse, J., and Knapp, C. 2000. Place-based curriculum and instruction: Outdoor and environmental education approaches. *ERIC Digest*. Available at http://files.eric.ed.gov/fulltext/ED448012.pdf (accessed 14 September 2016).