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Elementary Teachers' Conceptions of Flooding Before and After Professional Development

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Abstract

This study focuses on elementary teachers' conceptions of flooding before and after inquiry-based Earth science content-based professional development. Several misconceptions emerged from the science content two tier pre-post test, some of which persisted throughout the institute while others led to evidence of teachers' conceptual change. On the post-test some teachers' ideas emerged as hybrid conceptions as they applied newly acquired academic language to prior conceptions. There was a significant increase (n = 17, mean gain = 4.3 (SD = 3.27, t (17) = 5.69, p < .000) from the pre- to post-test. The concepts most resistant to change from pre- to post-test were analyzing an overall topographic region, reading a map image, and hydrograph interpretation. The highest frequency of hybrid conceptions occurred as teachers attempted to add new academic language, such as storm surge and discharge, to their prior understandings. Teachers' greatest conceptual change occurred in understanding the probability and role of ground conditions in flooding events. Teachers demonstrated significant growth in their understanding of flooding concepts through scaffolded inquiry lessons modeled through the professional development. Teachers who had greater levels of prior knowledge showed the most change to a normative view of flooding. This speaks to the importance of building teachers' background knowledge before initiating professional development with complex science concepts.

Key words: Elementary teacher professional development, flooding, misconceptions, conceptual change, two-tier test design

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Introduction

Both the National Science Education Standards (NRC, 1996) and Benchmarks for Scientific Literacy (AAAS, 1993) clearly outline K-12 Earth and space science as a critical domain of students' scientific literacy. Many elementary teachers do not have strong backgrounds in science as most become teachers through undergraduate programs in elementary education, or in post-baccalaureate programs. These programs emphasize state mandated elementary certification requirements in reading and writing literacy skills and usually only single methods classes for teaching various content areas such as science and social studies. In promoting scientific literacy and Earth systems science education (Mayer, 2002) it is critical to better understand how teachers' and students' conceptions affect their learning about, and perceptions of, their environment. Professional development can improve teachers' science content knowledge (Baker, Lewis, Uysal, Yasar, Lang, & Baker, 2008).

Purpose

The purpose of this study was to determine the effects of professional development on elementary teachers' learning of science content and misconceptions about geoscience content. From these results we present a model for translating two-tier test results into conceptual change categories. Additionally, we add to the misconception literature on natural disasters by presenting a range of teacher understanding of flooding concepts.

Background Research & Theoretical Framework

Background Literature

Cognitive aspects of learning geoscience include: learners' alternative frameworks, visualization and spatial reasoning, temporal thinking, and systems thinking (Orion & Ault, 2007). Most research on common misconceptions focuses on physical science, in which water plays a role, but not commonly within the context of Earth systems science (Henriques, 2000). Commonly-held beliefs from the limited research that does exist are that flooding only occurs along rivers when the snow melts in the spring or after a heavy rainfall (Schoon, 1989). Very little other research exists on conceptions of flooding. Recent work has examined student conceptions of rivers (Sexton, 2006; Sexton, 2008), which may be a strong complement to some of the flooding concepts studied here. However, it is limited in scope and not directly applicable to our research. The Geoscience Concept Inventory (GCI), which summarizes the most recent research in geoscience misconceptions, includes the water cycle and groundwater, but nothing that addresses river systems and flooding (Libarkin & Anderson, 2006).

There has been some ancillary research on students' understanding of the hydrologic cycle (Shepardson, Wee, Priddy, Lauren Schellenberger, & Harbor, 2008). Shepardson, et al. (2008) found that the students in their study held naive views of the hydrologic cycle and tended not to make connections between their own local context and textbook representations. For example, students in the topographically flat Midwestern region of the US were presented with examples of hydrologic activity that included mountains and coastal regions rather than typical drainage pattern they might have seen first-hand. As a result, the student's conceptions of the hydrologic cycle only included these textbook components and did not demonstrate any representation of regions in their own environment. Students from urban regions focused on the hydrologic cycle as purely a weather event without connecting their understanding to natural geomorphic processes because of the urbanized landscape of the cities where they live.

Libarkin (2005) has highlighted the critical need for the geosciences to increase conceptual change research to the level found in other scientific fields. From this research, we recognize the importance of tying factual knowledge into a conceptual framework, as well as making connections to students' lives and their home environments. If teachers do not understand the phenomenon of flooding and therefore lack the pedagogical content knowledge, then it is unlikely that they will teach it in a way that students can make meaning of their world. In a similar study of teacher learning of Earth science in professional development, Monet and Etkina (2008) found that "teachers who could describe how they reasoned from evidence to understand a concept had the highest learning gains" (p.455). Monet and Etkina recommend that teachers' reflections upon learning science content should be embedded throughout professional development. This finding supports our choice of using a two-tier test and embedding multiple opportunities for teachers to reflect on their learning in the professional development and how they can apply what they have learned into their own classrooms.

Theoretical Framework

Treagust (1988) discusses the use of two-tier tests to reveal student misconceptions in chemistry and biology. Anderson, Fisher, and Norman (2002) used two-tier tests as a starting point to build a conceptual inventory of natural selection and Tan, Goh, Chia and Treagust (2002) developed a two-tier test to assess students' understanding of inorganic chemistry. In this case we have employed such an approach to flooding in order to better understand elementary teachers' conceptions. In the conceptual change literature Chinn and Brewer (1993) provide a general framework of individual responses to anomalous data with seven categories of responses: ignore new anomalous data, reject data, exclude data from current understandings (theories), hold data in abeyance, reinterpret data while maintaining current understandings (theories), peripheral theory change, and theory change to accepting a normative scientific view. We use parts of this framework as a means of categorizing conceptions about flooding, but also use an empirical approach to categorizing the data to make low-level inferences.

Professional Development & Research Context

The Communication in Science Inquiry Project (CISIP) endeavors to provide school-based teams of science and English and/or English Language Learner (ELL) teachers with year-round professional development to enact pedagogical strategies that create scientific classroom discourse communities (SCDC) in their classrooms. The CISIP model focuses on: a) academic language development; b) written discourse; c) oral discourse; d) scientific inquiry; and e) learning principles (e.g., accessing prior knowledge, the use of conceptual frameworks and embedded metacognition (NRC, 2000, 2005). The CISIP program provided 5th and 6th grade teachers with professional development through a state math and science partnership grant with the dual goal of learning how to establish scientific classroom discourse communities and learning more science content. Teachers also participated in collaborative lesson planning activities with scaffolded support using a CISIP model lesson template. A condition of the grant was to select teachers from schools with high populations of ELLs and low SES. From March to April 2008 teachers attended four 6-hour workshops to introduce them to the CISIP model of teaching science through inquiry using oral and written discourse and cognitive learning principles. These introductory days were followed up by a three-week (12 days) content-rich summer institute in June 2008. Teachers had the opportunity to attend a total of 96 hours of professional development. Fifty teachers participated and during the summer institute teachers chose one of two science content strands, life science (n = 28) or Earth science (n = 22). This study focuses only on the teachers who chose to participate in the Earth science strand activities.

Professional Development Timeline. The Earth science strand activities spanned 35 hours (Table 1) and alternated with days that the entire group engaged in common professional development activities to learn overarching CISIP instructional strategies. The science content focus was flooding disasters, which was the only overlapping state standard between 5th and 6th grades. The institute's intent was to implement specific science content inquiry that encouraged participants to build a conceptual framework (NRC, 2000; NRC 2005) of flooding over time.

Table 1. Timeline of CISIP summer institute professional development activities and data collected.

Day of Institute	Date	Topic	Data Collected
1	6/2	Whole Group Session	Pre-assessment on causes of flooding
2	6/3	Lesson 1: Types of Flooding	Content pre-test Post-assessment on causes of flooding
4	6/5	Lesson 2: Flooding Case Studies	Poster Reflection (NCR)
5	6/8	Lesson 2 (con't): Peer Review of Scientific Arguments Lesson Planning	Communication Reflection
7	6/10	Lesson 3: River Table Exploration	Feedback Reflection
8	6/11	Lesson 4: Self-directed River Table exploration	
9	6/16	Lesson 4 cont: Scientific Investigation Report (SIR) group revisions Lesson Planning	SIR Reflection
10	6/17	Whole Group Session	Content post-test

Modeling and Scaffolding the Inquiry Process. Prior to the summer institute, teachers participated in professional development inquiry activities over four Saturday workshops in the spring of 2008, however these were tied to general science content, such as the nature of science (e.g., mystery boxes). In order to model how to scaffold inquiry-based instruction, lessons were designed to start with more teacher-directed activities to more student-directed investigations (Table 2). The lessons' trajectory was as follows:

- Lesson 1 (Directed inquiry, building background knowledge): Teachers read narrative accounts of flooding disasters describing different types, causes, and general properties of floods.
- Lesson 2 (Guided inquiry): Teachers examined two different modern Arizona floods through analyzing data from technical scientific reports.
- Lesson 3 (Guided inquiry): Teachers applied their comprehension to stream table investigations. This included modeling scaffolded support strategies (e.g., guided questions, investigation template) in order to ensure success.
- Lesson 4 (Open-ended inquiry): Based on the outcomes of Lesson 3, teachers proposed and carried out their own inquiry investigations using stream tables.

Description of CISIP Summer Institute Professional Development Strand in Earth Science

For three weeks in June 2008, 22 fifth and sixth grade in-service teachers participated in a series of four inquiry-based Earth science activities. Teachers engaged in each activity over one or two PD days. The series of activities modeled increasing levels of inquiry so that the first activities provided more guidance and as the workshop proceeded the scaffolding was removed. The content was linked to state and national science content standards for these particular grade levels, but were taught to the teachers at an adult's cognitive level. For example, the Arizona state student science standards that correlated to Lesson 1 are: 1) "Analyze the impact of large scale weather systems on the local weather; 2) Explain the impacts of natural hazards on habitats (floods); and 3) Evaluate the effects of the natural hazard of a hurricane" (Arizona Department of Education, 2005). Teachers read passages that were at an undergraduate college-level and were asked to consider how they might design lessons for their own students using the CISIP model.

Table 2. Description of the geoscience content PD activities. Each lesson took one to two days (5-hour days) for a total of 35 hours.

Activity	Description	Objective	Teacher Outcomes
Lesson 1: Personal Narrative	Examine floods from first-person accounts to assess the causes and flood properties. Provide support for participants to be successful in self-guided learning process.	By reading personal narratives of flooding events, teachers will identify features and causes of various types of flooding. They will also find commonalities and differences between flooding types by negotiating meaning with other teachers using small and whole group discussions.	After completing this activity teachers will be able to: • identify features, causes, contributing factors of 4 types of flooding; and • identify commonalities and difference between types of flooding.
Lesson 2: Case Studies of Flooding in Arizona	Examine data from past Arizona flooding events and determine the causes, effects, conditions, and history in order to gain a deeper understanding of flooding, how floods are studied, tools that are used, how graphs and data are used as a part of the process, and how humans play a role	Teachers examine data from real floods that have occurred in Arizona and determine the causes, effects, conditions, and history in order to gain a deeper understanding of flooding: how flood areas are studied; tools that are used; how graphs and data are used as a part of the process; and how humans play a role.	After completing this activity teachers will be able to: • identify evidence that contributed to flooding due to ground conditions, poor management decisions, topography, and weather conditions; • determine the likelihood of a similar event occurring in the region in the future; and • assess what remediation efforts should be done to prepare for/manage future flooding and make recommendations based on that assessment.
Lesson 3: Scaffolded Project	Provide teachers with a variety of research questions to answer and	Teachers will select a research question and design an investigation to	After completing this activity teachers will be able to: • design their own

Design	selected materials as they design a procedure to answer their assigned questions. Teachers begin to have more executive control of their learning.	attempt to isolate a variable and answer the question. Teachers will receive feedback from other teachers on their design, which they will use to design a new research question.	procedure; • propose their own research question; and • conduct an inquiry investigation
Lesson 4: Full Inquiry Project Design	Have teachers ask a question based on previous research in Lesson 3 and design an inquiry investigation. Present their results in an oral poster session in order to receive feedback which will result in a written *Student Investigation Report* (SIR). Create a concept map that outlines the framework of the science content they have learned as well as outline the professional development strategies that they have employed.	Teachers design a self-directed, independent inquiry investigation to attempt to isolate experimental variables and answer a question they have proposed. After conducting their investigations, they will present their results in a poster session to experience the importance of "going public" (oral discourse) with their results and how peer feedback can be an important part of the comprehension process.	After completing this activity teachers will be able to: • conduct an independent inquiry investigation; • identify critical elements within a CISIP lesson; and • write a *Student Investigation Report* (SIR) to report on findings from their inquiry activity.

As the two authors responsible for developing the content for the professional development, Kraft and Wilson made deliberate choices for the selection of geographic regions on which to focus the activities. For example, there were many examples of regional flooding available from which to choose for the personal narrative in Lesson 1, however we chose Venezuela, as we thought teachers might find this useful and pertinent for their own student populations, many of whom are originally from South and Central American regions. In Lesson 2, we chose to focus on specific floods in the local area of the southwestern US. One was from a time frame that many of these teachers remember experiencing (1993) and another was near the location of where some teachers taught. Providing a local context generated a more meaningful opportunity to investigate flooding in the spirit of place-based education research (Semken & Butler-Freeman, 2008; Gruenewald, 2003; Sobel, 2004; and Steele, 1981).

Methods

The authors of this paper include three members of the university research team as well as three of the professional development designers and facilitators so as to better reflect the collaborative nature of the professional development program and the research. Two of the professional development facilitators also analyzed the data that was generated through the study. The research questions for the study were as follows:

1. Does the application of the CISIP model, using scientific inquiry activities that promote academic language development and include opportunities to use oral and written discourse, lead to significant increases in teacher understanding of flooding?
2. What conceptions of flooding do teachers have before and after such professional development?

A quantitative approach has been employed to study the phenomenon of teachers' conceptions before and after professional development using a two-tier pre- and post-test of the science content. The data was processed and analyzed to compare the pre-post paired means and to rank order the items by difficulty for both tiers. Teachers' misconceptions were summarized and categorized using the Chinn and Brewer (1993) framework for individual responses to anomalous data. Teachers' reflections on various lesson activities were analyzed for response categories and frequencies.

Science Content Test

The Earth science strand developers constructed the two-tier pre-post science content assessment after designing the professional development activities for maximum alignment with instruction. Consequently, this was a pilot test of the assessment instrument. Key concepts (Table 3) included: types and causes of floods, factors that influence flooding, map and graph reading skills, and inquiry instruction vs. hands-on instruction. The pre-post assessment was composed of eleven two-tier multiple choice questions and three constructed response questions. All questions were about the various types and causes of flooding except for the final question, which concerned the difference between hands-on and inquiry-based instruction. Although there were 22 participants in the Earth science strand, one was a science curriculum coordinator who only attended a few days of the institute and four others missed one of the testing days. Consequently, at the end of the institute 17 participants had taken both pre- and post-tests. Science content gain scores were calculated based on questions 1 though 12 only as the last question was about teachers' understanding of hands-on and inquiry-based instruction and not flooding.

Causes of Flooding Writing Prompts Pre- and Post- Day One Instruction

Before beginning flooding instruction, along with the pre-science content test, teachers were asked to respond to the prompt, "*Draw and label or describe one or more causes of flooding*" on carbon-copy paper as a diagnostic assessment. Teachers then attached the carbon copy of their answers to their science journals, while we retained the original for analysis. On the following day, after Lesson 1 instruction, the questions for the post- prompt were, "*What would you revise about your previous statement? How has your understanding changed and what helped you to most effectively create that change in understanding?*"

Table 3. Pre-post test assessment categories (instrument in Appendix).

Question	Reading topographic maps	Periodicity of flooding events	Effects of runoff	Properties of flood types	Map & graph reading comprehen-sion	Term recall
1	X					
2				X		
3	X			X		

4	X		X		X
5	X				
6		X			
7				X	
8		X			X
9			X		X
10				X	
11				X	
12			X	X	

Causes of Flooding Writing Prompts Pre- and Post-Day One Instruction

The pre- and post- “causes of flooding” writing prompts could not be directly compared, as they were not true pre- and post- items. The question for the pre-prompt was, “*Draw and label or describe one or more causes of flooding*," while the associated questions for the post- prompt were, “*What would you revise about your previous statement? How has your understanding changed and what helped you to most effectively create that change in understanding?”* We analyzed this set of writing prompts after transcribing the written text. We then used the teachers' pre-activity responses to make codes by identifying words and ideas, with each idea \counted once per teacher, even if the teacher used it repeatedly throughout their response. Finally, each idea category and number of participant responses was totaled. Sections of the post-activity prompt that seemed to answer the question, “*How has your understanding changed?*” were identified for additional analysis. Sections of the post-activity prompt that seemed to answer the question, “*What helped you to most effectively create that change in understanding?*” were separated for additional analysis. We coded the post-activity prompts by identifying words and ideas, with new ideas being added to the spreadsheet as necessary, and ideas found in answers to the previous two questions were counted when it was applicable. The teachers' pre-activity instruction prompts were re-examined to determine if any of the post-activity ideas were present. No instances were found.

Results

Learning of Flooding Science Content

A paired-samples t test was conducted using the total score on the pre- and post-test (maximum possible score was 26, partial and full credit was given to second tier explanations) to determine if teachers' understanding of flooding was enhanced by their participation in the activities. There was a significant increase (n = 17, mean gain = 4.3 (a 16.5% increase), SD = 3.27, t (17) = 5.69, p < .000) from pre- to post-test. Two participants did not complete the post-test second tier justifications, and therefore had the two lowest post-test scores. The results of the t test without these two participants' tests was a mean gain of 4.75 (an increase of 18.3% from pre to post), SD = 3.23, t (15) = 5.69, p < .000. As a group the teachers showed improvement in their understanding of flooding as a result of the inquiry-based professional development activities. When these results were compared to just the first tier multiple choice questions there was still a significant equivalent gain (mean gain = 2.24 (a 20.4% increase), SD = 1.75, t (17) = 5.26, p < .000). However, the added benefit of the two-tier test design was that it revealed teachers' rationales for their multiple choice answers, their misconceptions, and better informed the instructors and professional development program as to the effectiveness of their instruction and how to modify lessons for future use.

In terms of individual multiple choice item responses, the easiest pre-test items (*n* = 19) were: a) (Q2) weather report interpretation (properties of flood types), 89.5% correct (78.9% correct explanation), b) (Q6) run-off/ground absorption (effects of runoff, relates to everyday experiences), 89.5% correct (44.7% correct explanation), c) reading a (Q7) weather map (map reading comprehension), 94.7% correct (86.8% correct explanation), and d) (Q11) simple graph reading of flood discharge (graph reading interpretation), 94.7% correct (86.8% correct explanation). The hardest pre-test items were: a) (Q9) specific application of academic language (term recall and properties of flood types), 31.6% correct (0% correct explanation), b) (Q8) understanding of drainage systems (term recall and effects of runoff) at 36.8% correct (10.5% correct explanation), and c) (Q4) understanding of paleoflood deposits and probability of modern flooding (term recall, properties of flood types, and periodicity of flooding events) 42.1% correct (10.5% correct explanation).

The greatest total gain (*n* =19) was shown in tier one multiple-choice items: a) (Q9) specific application of academic language (term recall and properties of flood types) a 52.6% increase (44.7% increase in correct explanation), b) (Q4) understanding of paleoflood deposits and probability of modern flooding (term recall, properties of flood types, and periodicity of flooding events) a 52.6% increase (57.9% increase in correct explanation), c) (Q3) interpreting topographic map elevations with respect to stream flooding (reading topographic maps and properties of flood types) a 42.1% increase (7.9% increase in correct explanation). The lowest scoring item and concept from the pre-test that was most resistant to change through instruction was (Q8) understanding of drainage systems (term recall and effects of runoff) with a 5.3% increase from 36.8% to 42.1%. However, the correct explanation increased 42.1%, from 10.5% to 52.6%. This suggests that greater depth of learning of the concept occurred, but mainly with those teachers who were already able to pick out the correct answer on the pre-test.

Table 4. *Frequency count of ideas expressed by participants pre- and post- instruction for Lesson 1.*

Cause of Flooding Categories	**Pre-instruction (*n* = 20)**	**Post-instruction (*n* = 19)**
Excess Rain	15	12
Rapid Downpour	5	4
Soil Composition	5	0
Soil Saturation	8	4
Land is too dry to absorb water	6	2
Snow Melt	4	1
Glacier Melt	2	0
Sea Level Rise	1	1
Ocean	2	0
River Overflow	6	0
Dam Breaks	9	2
Water Table rises (gets filled up)	1	0
Flash Flooding	2	12
Regional Flooding	0	9
Storm Surge	1	11

Tsunami	2	13
Hurricane/Monsoon	2	2
Thunderstorm	1	1
Earthquake	4	10
Wind	1	4
Fire burns vegetation	1	0
Erosion	3	0
Temperature Increase	1	0
Valleys/arroyos/canyons	3	6
Flat land	1	0
People move the land	1	3
Building homes in a flood zone	2	2
Tides	0	5
Ocean-based	0	5
Land-based	0	5

Understanding Causes of Flooding Prompt Data

Twenty teachers responded to the additional pre-instruction prompt (Table 4). The number of responses ranged from one to nine ideas per teacher. The most pervasive idea pre-instruction was that excessive amounts of rain (75%) cause flooding, followed by soil saturation (40%), and the bursting of dams or levees (45%). Thirty percent of the teachers expressed the idea that the land was too dry to hold the water, while twenty-five percent mentioned that the composition of the soil did not allow the water to be absorbed. Rapid downpour of rain was also mentioned five times. Rivers overflowing their banks (30%), snow melt (20%), glaciers melting (10%), and erosion (15%) were also discussed. Flash flood (10%), storm surge (10%), and tsunami (5%) were mentioned by name infrequently, while regional flooding was not mentioned at all. Hurricanes or monsoons (10%), thunderstorms (5%), earthquakes (20%), wind (5%), and fire (5%) were also listed. Topography in the form of valleys or arroyos (15%), or flat land (5%) was held responsible for channeling the water, and people moving the land (5%) and building houses in flood plains (10%) was said to influence the devastation resulting from flooding.

Nineteen teachers responded to the post-instruction prompt and the number of responses ranged from zero to thirteen ideas per participant. The most pervasive idea post-instruction was still that excessive amounts of rain (63%) cause flooding, followed by earthquakes (53%). Eleven percent of the participants still expressed the idea that the land was too dry to hold the water. No participants mentioned that the composition of the soil did not allow the water to be absorbed, and soil saturation (21%) was mentioned less often. Rapid downpour of rain (21%) was also listed. Common causes of flooding such as, rivers overflowing their banks (0%), snow melt (5%), glaciers melting (0%), and erosion (0%) were named infrequently or not at all. However, teachers did learn the names of the four main types of floods; flash flood (63%) storm surge (58%), tsunami (68%), and regional flooding (47%) all increased a great deal in numbers of instances reported. Hurricanes or monsoons (11%) and thunderstorms (4%) remained at the same count, while fire was not mentioned, and wind (21%) increased. Topography in the form of valleys, arroyos and canyons (32%) increased in frequency, while flat land was no longer mentioned. Anthropogenic causes such as resurfacing the landscape and contributing to global warming, and glacial ice melting, were cited three times (16%), with building houses in flood plains mentioned twice. In addition, three new ideas surfaced in the post- prompt. Tides (26%) were reported to contribute to flooding, and five teachers linked tsunamis and storm surge with ocean-based causes and flash flood and regional flood with land-based causes. Overall, the total number of teachers' post-instruction ideas (*n* =114) outnumbered pre-instruction ideas (*n* =89).

Interpretations

Pre-post Test Results and Conceptual Change

The elementary teachers' conceptual change is summarized in Tables A-1 (Appendix) using the coding matrix in Tables 7 and 8. The pre- and post-test scores were used to determine how much change had occurred. The result was seven categories of conceptual change profiles for these teachers on this test (Table 9). Normative views were determined if the teacher had at least 66% of the multiple choice questions completely correct. Seven (41.2%) of the teachers achieved a normative view of flooding concepts from a strong prior knowledge base. One teacher (6%) also achieved a normative view from partial prior knowledge. Another teacher (6%), while she did not obtain it, did make a significant shift toward a normative view from partial prior knowledge. Two other teachers (11.7%) also made significant shifts, but from weak prior knowledge. An additional two teachers (11.7%) made smaller gains from partial prior knowledge. Four teachers, one with strong prior knowledge (7%) and three (17.6%) with weak prior knowledge, showed no conceptual change.

Based on our observations throughout the professional development, we concluded that two of the teachers were frequently off-task and at times resistant to participating in the daily activities. Additionally, this attitude did not facilitate our data collection efforts as they didn't write explanations to their multiple choice questions on their two-tier post-tests. This speaks to the importance of recruiting self-motivated teachers who have professional and mastery goals for improving their teaching practices. Overall, it appears that having a stronger conceptual framework before starting the unit of lessons on flooding gave teachers a better chance at obtaining a normative view. This suggests that it is important to spend time building background knowledge with students before starting a unit of a study.

Comparison with theory. When we look at Chinn and Brewer's model of conceptual change and our two-tier matrix we find the following alignment:

(a) Ignore, (b) reject, (c) exclude, (d) abeyance = 16
(e) Reinterpret while retaining Theory A (original idea) = 6, 11
(f-1) Reinterpret with peripheral negative changes = 5, 9, 13, 14, 15
(f-2) Reinterpret with peripheral positive changes = 7, 8, 10, 12
(g) Accept (and change) = 2, 3, 4

- Normative view maintained (i.e., no conceptual change required) = 1

Table 7. Conceptual change matrix used for pre-post two-tier multiple choice responses and explanation matrix. Sixteen categories of conceptual change for each question result from the four-by-four matrix.

		Post			
		Correct Answer / Correct Explanation	**Correct Answer / Incorrect Explanation**	**Incorrect Answer / Correct Explanation**	**Incorrect Answer / Incorrect Explanation**
Pre	**Correct Answer / Correct Explanation**	(1) Most consistent and correct, highest prior knowledge, no conceptual change necessary.	(5) Partial confusion, move from completely correct to partially correct.	(9) Partial confusion, move from completely correct to partially correct.	(13) Greatest negative conceptual change. New information confounds understanding.
	Correct Answer / Incorrect Explanation	(2) Partial prior understanding or ability to guess correct answer, but unable to explain choice; conceptual change to normative view achieved.	(6) No change. Maintained partial correct understanding.	(10) Partial assimilation of new information into prior knowledge. Little prior knowledge and little assimilation of new material.	(14) New information confounds limited prior knowledge with introduction of new material. Resistance to conceptual change.
	Incorrect Answer / Correct Explanation	(3) Partial prior understanding, conceptual change to normative view achieved.	(7) Partial assimilation of new information into prior knowledge. Little prior knowledge and little assimilation of new material.	(11) No change. Maintained partial correct understanding.	(15) New information confounds limited prior knowledge with introduction of new material. Resistance to conceptual change.
	Incorrect Answer / Incorrect Explanation	(4) Greatest positive conceptual change from no understanding to normative view of concept.	(8) Small shift from no prior normative understanding. Some assimilation of new material resulting in partial conceptual change.	(12) Small shift from no prior normative understanding. Some assimilation of new material resulting in partial conceptual change.	(16) No change. Most resistant to change. New information not assimilated.

Table 8. Conceptual change matrix used for pre-post constructed responses. Simplified version of the two-tier multiple choice with explanation matrix. The scaling requires rounding up to the nearest 0.5 points (in this case out of 4 points for the question). This could be modified for any point scale.

		Post			
Pre		**Correct Answer (3.5, 4)**	**High Partial (2, 3)**	**Low Partial (0.5, 1, 1.5)**	**Incorrect Answer (0)**
	Correct Answer (3.5, 4)	(1) Most consistent and correct, highest prior knowledge, no conceptual change necessary.	(5) Some confusion, move from completely correct to high level of partially correct.	(9) Significant confusion, move from completely correct to partially correct.	(13) Greatest negative conceptual change. New information completely confounds prior understanding.
	High Partial (2, 2.5, 3)	(2) High prior understanding; conceptual change to normative view achieved.	(6) No change or refinement of ideas. Maintained high partial correct understanding.	(10) Some confusion of new information into high partial prior knowledge. resulting in low prior knowledge.	(14) Significant negative conceptual change. New information confounds high prior knowledge with introduction of new material.
	Low Partial (0.5, 1, 1.5)	(3) Low partial prior understanding, conceptual change to normative view achieved.	(7) High partial assimilation of new information into low prior knowledge.	(11) No change. Maintained low partial correct understanding. Resistance to conceptual change	(15) New information confounds low partial prior knowledge with introduction of new material. Resistance to conceptual change.
	Incorrect Answer (0)	(4) Greatest positive conceptual change to normative view of concept from no prior understanding.	(8) Significant shift from no prior normative understanding. Some assimilation of new material resulting in high partial conceptual change.	(12) Small shift from no prior normative understanding to low partial conceptual change. Resistance to conceptual change.	(16) No change, most resistant to conceptual change. Maintained no understanding; no new information assimilated.

Table 9. Summary of numbers and percents of teachers who were classified in specific conceptual change profile categories.

Conceptual Change Profile	**# of teachers**	**Percent (%)**
Normative view achieved from strong prior knowledge base (1)	7	41.2
Normative view achieved from partial prior knowledge base (2)	1	6
Significant shift toward normative view from partial prior knowledge base (3)	1	6
Significant shift toward normative view from weak prior knowledge base (4)	2	11.7
Some positive shift from partial prior knowledge base (5)	2	11.7
Little to no shift from strong prior knowledge base (6)	1	6
Little to no shift from weak prior knowledge base (7)	3	17.6

The conceptual change category of "(1) Most consistent and correct, highest prior knowledge, no conceptual change necessary," no conceptual change is required in that full understanding was achieved and maintained from pre- to post-test. It is difficult to distinguish between Chinn and Brewer's categories of "ignore," "reject," "exclude," and "abeyance" as we did not conduct interviews with the teachers to probe them further on their explanations to the multiple choice questions and obtain a sense of their attitude toward the concepts. However, these four categories are the result of the same outcome, which is that there is no shift in conceptual change toward a normative scientific view. This is equivalent to our conceptual change category (16) "No change. Most resistant to change. New information not assimilated." With the use of the two-tier question and constructed response format we do feel confident in our ability to distinguish between the other three categories, even to the extent of making two categories of "reinterpret with peripheral changes," one exhibiting positive changes and the other, negative changes.

Flooding Misconceptions

Resistant misconceptions. Of persistent misconceptions, the most frequent were: a) difficulty in reading a map image (comprehension of sun angle interpretation), and b) graph interpretation skills (comparing different axis scales and interpretation). This persistence suggests the lack of direct experience with these concepts/skills. Graph reading skills were an implicit activity within the case study experience, but there was no direct instruction provided or assessment of the teachers' skill level.

Reinterpreting data while maintaining current theories. The highest frequency of these types of hybrid conceptions occurred as teachers attempted to add new academic language to their prior understandings. These included equating discharge with rainfall on the post-test when previously most were unfamiliar with the term discharge. Teachers increased in their use of, but more frequently misused, the term "storm surge" to describe a general event rather than using it appropriately in an academic context. Another hybrid conception emerged after the first lesson activity post-write on the causes of flooding. When teachers were asked what had changed in their understanding about causes of flooding, many listed the types of floods they now knew rather than which factors causes them.

Conceptual change. Of those misconceptions that led to evidence of conceptual change, the most common were the probability of flooding and the role of ground conditions in flooding events.

Both topics were specifically addressed with activities that required teachers to process data and consider how these variables affected their interpretation of a region. The probability of flooding was one that was particularly well illustrated as the institute corresponded to concurrent major flooding in the Midwestern United States. The timely nature of the content in the national media lent authenticity to the topic for teachers. The ground conditions variable was not thoroughly assessed within the pre-post-test, but emerged as a misconception from an additional activity pre-write on the causes of flooding. Many teachers identified excessively dry land as a cause of flooding. In the post-test teachers voluntarily identified hydraulic conductivity in a question that did not specifically address ground conditions (accurately applying newly acquired academic language). Teachers clearly understood from the professional development activities that ground material plays a more significant role in flooding, rather than a lack of water content. This is a topic that will need to be addressed more specifically in the future.

The questions that teachers demonstrated the greatest change on were questions 3, 4, and 9, and all involved term recall as some component of the question. This indicates that teachers successfully incorporated the new academic language into their current understanding of content. However, due to the fact that this is a lower order comprehension of content, it is questionable how long this understanding will persist after the institute has completed. The combination of term recall and properties of the types of flooding most likely had some of the greatest gains due to the delivery of the content during the PD. Participants built their background by reading narratives of different types of flood events. These narratives were vivid and had some emotionally powerful descriptions that stuck with the teachers. This knowledge was shared with the rest of the group, sharing the stories and details associated with the events from the different types of floods. To support the development of academic language (term recall), we developed a visual word wall before participants moved on to Lesson 2. This was in an effort to anticipate future possible problems with reading primary literature from the geoscience research community. Words like paeloflood and isohyetal became a part of teachers' working language before they engaged in an activity that used such terms. The success of these initial activities bears out in the data of those questions which result in the greatest conceptual change.

The question that started as the most difficult and resulted in the least conceptual change overall (Q8) was most likely due to the fact that the question was an analysis question. It was a higher order question and required greater depth of knowledge to accurately capture the scenario. As a result, teachers may have lacked the academic language to accurately describe their response in the second tier (justification) of the question. For example, one teacher's (S16) response was, "I'm taking a guess on this but looking at the elevation, instead of the isohyetal key, I think that the lower elevation would have a higher discharge since water runs downhill..." Here the teacher's logic is on the right track, however, she selected the wrong location, resulting in a misinterpretation of the map itself and how rivers flow. These are aspects of content that were inferred during the PD and not explicitly taught.

Some of the scores in the post-test may not have been a reflection of what was learned during the PD, but rather a reflection of teacher's affective state at the end of the institute itself. Teachers' had engaged in an assessment everyday that week and they were told they would not be paid unless they completed their final assignment (with only one day left for the institute), so there was more concern to finish the assignment rather than spend time on the post-test. For example, three participants did not fill out the second tier at all, and some who did, did not spend as much time on the post-test as they had on the first with their second-tier responses. For example, on Q 10, one respondent (S10) answered, “looks like rivers where A looks like land,” on the pre-test, which was the correct explanation. On the post test, the response for the same question was, “looks like the [picture] I saw,” which received no points, however hints at the pictures that were used during the PD activity of rivers on Mars. Due to the vagueness of the response, it could indicate that the teacher is resistant to conceptual change, but may in fact indicate that the participant chose to not be overly explicit with the wording on the post-test.

Lastly, some of the responses, while not indicating a change in conceptual understanding, still indicated a growth in understanding, just not to the level that showed a significant amount of growth. For example, on the pre-test for question 12, one teacher (S23) wrote, “I seriously don't know.” Whereas, in the post-test, this teacher wrote, “The difference may be associated with different ground terrains. And the type of graph may also be different because of the different reportings. One graph could report a storm surge, while the other reports discharge after the storm.” There was no change in her score, both responses were awarded no credit, however, this teacher went from having no idea at all to engaging with the academic language from the institute and hinting at a greater awareness of flooding. There are inaccurate views here; however, a conceptual change is beginning to occur within this participant’s understanding of the content. Without interviews, however, it is impossible to know exactly how much of that knowledge is there since the post response is still too vague to accurately answer the actual question.

Supports for conceptual change. From our analysis of the data on teachers' conceptual change as measured by the pre-post test, it would appear that having a stronger conceptual framework before starting the unit of lessons on flooding gives teachers a better chance at obtaining a normative scientific view. Consequently, this suggests that it is important for teachers, and professional development providers, to spend time building background knowledge with students before starting a unit of a study.

Research Implications

Teachers were able to demonstrate significant growth in their understanding of flooding concepts through scaffolded inquiry lessons modeled on the CISIP professional development. However, most teachers' conceptual change was incomplete. Teachers who had greater levels of prior knowledge at the beginning of the professional development institute showed the greatest potential for change to a normative view of flooding. Granted delayed post-testing six months after the PD would confirm the robustness of the change. Regardless, this speaks to the importance of building teachers' background knowledge before initiating professional development with complex science concepts. Elementary teachers with weaker prior knowledge in particular may need iterative professional development to reach greater levels of understanding.

Lessons Learned

From our experiences teaching and observing these flooding professional development lessons with the elementary teachers we learned that the reflection questions need to be more explicitly written and focused on a single point, otherwise we can expect that the associated responses themselves will be less focused. Explicit teaching of reading hydrographs and aerial photos should be done to build teachers' background and skill level before engaging in flooding activities that requires these skills. The pre-post assessment instrument of the flooding science content needs to include a new item to address the dry ground misconception. Additionally, some of the two-tier questions that were basic fact-recall were not a true two-tier item and need to be revised to test a higher level of understanding.

Educational Importance

The need for expanding our understanding of geoscience conceptions and how these conceptions affect people's understanding of their natural environment and their daily lives is a critical agenda item in geoscience education. Additionally, what teachers learn from professional development and how professional development designers and facilitators use such information to refine professional development is key to geoscience education reform.

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Appendix

Table A-1. Summary of frequencies of conceptual change categories by question for whole group (N=17 matched pre- and post-tests).

Conceptual change	Two-tier response	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12
Most consistent and correct, highest prior knowledge, no conceptual change necessary. (1)	Pre-test correct choice and correct explanation to post-test correct choice and correct explanation	3	14	2	2	1	8	13	2		4	11	
Partial prior understanding or ability to guess correct answer, but unable to explain choice; conceptual change to normative view achieved. (2)	Pre-test correct choice and incorrect explanation to post-test correct choice and correct explanation	1		3	4	6	2	1	1	3	2	2	
Partial prior understanding, conceptual change to normative view achieved. (3)	Pre-test incorrect choice and correct justification to post-test correct choice and correct justification	3		1		2		1				1	
Greatest positive conceptual change from no understanding to normative view of concept. (4)	Pre-test incorrect choice and incorrect justification to post-test correct choice and correct explanation	1	1	1	6	1			5	5	1		
Partial confusion, move from completely correct to partially correct. (5)	Pre-test correct choice and correct justification to post-test correct choice and incorrect justification			2		1	1	2				3	1
No change. Maintained partial correct understanding. (6)	Pre-test correct choice and incorrect justification to post-test correct choice and incorrect justification	1	1	2	2	2	4			2	2		3
Partial assimilation of new information into prior knowledge. Little prior knowledge and little assimilation of new material. (7)	Pre-test incorrect choice and correct justification to post-test correct choice and incorrect justification					1					1		4
Small shift from no prior normative understanding. Some assimilation of new material resulting in partial conceptual change. (8)	Pre-test incorrect choice and incorrect justification to post-test correct choice and incorrect justification		1	4	2	2	1			4	1		

Partial confusion, move from completely correct to partially correct. (9)	Pre-test correct choice and correct explanation to post-test incorrect choice and correct explanation	1									1		
Partial assimilation of new information into prior knowledge. Little prior knowledge and little assimilation of new material. (10)	Pre-test correct choice and incorrect explanation to post-test incorrect choice and correct explanation	1											1
No change. Maintained partial correct understanding. (11)	Pre-test incorrect choice and correct explanation to post-test incorrect choice and correct explanation	3									1		2
Small shift from no prior normative understanding. Some assimilation of new material resulting in partial conceptual change. (12)	Pre-test incorrect choice and incorrect explanation to post-test incorrect choice and correct explanation	1							3	1			2
Greatest negative conceptual change. New information confounds understanding. (13)	Pre-test correct choice and correct explanation to post-test incorrect choice and incorrect explanation								1				
New information confounds limited prior knowledge with introduction of new material. Resistance to conceptual change. (14)	Pre-test correct choice and incorrect explanation to post-test incorrect choice and incorrect explanation					1			1	1	1		
New information confounds limited prior knowledge with introduction of new material. Resistance to conceptual change. (15)	Pre-test incorrect choice and correct justification to post-test incorrect choice and incorrect justification										1		2
No change. Most resistant to change. New information not assimilated. (16)	Pre-test incorrect choice and incorrect justification to post-test incorrect choice and incorrect justification	2		2	1		1		4	1	2		2

Table A-2. Summary of conceptual change from pre- to post-test by teacher (N=17 for pre-post matched tests) and test item. Numbers in the table for columns Q1-Q12 refer to the two-tier test explanation matrix categories of conceptual change (Tables 7 and 8). Pre- and post-total include both multiple choice and explanation scores for questions 1-12. Maximum score on test was 26 points (question 12 was a constructed response and was awarded 4 points instead of 2 points as questions 1-11 were scored, 1 point for correct multiple choice answer and 1 point for explanation). Prior knowledge was considered "strong" if teachers scored greater than 14 points (66.6 percentile), "partial" between 11 and 14 points, and "weak" if less than 11 points (33.3 percentile). Cut-off boundaries for prior knowledge were determined by percentiles for the whole group (N=19) achieved on the pre-test.

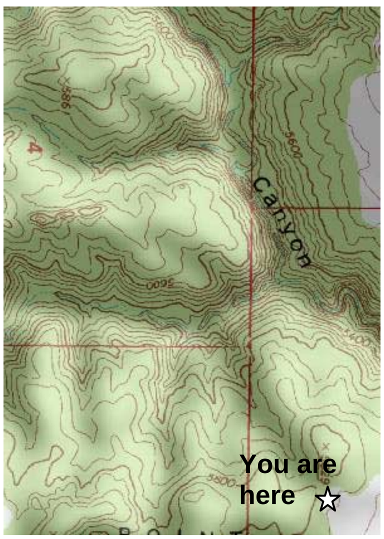
Teacher Code ID	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Q7**	**Q8**	**Q9**	**Q10**	**Q11**	**Q12**	**Pre-total**	**Post-total**	**Gain score**	**Conceptual Change Profile**
S03	11	1	3	4	2	1	2	4	8	1	1	6	14	21.5	0.63	Normative view achieved from strong prior knowledge base (1)
S04	1	1	16	4	3	1	1	1	4	4	1	7	12.5	21.5	0.67	Normative view achieved from partial prior knowledge base (2)
S05	11	1	1	2	2	6	1	12	2	1	1	11	17	20	0.33	Normative view achieved from strong prior knowledge base (1)
S09	10	1	16	2	5	6	3	16	8	11	2	6	12	14.5	0.18	Some positive shift from partial prior knowledge base (5)
S10	12	1	5	2	8	5	1	13	2	7	1	15	15	14	-0.09	Little to no shift from strong prior knowledge base (6)
S11	1	1	2	6	8	6	1	16	6	2	5	7	13.5	16	0.20	Some positive shift from partial prior knowledge base (5)
S12	9	1	2	4	4	1	1	1	4	1	1	7	15	23	0.73	Normative view achieved from strong prior knowledge base (1)
S13	3	4	6	4	2	2	1	12	16	6	1	12	8.5	17	0.49	Significant shift toward normative view from weak prior knowledge base (4)
S14	3	1	4	8	7	2	1	4	12	15	1	15	9	16.5	0.44	Significant shift toward normative view from weak prior knowledge base (4)
S15	3	1	8	1	2	1	1	4	2	16	1	6	14.5	21.5	0.61	Normative view achieved from strong prior knowledge base (1)
S16	4	1	1	4	2	1	1	12	4	2	1	10	14	20.5	0.54	Normative view achieved from strong prior knowledge base (1)
S17	11	1	5	4	2	1	1	4	4	1	3	5	15.5	22.5	0.67	Normative view achieved from strong prior knowledge base (1)

S19	2	1	8	2	1	1	1	4	8	6	1	11	12.5	18.5	0.44	Significant shift toward normative view from partial prior knowledge base (3)
S21	16	1	6	16	6	6	1	16	14	14	2	12	10	9.5	-0.03	Little to no shift from weak prior knowledge base (7)
S22	1	1	2	1	3	1	1	2	4	9	1	7	17.5	23.5	0.71	Normative view achieved from strong prior knowledge base (1)
S23	16	8	8	6	6	8	5	14	8	16	5	16	7	8	0.05	Little to no shift from weak prior knowledge base (7)
S24	6	6	8	8	14	16	5	16	6	8	5	16	8	8	0.00	Little to no shift from weak prior knowledge base (7)

Flooding Pre-Post Test

For each question, please identify the correct answer and place it on the scantron. On the accompanying "Earth Science Answer Sheet," please describe ***why*** *you answered the questions the way you did (include question #'s). Be sure to put your Code ID on both papers.*

Answer questions 1-3 with the following information:
You're taking your family on a hike in northern Arizona. You're "geared up" with plenty of water, lightweight windbreakers, and lunch provisions (and of course, your camera). As you approach the trailhead, you read the general information sign:

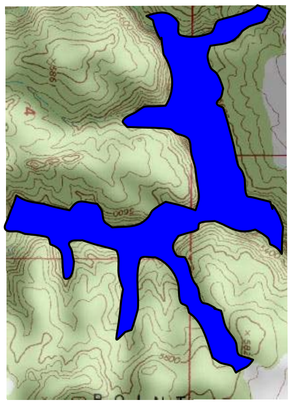
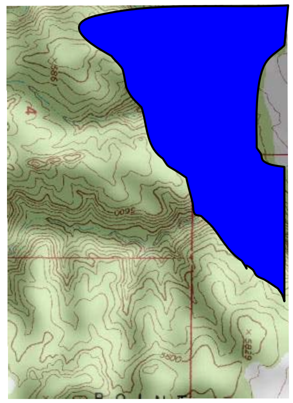
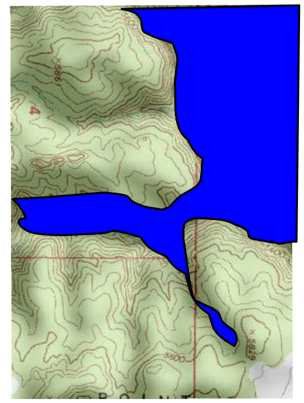


Announcements
There is no water along this trail, be sure to bring plenty of water.
Please, take only photographs, leave only footprints.
Warning: This is a flash flood prone area, do not enter when flooding

Weekend Weather Forecast
Friday: Sunny, high 90, low 70
Saturday: Sunny, high 88, low 65, chance of localized thunderstorms
Sunday: Partly cloudy, high 86, low 68, high wind advisory

1. Looking at the map, what kind of terrain might you expect for this region?
   a. Steep, continuous hill to a plateau.
   b. Narrow, steeply sloped walls.
   c. Wide open spaces along a dry wash.
   d. I don't know, I can't read maps

2. Which day would be the most dangerous for hiking?
   a. Friday
   b. Saturday
   c. Sunday
   d. Any day, I'm desperately out of shape

3. If the discharge within the canyon begins to increase, select which map would best represent flood stage.
   a. 
   b. 
   c. 

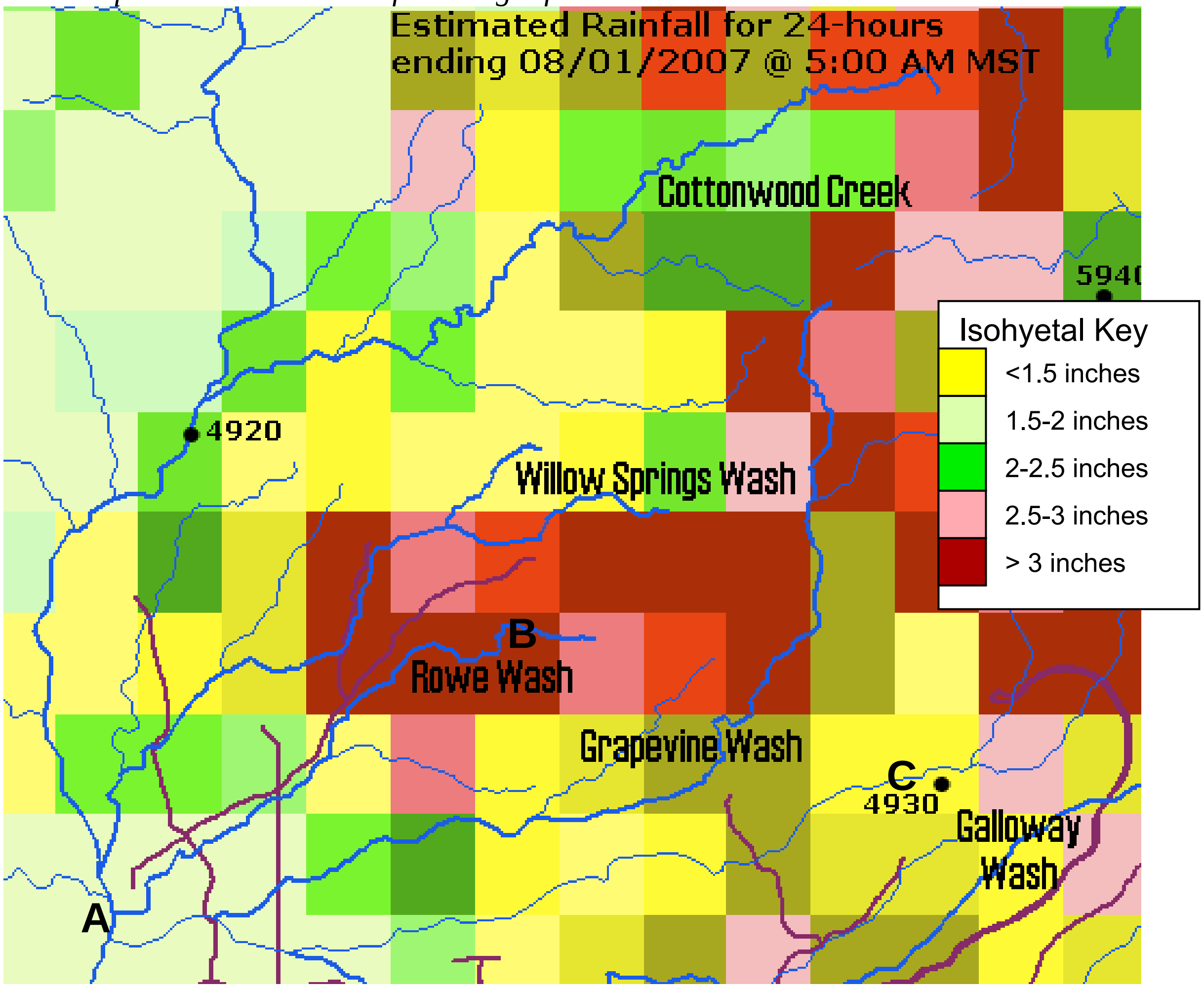
Answer questions 4-6 with the following information:
You're moving to beautiful Cookville, a small town located in the grassy plains along Lang River. There are paleoflood deposits throughout this region. You're concerned about the possibility of flooding in the home you buy.

4. You determine that there are paleoflood deposits that are dated at 1000 years old. What does this imply about this properties potential for flooding?
   a. Paleofloods show that flooding has occurred and therefore could occur in the same area.
   b. A paleoflood indicates areas that this area once flooded but is no longer susceptible to flooding.
   c. Paleofloods imply nothing about future or past flooding events.

5. Your real estate agent told you that the 100-year flood for this region occurred 10 years ago. So by all accounts, you should have 90 years of worry free home ownership for this area. Do you agree?
   a. Yes, a flood of that size means that it will occur every 100 years.
   b. No, the discharge value for the last 100 year flood may be significantly greater for the next 100 year flood.
   c. No, the likelihood of a 100 year flood is a 1% chance every year.

6. A super Wal-Mart has been built directly upstream from your new home. What potential effects might this have on your home?
   a. Building and pavement decreases absorption and increases the potential for runoff.
   b. Building and pavement increases absorption and increases the potential for runoff.
   c. Building and pavement decreases absorption and decreases the potential for runoff.

Answer questions 7-9 with the following information:

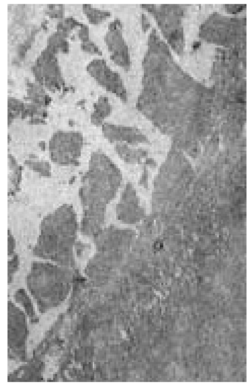


7. Which station recorded the highest rainfall?
   a. Station A
   b. Station B
   c. Station C

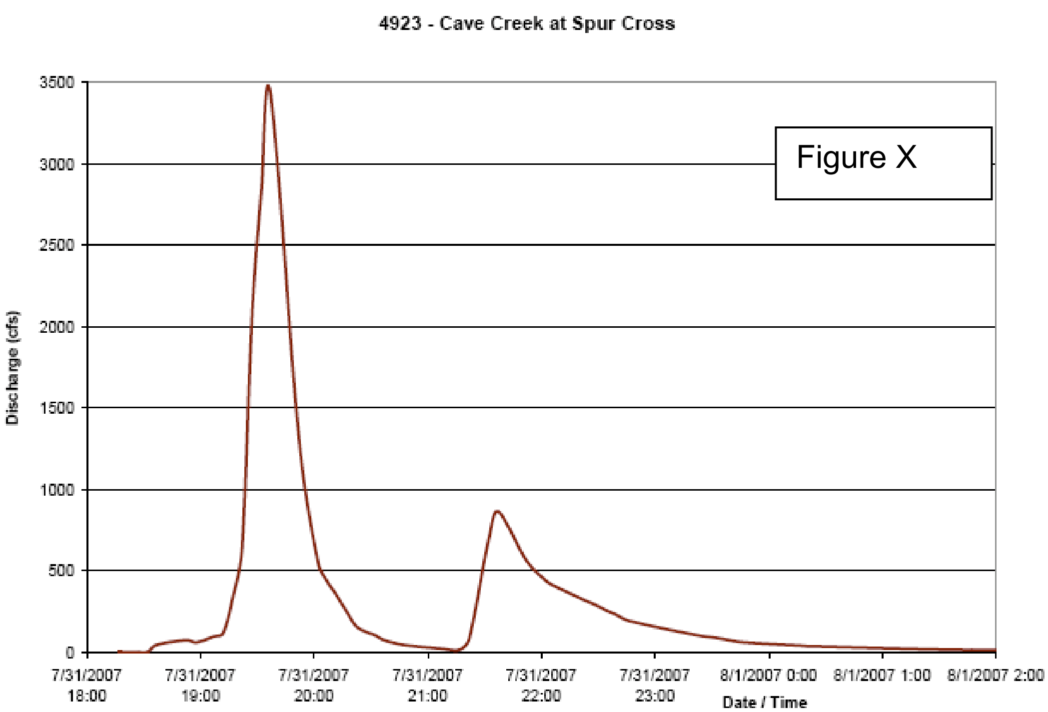
8. Which station will most likely have recorded the highest discharge after the storm?
   a. Station A
   b. Station B
   c. Station C

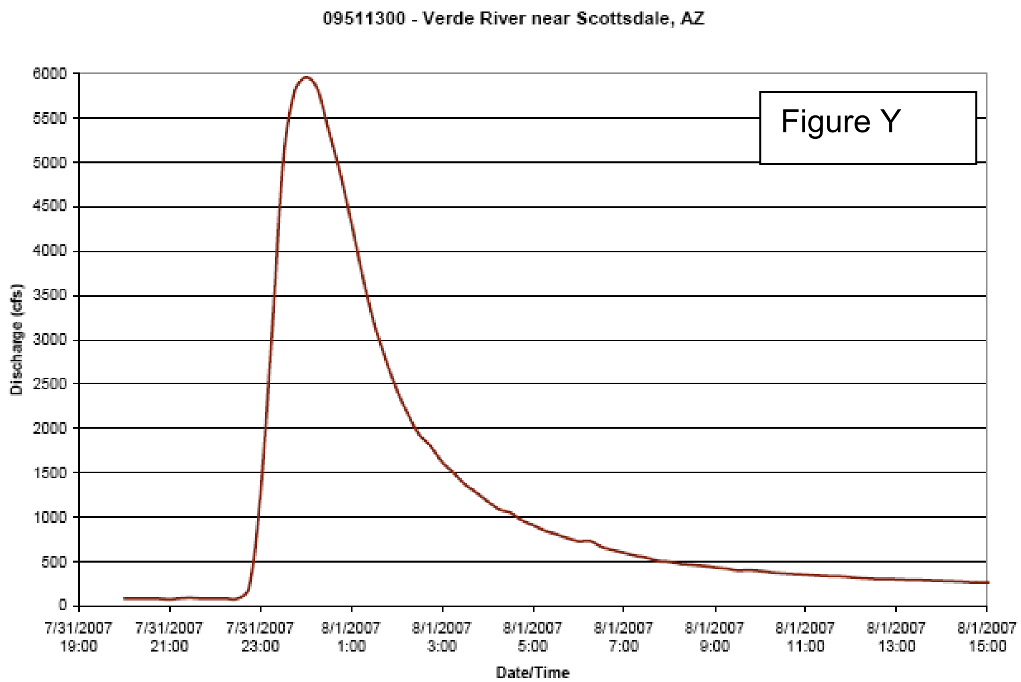
9. What kind of storm tracking could **not** be represented by this map?
   a. Flash Flooding
   b. Regional Event
   c. Storm Surge

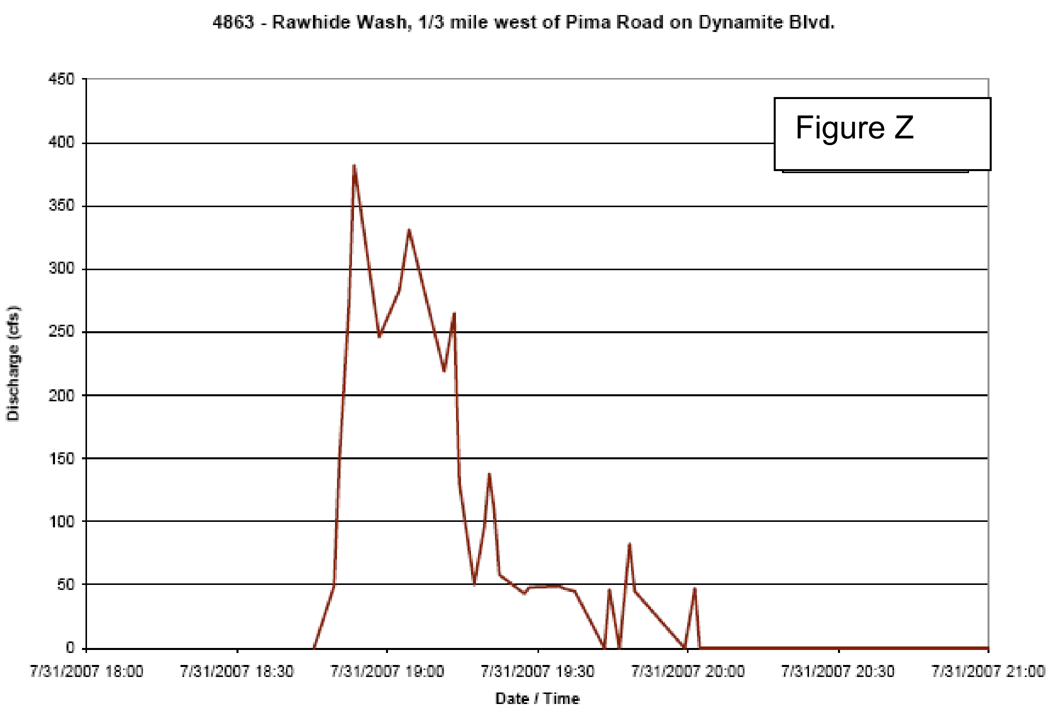
10. The year is 2064, and you are selected to be one of the people to head to Mars. If you were to look out over the planet as you came in for a landing, which area would you most likely expect to see river deposits.

a.  b.  c. 

11. A summer storm hits in Maricopa County, which of the following hydrographs best describes the following scenario? A thunderstorm has a very rapid release of precipitation which causes the stream to rapidly increase discharge. The discharge lessens as the storm subsides, and resurges as a second storm burst hits. The discharge gradually decreases back to the original dry wash.
    a. Figure X
    b. Figure Y
    c. Figure Z

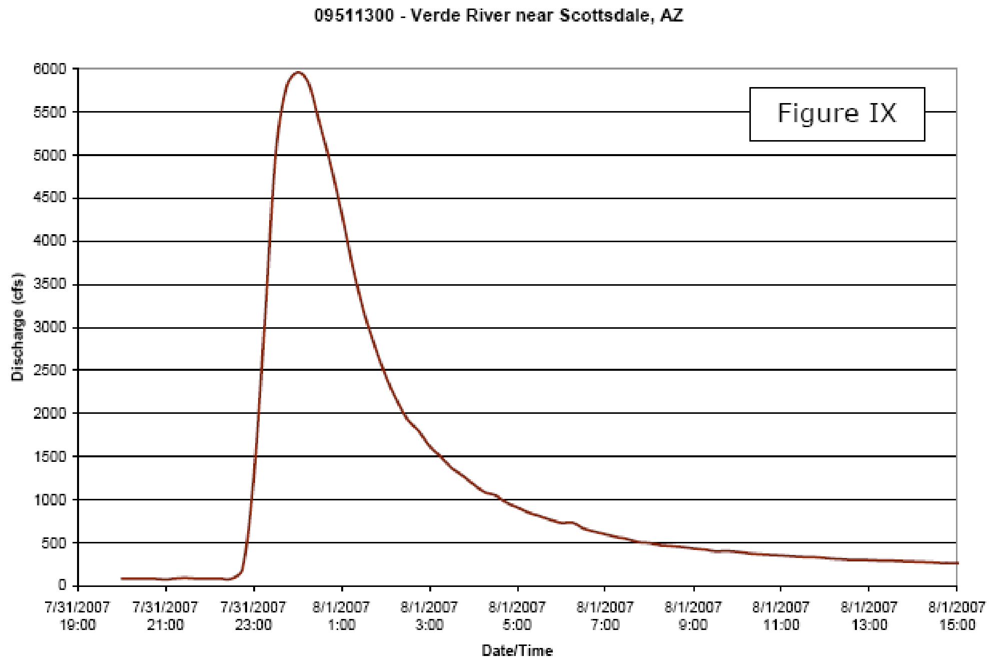


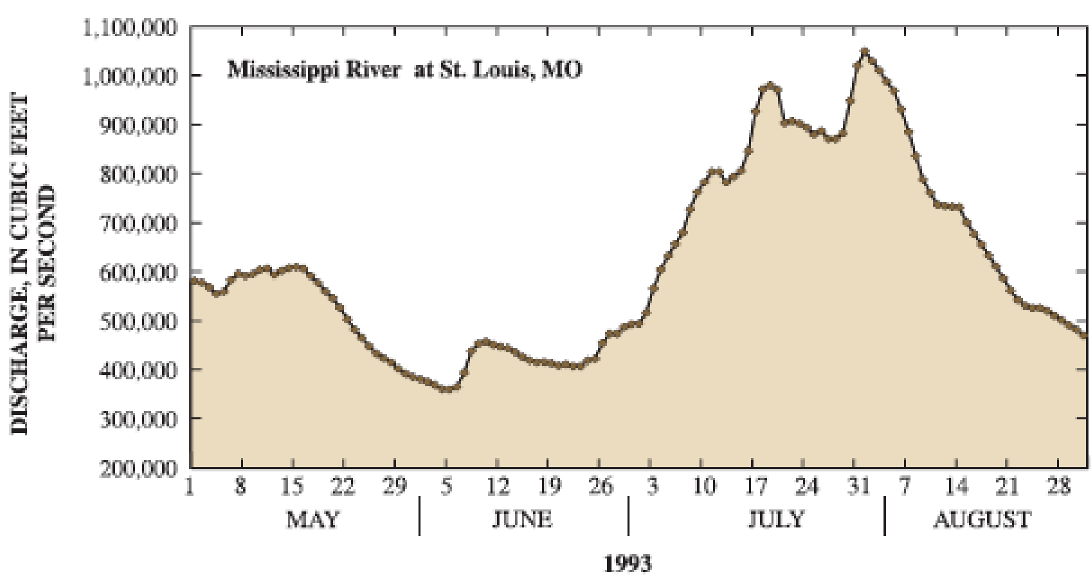

09511300 - Verde River near Scottsdale, AZ
Figure Y
Discharge (cfs)
6000
5500
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
7/31/2007 19:00
7/31/2007 21:00
7/31/2007 23:00
8/1/2007 1:00
8/1/2007 3:00
8/1/2007 5:00
8/1/2007 7:00
8/1/2007 9:00
8/1/2007 11:00
8/1/2007 13:00
8/1/2007 15:00
Date/Time


4863 - Rawhide Wash, 1/3 mile west of Pima Road on Dynamite Blvd.
Figure Z
Discharge (cfs)
450
400
350
300
250
200
150
100
50
0
7/31/2007 18:00
7/31/2007 18:30
7/31/2007 19:00
7/31/2007 19:30
7/31/2007 20:00
7/31/2007 20:30
7/31/2007 21:00
Date / Time

The following questions are short answer and do not require using the scantron.

12. Examine the following hydrographs, what might account for the differences in shapes of these two hydrographs. Include descriptions of river characteristics, storm characteristics and surrounding terrain and ground conditions.





13. Describe what you see as the difference between hands-on instruction and inquiry instruction in a classroom. What does it look like, what does it sound like?