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Abstract

This study focuses on elementary teachers' comprehension of flooding before and after inquiry-based professional development (PD). There was an improvement in teachers' understanding toward a normative view from pre- to post-test (n = 17, mean gain = 4.3, SD = 3.27). Several misunderstandings and a general lack of knowledge about flooding emerged from the geoscience content two-tier pre-test, some of which persisted throughout the PD seminar while other responses provided evidence of teachers' improved understanding. The concepts that teachers struggled with were also apparent upon examining teachers' reflections upon their learning and teaching practices throughout the seminar. Teachers were challenged as they attempted to add new academic language, such as storm surge and discharge, to their prior understandings. Flooding concepts that teachers showed the least improvement on included analyzing a topographic region, reading a map image, and hydrograph interpretation. Teachers' greatest areas of improved understanding occurred in understanding the probability and role of ground conditions in flooding events. Teachers demonstrated considerable growth in their understanding of some flooding concepts through scaffolded inquiry lessons modeled throughout the PD. Those teachers who had greater prior knowledge and demonstrated more use of self-regulated learning showed the most change toward a normative view of flooding. The explicit modeling and participation in inquiry-based science activities and written responses to self-regulatory learning prompts throughout the seminar supported teachers' learning.

Keywords: elementary teacher professional development, science education, geoscience, flooding, two-tier test, self-regulated learning strategies

Introduction

In the most recent handbook of research on science education, Appleton (2007) reminds us that elementary teachers tend to avoid science and that historically this has been a limiting factor ever since they have been expected to teach science. In his synthesis of the elementary science education research literature, Appleton identified three major issues elementary science teachers have with teaching science: (1) limited science subject matter knowledge; (2) limited science pedagogical content knowledge; and consequently (3) low confidence and self-efficacy with science content and science teaching. Many elementary teachers do not develop a strong background in science because of the lack of science content requirements for undergraduate, and post-baccalaureate, certification and degree programs in elementary education. In the USA, these programs generally only emphasize state-mandated elementary certification requirements, with a greater emphasis on reading and writing literacy and math skills. They include a few introductory level content courses for core academic subjects and a single pedagogical methods class for teaching in each content area. Consequently, many elementary teachers who themselves lack scientific literacy are responsible for providing productive opportunities for their students to develop the roots of scientific literacy.

Other researchers have noted that because of their discomfort in teaching science, elementary teachers tend to teach science lessons that facilitate maximum classroom control, but are not appropriate for engaging students in inquiry-based science investigations (Roth, 1996; Skamp, 1993; Woodbury, 1995). Well-designed professional development (PD) programs that leverage current research findings in teacher learning are one way in which elementary teachers can gain the content area knowledge needed to teach science appropriately. Our PD work has been shown to improve both secondary school teachers' biology content knowledge and teachers' pedagogical skills, when designed to do so (Baker et al., 2008). In the Communication in Science Inquiry Project (CISIP), we were concerned with enhancing elementary teachers' scientific literacy, specifically to better understand Earth systems science, within a framework of instructional strategies that support the development of a scientific classroom discourse community. To be effective in these efforts as teacher PD providers and educational researchers, it is critical that we understand how teachers'—and consequently their students'—ideas affect their learning about, and perceptions of, their environment as part of their global literacy (Mayer, 2002).

The purpose of the research was to: (1) evaluate the degree to which the PD supported elementary teachers in developing normative scientific understandings of flooding; (2) examine the challenges the elementary teachers encountered in learning this content; and (3) ascertain the role of self-regulation strategies, including metacognition, in the learning process. While teachers learned about flooding over a few weeks within a summer PD context, the ultimate goal was that they would use the inquiry-based and metacognitive instructional strategies modeled for them to reform their own science instruction with their elementary students. We chose to examine the role of metacognition in teachers' learning because it is one of the three key learning principles identified by the National Research Council (NRC, 2000, 2005) that was part of the PD model and employed regularly within the PD flooding activities. This PD program was designed with the NRC standards in mind and as such was designed with a metacognitive lens. However, in our research, we chose to take a broader perspective of self-regulated learning (SRL), of which metacognition is a component (Zimmerman, 1995). We interpreted the two-tier pre–post test data on teachers' learning of flooding to reveal degrees of normative scientific understanding. Two-tier tests use an extended multiple choice format in which the respondents select an answer to the item prompt and then provide an explanation for why they chose that answer from the possible multiple choice answers. We then compared teachers' degree of SRL reflection on embedded writing prompts with their demonstrated learning gains.

Literature Review

Flooding Misconception Background Literature

One of the few validated instruments available to study misconceptions in the geosciences is the *Geoscience Concept Inventory* (GCI) (Libarkin & Anderson, 2006). This is an instrument based upon the most recent research on undergraduate students' geoscience misconceptions. It includes the water cycle and groundwater but nothing that directly addresses river systems and flooding. Indeed, most research on common misconceptions has focused on physical science, in which water plays a role, but not commonly within the context of Earth systems science (Henriques, 2000).

Research on students' understanding of the hydrologic cycle (Shepardson, Wee, Priddy, Schellenberger, & Harbor, 2009) determined that students retained naive views of the hydrologic cycle and tended not to make connections between their own local contexts and textbook representations. For example, when students in the topographically flat Midwestern region of the USA were presented with examples of hydrologic activity of mountains and coastal regions, their conceptions of the hydrologic cycle only included these textbook components. They did not demonstrate any applied understanding of their environment (Schoon, 1989). Students from urban regions focused on the hydrologic cycle as purely a weather event without connecting their understanding to natural geomorphic processes. Commonly held misconceptions among these students were that flooding only occurs along rivers when the snow melts in the spring or after a heavy rainfall (Schoon, 1989). Sexton's (2006, 2008a, 2008b) recent work with undergraduate student perceptions of rivers and flooding found that some of the alternative scientific explanations for flooding included God, other planets, melting of ice caps related to global warming, tsunami, and a full water table. It should be noted that in this study we examined both river and coastal flooding, so tsunami and global warming were included as accurate sources of flooding.

Due to the lack of understanding of people's misconceptions about flooding, we adopted an exploratory approach and focused on teacher learning of flooding, not the documentation of misconceptions, although the two are related in similar ways. By exploring elementary teachers' learning of flooding concepts, we offer some insights into how PD can be designed to affect and support teachers' experiences with new scientific ideas. From our work here further studies with other groups of learners can be performed to craft formal misconceptions about flooding.

Teacher Learning

In a study of teacher learning of Earth science in a PD context, Monet and Etkina (2008, p. 455) found that "teachers who could describe how they reasoned from evidence to understand a concept had the highest learning gains [in Earth science content]." Monet and Etkina recommended that teachers' reflections upon learning science content should be embedded throughout PD. This finding supports our choice of embedding multiple opportunities for teachers to reflect on their learning at the PD summer seminar and how they could apply what they learned to their own classroom science lessons.

Social cognitive learning perspective. We used a perspective of individual cognition and learning to categorize teachers' ideas and understandings of flooding and an empirical approach to categorizing the data to make low-level inferences. However, teachers also engaged in learning through social interactions that involved small group discussion and writing in science notebooks in a situated learning context (Lave & Wenger, 1992). The CISIP PD grant deliberately recruited school-based teams of teachers so that not only did they have the opportunity to discuss what they were engaged with during the summer seminar, but that they would also have a professional learning community available to them as they tried to use their new knowledge and instructional strategies later during the academic year with their students. Consequently, teacher learning occurred through a small-group, constructivist, inquiry-based approach to exploring flooding. Thus, we examined teachers' reflective prompts to better understand their initial pre-PD conceptions of flooding as well as their final ideas in an effort to determine the degree to which their statements about flooding changed as a result of the PD.

Self-regulated Learning and Cognitive Overload

Self-regulated learning (SRL) includes three components: (1) the use of metacognitive strategies; (2) cognitively engaging in a task; and (3) cognitive strategy use (Pintrich & DeGroot, 1990). SRL has also been described as a student's ability to have a skill set for learning, motivation to employ those skill sets, and executive control to know when to apply the appropriate strategy to a task (Weinstein, Meyer, Husman, Van Mater, & McKeachie, 2006; Zimmerman, 2001). These processes are used within a cycle of learning forethought (planning) into a phase of volition (action) and then a phase of reflection (Zimmerman, 2000). In the reflective phase, students may make cognitive judgments, react to the experience through affect, and make choices about present and future behaviors (Pintrich, 2004). Students with high SRL skills tend to use deeper learning strategies, rather than rote memorization, and have a greater understanding of how one area of knowledge and skills can transfer to another (Weinstein, Husman, & Dierking, 2000). Students who are able to connect what they are learning to what they already know are more likely to sustain learning of new content and assimilate it into their knowledge structures, also referred to as conditional knowledge (Weinstein et al., 2000). This conditional knowledge is fundamental to successful transfer but may be a challenge for those students who struggle with both procedural knowledge and content knowledge concurrently (Mayer & Moreno, 2003; Weinstein et al., 2000). In our study, teachers undergoing PD, who are new to both science content and the inquiry-based instructional methods employed, may struggle with new science concepts.

Theoretical and Research Literature Supporting the Professional Development Model

Until recently, learning through talking and writing has been largely ignored in science instruction (Hand et al., 2003). In response to the research findings in content area literacy, the CISIP PD model of a scientific classroom discourse community includes scientific talking and writing as central aspects of science lessons. CISIP also emphasizes academic language development and research-based cognitive learning principles within a student-centered curriculum. In the CISIP model, scientific inquiry is a vehicle for written and oral scientific discourse, academic language development strategies, and learning principles in science instruction.

Research Methods

Professional Development and Research Context

The CISIP provided fifth- and sixth-grade teachers with PD 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. The CISIP PD model was originally funded by the National Science Foundation and designed using current research findings from the science education and language literacy research literature. CISIP (Baker et al., 2009) leverages situated learning where learning is a social activity (Lave & Wenger, 1992; Wenger, 1998), and learning to talk and write in the genres of science contributes to the development of structured and coherent ideas (Kelly, 2007). The CISIP model focuses on: (1) academic language development; (2) written discourse; (3) oral discourse; (4) scientific inquiry; and (5) cognitive learning principles (e.g., accessing prior knowledge, the use of conceptual frameworks to organize factual information, and embedded metacognition) (NRC, 2000, 2005). As part of the CISIP PD activities, teachers also participated in collaborative lesson planning activities with scaffolded support using a model lesson template. The academic language support is essential not only for the academic comprehension for the teachers but also for providing examples and models of classroom strategies for the large numbers of ELL student populations these teachers encounter in their classrooms.

From January to April 2008, teachers attended four 6-hour monthly seminars to introduce them to the CISIP model of a scientific classroom discourse community. These introductory days were followed by a three-week (12 days) science content-rich summer PD seminar in June 2008. Teachers were provided with a stipend to attend a total of 96 hours of PD with an agreement to implement CISIP strategies in their own classroom in the following academic year. Fifty teachers participated in the summer seminar and chose one of two science content strands, life science (n = 28) or Earth science (n = 22). This study focuses only on those teachers who chose to participate in the Earth science strand activities.

Professional development timeline. The Earth science strand activities spanned 35 hours in total (Table 1) and alternated with whole group (i.e., both life and Earth science participants) PD activities focusing on the CISIP instructional strategies. The Earth science content focus was on flooding disasters, which was the only overlapping state science standard between fifth and sixth grades. The instructional goal was to implement specific science content using inquiry-based instruction that encouraged teachers to build a working knowledge of flooding over time. For this study and the PD purposes, flooding was defined both as an overtopping of river banks as well as inundation of coastal waters to surrounding regions (Abbott, 2008; Coch, 1995; Keller & Blodgett, 2008; Marshak, 2005; Reynolds, Johnson, Kelly, Morin, & Carter, 2008; Smith & Pun, 2006). Flooding was classified as a temporal event and its causes include: (1) excessive rainfall associated with hurricanes and short thunderstorms; (2) a specific ground material's inability to absorb water; (3) the shape of the surrounding topography; (4) earthquake-generated tsunami; and (5) a rise in sea level and high winds associated with hurricanes.

Description of CISIP 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 independent inquiry so that the first activities provided more guidance and as the summer seminar proceeded more scaffolding was removed.

As shown in Table 1, the first Earth science lesson provided background information to ensure that all the teachers had the same access to basic information

Table 1. Description of the geoscience content professional development activities, data collected, and teacher learning outcomes

Activity	Description	Data collected	Teacher learning outcomes
Assessment	Pre–post two-tier test on causes of flooding and content.	Teachers' test responses	
Lesson 1: Personal narrative	Teachers read narrative accounts of flooding disasters describing different types, causes, and general properties of floods.	Post-assessment on causes of flooding	After completing this activity teachers will be able to identify: • features, causes, contributing factors of four types of flooding; and • commonalities and difference between types of flooding.
Lesson 2: Case studies of flooding in Arizona	Teachers examined two different modern Arizona floods through analyzing data from technical scientific reports.	Poster reflection Q1: 'What would you change about your poster if you could?' (*cognitive*) Q2: 'Which posters did you find to be most helpful?' (*metacognitive*) Q4: 'Brainstorm some ideas of what components in this lesson could be applied to your classroom?' (*motivation/ behavior*) Communication reflection Q2: 'What did you find to be the most helpful form of communication?' (*metacognitive*)	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 design	Teachers applied their comprehension to stream table investigations, which included modeling scaffolded support strategies (e.g., guided questions, investigation template).	Feedback reflection Q1: 'Did the feedback/ revision process help you better understand content?' (*metacognitive*) Q2: 'Did the feedback/revision process help your confidence/ understanding of the content?' (*affective/metacognitive*)	After completing this activity teachers will be able to: • design their own procedure; • propose their own research question based on results from their investigation; • provide effective feedback to their colleagues; and • conduct an inquiry investigation.

(Continued)

Table 1. *(continued)*

Activity	Description	Data collected	Teacher learning outcomes
Assessment	Pre–post two-tier test on causes of flooding and content.	Teachers' test responses	
Lesson 4: Full inquiry project design	Based on the outcomes of Lesson 3, teachers proposed and carried out their own inquiry investigations using stream tables.	SIR reflection Q1: 'Were the poster session and the SIR helpful with your overall content comprehension?' (*metacognitive*) Q2: 'Would the SIR be something you would use in your classroom?' (*motivation/behavior*) Q3: 'Did the group rewrite increase your confidence in your conclusions?' (*cognitive/affective*)	After completing this activity teachers will be able to: • conduct an independent inquiry investigation and present their findings in a public (classroom) format; and • write a *Student Investigation Report* (SIR) to report on findings from their inquiry activity in which they justify a claim using evidence from their investigation.

about flooding in a case study format. The content was linked to state and national science education content standards (NRC, 1996) for fifth and sixth grades. For example, the Arizona state science standards that correlated to Lesson 1 were: (1) "Analyze the impact of large scale weather systems on the local weather" (p. 61); (2) "Explain the impacts of natural hazards on habitats" (i.e., flooding) (p. 21); and (3) "Evaluate the effects of the natural hazard of a hurricane" (p. 21) (Arizona Department of Education, 2005). However, the content was taught to the teachers at an adult learner's level. Teachers also read text passages that were written at an undergraduate college level and were asked to consider how they might design lessons for their own students applying the CISIP model. Each lesson took one to two 5-hour days for a total of 35 hours.

Two authors, van der Hoeven Kraft and Wilson, were responsible for developing the content for the PD and made deliberate choices for the selection of geographic regions on which to focus the activities. In one instance, a flood in Venezuela was selected for Lesson 1, because we thought teachers would find this relevant to their own Latino/a students' culture and heritage, many of whom are originally from South and Central American regions. In Lesson 2, the focus was on specific floods in the local area of the southwestern USA. Many of the teachers remembered experiencing one local flooding event (House, 1993; House & Hirschboeck, 1995) and another from a recent storm event that occurred near where some teachers taught (Waters, Perfrement, & Gardner, 2001; Youberg, 2002). These lessons provided a local context and generated a meaningful opportunity to investigate flooding in the spirit of place-based education (Gruenewald, 2003; Semken & Butler Freeman, 2008; Sobel, 2004; Steele, 1981) and were designed to address some of the past misconceptions identified by Shepardson et al. (2009).

Analytic Methods

The authors of this paper included three members of the university research team as well as three of the PD designers and facilitators. The authorship reflects the collaborative nature of the PD program and the research. Two of the PD facilitators also assisted in analyzing the data that were generated through the study. The research questions for the study were as follows:

(1) What, if any, learning gains do teachers demonstrate about flooding from pre- to post-seminar?
(2) What were the challenges that the elementary teachers faced when learning about flooding and related Earth science?
(3) Do self-regulatory learning strategies contribute to teachers' learning of flooding within this PD context?

A multi-method approach was employed to study the phenomenon of teachers' conceptions before and after PD. The science content data were collected using a two-tier pre–post test on flooding concepts. We compared the pre–post paired means and the rank order of the items by difficulty for both tiers. We classified each teacher's learning gains by comparing the pre–post content results using a framework of prior knowledge of flooding. Gain scores from pre- to post-test were calculated using the whole group's responses for each item using the following equation: (post % correct − pre % correct)/(100% − pre % correct).

In accordance with our theoretical framework for teacher learning, one of the PD goals was to model how teachers could use metacognitive prompts with their students to improve their understanding of both the science content and themselves as learners. Consequently, we also employed an analytical framework of SRL from the motivation research literature to analyze teachers' responses to various reflective writing prompts. We collected data from all four lessons using these writing prompts. We then analyzed these data for the degree of SRL exhibited in each teacher's response and compared the total number of partially reflective and reflective prompts to his or her conceptual profile. By way of example and to show the range of understandings, we present three teachers' responses to the assessments and reflective prompts in addition to the whole group analyses.

Multiple verbal and written communication activities were used to support content acquisition (Table 1) with teachers situated in small groups. The goals of the poster session and letter-writing exercise following Lesson 2 were to support the development of a scientific argument, using claims and evidence, and application of academic language. The purpose of the poster presentation session and scientific investigation report (SIR) that followed Lesson 4 was to write a scientific explanation with claims, evidence, and reasoning. The goals of the whole group debriefing sessions after Lessons 1 and 3 were to support the development of academic language and science process skills associated with inquiry.

Science Content Test and Validity

Two-tier tests have been used to identify student misconceptions in chemistry and biology (Anderson, Fisher, & Norman, 2002; Tan, Goh, Chia, & Treagust, 2002; Treagust, 1988). A two-tier test requires respondents to select an answer to an item, Tier 1, and then to either select a reason or write a reason, Tier 2, for the answer selected in Tier 1. In this case, we have employed such an approach to flooding concepts in order to better understand elementary teachers' understanding before and after PD. On our pre–post test, Tier 1 required the selection of a multiple choice answer, and Tier 2 was a constructed written response in support of the Tier 1 selection.

To address content validity, we developed the Earth science content assessment after designing the PD activities to assure maximum alignment with instruction. However, it should be noted that ultimately this was a pilot test of the assessment instrument. Key flooding concepts (Table 2) included reading topographic maps, periodicity of flooding events, effects of runoff, properties of flood types, map and graph reading comprehension, and flooding term recall. The pre–post assessment included 11 two-tier multiple choice questions and two constructed response questions. All of the test questions concerned various types and causes of flooding except for the final question, which concerned identifying the difference between hands-on and

Table 2. Pre–post test assessment categories

Question	Reading topographic maps	Periodicity of flooding events	Effects of runoff	Properties of flood types	Map and graph reading comprehension	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	

Instrument is included in the Appendix.

inquiry-based instruction and was not used in our analysis of teachers' learning gains on flooding concepts. Although there were 22 participants in the Earth science strand, one was a science curriculum coordinator who only attended a few days of the seminar and four others missed one of the pre–post testing days. Consequently, by the end of the seminar, 17 participants had completed both pre- and post-tests. Science content scores were generated by one university researcher and one PD facilitator on the tests through consensus and then pre–post gains were calculated for each item.

As the Earth science pre–post flooding test was a new instrument and the sample size was too small to estimate unbiased reliability statistics, we confine our results and interpretations to this particular group of teachers and the CISIP PD. From a qualitative perspective, we do offer patterns of learning that may be generalized to, and tested in, other settings in the future.

Scoring criteria. Table 3 shows the 16 categories of learning gains for each question resulting from the four-by-four matrix of possible combinations of (in)correct answer and (in)correct explanation for each item. A similar matrix was used to categorize gains for the constructed response questions. Normative views were determined for the entire instrument if the teacher had at least 66% of the Tier 1 multiple choice questions completely correct. 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). These boundaries for prior knowledge were determined by percentiles from the whole group (n = 19) achievement scores on the pre-test. The creation of correct responses to the Tier 2 responses was an

Table 3. Change matrix used for coding pre–post two-tier multiple choice responses and explanations

		Post			
	Tier 1/Tier 2	**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 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 change. New information confounds understanding.
	Correct answer/ incorrect explanation	(2) Partial prior understanding or ability to guess correct answer, but unable to explain choice; 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 change.
	Incorrect answer/ correct explanation	(3) Partial prior understanding, 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 change.
	Incorrect answer/ incorrect explanation	(4) Greatest positive 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 change.	(12) Small shift from no prior normative understanding. Some assimilation of new material resulting in partial change.	(16) No change. Most resistant to change. New information not assimilated.

Numbers in parentheses refer to the category of change in understanding from pre- to post-test.

iterative process based on the responses received from participants to produce a consistent scoring scheme. For some of the questions, there was more than one accurate normative scientific view possible.

Returning to our coding matrix, our first category, found in the upper left-hand corner, from pre- to post-instruction response with a correct answer and correct explanation to another correct answer with correct explanation: 1 = *Most consistent and correct, highest prior knowledge, no change necessary*, reflects that no improvement in understanding was required because full understanding was present and maintained from pre- to post-test. As we follow along the upper left-hand to lower right-hand diagonal of the matrix, no change in learning has occurred from pre- to post-test. At the lower right-hand corner, we have the other end of the spectrum, the last category that was used for incorrect responses with incorrect explanations on the pre-test to another incorrect answer with an incorrect explanation on the post-test: 16 = *No change. Most resistant to change. New information not assimilated*. We did not conduct interviews with the teachers to probe for elaborations upon their explanations to the multiple choice questions and to obtain a sense of their attitude toward the concepts. However, these four categories on the diagonal in the matrix are the result of the same outcome, which is that there was no change in understanding, a teacher either maintained a normative view, a partial understanding, or a lack of understanding of the concept. With our use of the two-tier question and constructed response test format we felt confident in our ability to classify teachers' understanding more reliably than with just a multiple choice test.

Causes of flooding pre- and post-lesson writing prompts. In conjunction with the pre- PD science content test, teachers were asked to respond to the diagnostic and formative assessment prompt, "Draw and label or describe one or more causes of flooding." The information from this assessment was used by the instructors to guide Lesson 1. After Lesson 1 instruction was complete teachers were asked to respond to the post-lesson reflective question prompts "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?" Since the pre- and post- "causes of flooding" writing prompts could not be directly compared, as they were not parallel pre- and post-items, we analyzed each set of writing prompts separately with each idea counted once per teacher, even if teachers used it repeatedly throughout their response. Each idea category and number of participant responses was totaled and the responses were categorized as normative or naïve understandings. We also tallied frequencies of types of floods that the teachers mentioned pre–post activity. Sections of the post-activity prompt that answered, "How has your understanding changed?" and/or, "What helped you to most effectively create that change in understanding?" were separated for additional analysis. Teachers' pre-activity instruction prompts were then re-examined for possible missed items.

The teachers' written reflection responses listed in Table 1 were analyzed both for content and for levels of self-regulation. When analyzing for content, we conducted

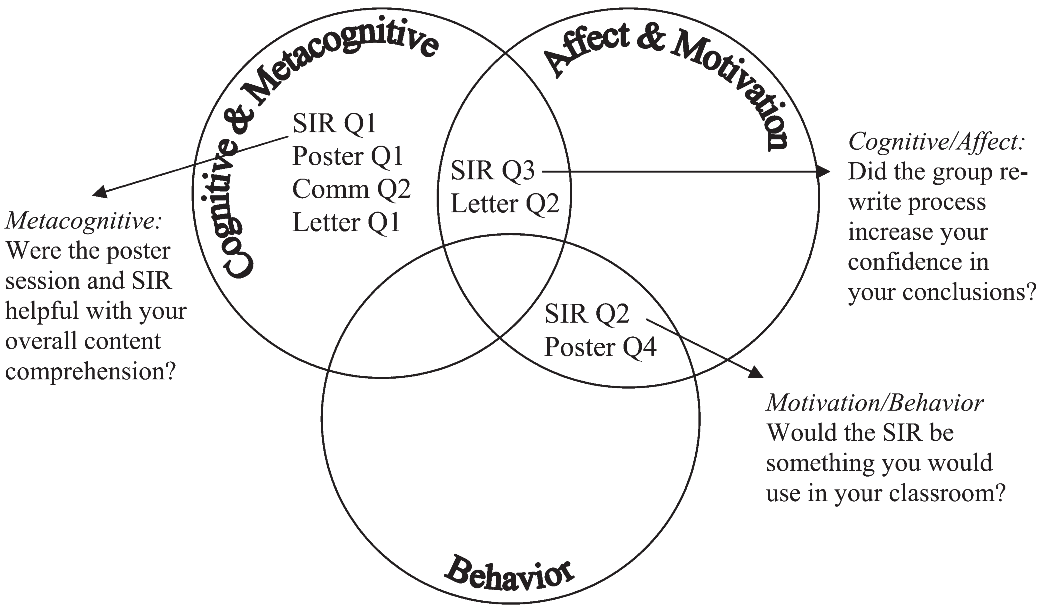

Figure 1. Three phases of SRL and the reflective prompts found within each phase and overlapping phases

a frequency count of responses and occurrences to determine an overall understanding of group experiences and then individual responses were examined for more detail. We also created categories for coding when analyzing for self-regulation. This was based on work by Pintrich (2004) in which we separated three categories of: (1) metacognition and cognition, (2) affect, and motivation, and (3) behavior (Table 4). In the reflective responses from the Student Investigation Report (SIR) SIR Q1, SIR Q2, Poster Q1, Communication Q2, and Letter Q1, teachers were asked to reflect on their cognitive or metacognitive experiences during the PD. No one item fell into a singular

Table 4. Stages of self-regulation

Stages of self-regulation		
Cognitive and metacognitive	Affect and motivation	Behavior
Cognitive judgments	*Affective reactions*	*Choice behavior*
Attributions	Attributions	Effort regulation
Rehearsal	Goal setting (Intrinsic and extrinsic)	Help-seeking
Elaboration organization	Task value	Time/study environment
Critical thinking	Control beliefs	
Metacognition	Self-efficacy	
	Test anxiety	

Adapted from Pintrich (2004, p. 390).

category. For example, in the reflective responses to SIR Q3 and Letter Q2, teachers were asked to merge cognitive and metacognitive reflections with their affect and goal setting. In the reflective responses SIR Q2 and Poster Q4, teachers were asked about their affective responses with respect to goal setting with future behaviors (Figure 1 and Table 1 for question prompts). Two of the authors coded the responses separately and any codes that were not the same were discussed until full agreement was attained.

Specific Participants as Examples

To provide deeper insight into the elementary teachers' experiences and learning process with the Earth science CISIP summer program, we chose three representative individuals to examine in-depth. We selected the teachers, Susan, Joanna, and Karen (pseudonyms), based on their degree of improved understanding from pre- to post-seminar. Their number of years of teaching experience, highest degree earned, undergraduate major, number of science and science teaching methods courses taken, certification(s), endorsements, and type of teacher preparation program are summarized in Table 5.

Results

Learning of Flooding Science Content

There was a maximum possible score of 26 on the 12-item pre- and post-test, and partial and full credit was given to second tier explanations to determine if learn-

Table 5. Teacher demographic information

	Susan	**Joanna**	**Karen**
Teaching experience	Five years total. Taught fifth-grade for three years, eighth-grade for two years.	One year total. Taught fifth/sixth-grade for one year.	12 years total. Taught second-grade for 10 years and fifth-grade for two years.
Highest degree earned	BA	BA	MEd (Elem. Ed.)
Undergraduate Major	BA Elementary education	BA Elementary education	BA Journalism
Number of science classes taken	two biology, zero chemistry, three physics, three geology/Earth science	one biology class, one geology/Earth science	one geology/Earth science
Certification(s)	General science (middle school)	Elementary Ed. (K-6)	Elementary Ed. (K-8)
Endorsements	K-8 Elementary education	None listed	None listed
Teacher prep program	Undergraduate, fifth-year for teacher certification	Undergraduate, as part of four-year program	Graduate program for teacher certification
Number of science methods classes	2	1	2

ing gains occurred from teachers' participation in the PD activities. There was an increase, an average of 4.3 points, or 16.5% of total possible points, *SD* = 3.27, from pre- to post-test. Two participants did not complete the post-test second tier justifications and as such had the two lowest post-test scores. The difference without these two participants was a mean gain of 4.75 points (+18.3% from pre- to posttest), *SD* = 3.23. As a group (n = 17), the teachers showed improvement in their understanding of flooding as a result of the inquiry-based PD activities. When these results were compared to only the first tier multiple choice question scores, there was still gain (mean gain = 2.24, a 20.4% increase), *SD* = 1.75. This is slightly higher than the two-tier scoring protocol and suggests that the pre–post test with only multiple choice responses without justification may have overestimated learning gains.

The greatest gains were found for Tier 1 multiple-choice items Questions 3, 4, and 9 (Table 6): (1) (Q9) specific application of academic language (term recall and properties of flood types) showed a 0.77 gain (a 52.6% increase in the selection of the correct multiple choice answer with a 44.7% increase in correct explanation); (2) (Q4) understanding of paleoflood deposits and probability of modern flooding (term recall, properties of flood types, and periodicity of flooding events) yielded a 0.91 gain score (a 52.6% increase in the selection of the correct multiple-choice answer with a 57.9% increase in correct explanation); and (3) (Q3) interpreting topographic map elevations with respect to stream flooding (reading topographic maps and properties of flood types) produced a 0.80 gain score (a 42.1% increase in the selection of the correct multiple choice answer with a 7.9% increase in correct explanation). The lowest scoring item 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 0.08 gain (a 5.3% increase in the selection of the correct multiple-choice answer from 36.8% to 42.1%). However, the correct explanation associated with this item increased 42.1%, from 10.5% to 52.6%, with a 0.47 gain score. This suggests that greater depth of learning of the concept occurred but mainly with those teachers who were already able to select the correct answer on the pre-test.

Understanding Causes of Flooding Prompt Data

Twenty teachers responded to the pre-instruction prompt for Lesson 1 ("Draw and label or describe one or more causes of flooding"). The number of responses ranged from one to nine ideas per teacher. The most frequently mentioned preinstruction idea was that excessive rain (75%) causes flooding, followed by soil saturation (40%), and the bursting of dams or levees (45%). Nineteen teachers responded to the post-instruction flooding prompt and the number of responses ranged from 0 to 13 ideas per teacher. The post-lesson prompt was worded a little differently but still resulted in an inventory of teachers' ideas about the causes of flooding. The most pervasive idea post-instruction was still that an excessive amount of rain (63.2%) causes flooding, followed by earthquakes (53%). Overall, the total number of teachers' post-instruction (n = 114) outnumbered preinstruction ideas (n = 89).

Table 6. Percent correct for pre- and post-PD responses for Tier 1 multiple choice and Tier 2 explanation

	Pre-PD scores		Post-PD scores		Post-pre difference		Gain score	
Question number	Multiple choice %	Explan. %	Multiple choice%	Explan. %	Multiple choice %	Explan. %	Multiple choice	Explan.
1	47.4	44.7	57.9	57.9	10.5	13.2	0.20	0.24
2	89.5	78.9	100	78.9	10.5	0	1.00	0.00
3	47.4	26.3	89.5	34.2	42.1	7.9	0.80	0.11
4	42.1	10.5	94.7	68.4	52.6	57.9	0.91	0.65
5	63.2	23.7	89.5	55.3	26.3	31.6	0.71	0.41
6	89.5	44.7	89.5	57.9	0	13.2	0.00	0.24
7	94.7	86.8	100	84.2	5.3	−2.6	1.00	−0.20
8	36.8	10.5	42.1	52.6	5.3	42.1	0.08	0.47
9	31.6	0	84.2	44.7	52.6	44.7	0.77	0.45
10	63.2	42.1	63.2	42.1	0	0	0.00	0.00
11	94.7	86.8	94.7	63.2	0	−23.6	0.00	−1.79
12	NA	28.3	NA	69.7	NA	41.4	NA	0.58

$n = 17$

We categorized teachers' written responses to the two pre- and post-lesson prompts for Lesson 1 on the flooding case studies (Table 7). From a descriptive standpoint, teachers' use of the terminology of the various types of floods increased greatly as a result of the PD activity. Our small sample size and the slight variation in how the prompts were written negate a statistical analysis and subtraction of pre- from post-lesson percentages. This change in wording was done intentionally to encourage teachers' use of self-regulation of learning. It is interesting to see that the teachers mentioned earthquakes more often in the post-lesson prompt as a normative view. Teachers also mentioned tides more frequently as a naïve conception. This may represent an intermediate stage of understanding toward distinguishing between storm surges as a result of hurricane conditions and normal tidal fluctuations. The greatest change was seen in the types of floods in the post-assessment. This first flooding activity provided teachers with an opportunity to be exposed to types of floods and flooding as a geoscience concept. It helped to build teachers' background knowledge and provide a common experience for all teachers to draw upon during the summer seminar.

Reflection Data

In an analysis of participants' reflection responses, the teachers' written responses were identified as reflective (Y), partially reflective (P), not reflective (N), or not present (NA). We show a few examples of how these data were coded in Table 8. Each participant was assigned a frequency score composed of tallies of each of the four possible outcomes. The greater the number of reflective responses provided, the more skilled the teacher was considered to be in the area of SRL. The following examples of the types of written responses by three teachers provide insight into our rating system.

Table 7. Pre–post PD teacher responses by normative and naïve conceptions of causes of flooding and academic language use for types of floods

Views Pre-PD	Concept category	Views Post-PD
%	Normative views	%
75	Excess rain	63
25	Rapid downpour	21
25	Soil composition	0
40	Soil saturation	21
20	Snow melt	5
10	Glacier melt	0
5	Sea level rise	5
30	River overflow	0
45	Dam breaks	11
10	Hurricane/monsoon	11
5	Thunderstorm	5
20	Earthquake	53
10	Building homes in a flood zone	11
	Naïve views	
30	Land is too dry (inability) to absorb water	11
10	Ocean	0
5	Water table rises ("gets filled up")	0
5	Wind	21
5	Fire burns vegetation	0
15	Erosion	0
5	Temperature increase	0
15	Valleys/arroyos/canyons	32
5	Flat land	0
5	People move the land	16
0	Tides	26
	Types of floods (Academic Language Use)	
10	Flash flooding	63
0	Regional flooding	47
5	Storm surge	58
10	Tsunami	68
0	Ocean-based	26
0	Land-based	26

Table 8. Examples of coded teachers' reflective responses for degree of self-regulated learning

	Cognitive/metacognitive					Affect and motivation/ behavior		Cognitive/ affective and motivation		Self-regulated learning frequencies			
Teacher Code ID	SIR Q1	Poster Q1	Poster Q2	Comm Q2	Letter Q1	SIR Q2	Poster Q4	SIR Q3	Letter Q2	NA	Not	Partial	Yes
S03	Y	Y	Y	P	Y	P	Y	P	Y	0	0	3	6
S04	P	Y	P	Y	Y	P	N	P	Y	0	1	4	4
S05	Y	Y	Y	Y	Y	Y	P	Y	Y	0	0	1	8
S09	NA	P	N	P	P	Y	Y	Y	Y	1	1	3	4
S10	Y	Y	Y	Y	P	Y	P	Y	P	0	0	3	6

Key: Y = reflective response, P = partial reflection, N = not reflective, and NA = not present to write reflection.

Teacher Examples

Pre–post test scores. Of the three teachers we present here (Table 5), Susan started with the strongest prior knowledge and had the greatest gains, achieving a normative view of the flooding concepts. Her pre-test score was 14 (54%) out of a total possible 26 and her post-test score was 21.5 (83%). Joanna had the weakest prior knowledge, but showed a large shift in doubling her score on the assessment (pre-test = 8.5, 32.7%, post-test = 17, 65.4%), and while she did not achieve a fully normative view, she still showed considerable learning gains. Karen also started with weak prior knowledge with a pre-test score of 10 (38.5%) and based on her post-test score (9.5, 36.5%), showed no improvement after participating in the summer seminar.

Reflection data. When asked, "what would you change about your poster if you could?" in referring to the first poster session (Poster Q1) participants experienced, Susan mentioned specific tools that would be helpful, "I really liked the ideas [from another group] of runoff where the majority of the water came from and marking it on a map for easy viewing." This response was rated as a fully reflective response. Joanna's response for this reflection "we need a more detailed explanation for our recommendation" was rated as a partially reflective response. Karen was not present on that day, so she was scored as not present.

Another example of a reflection response and associated scoring is from a question about the SIR the teachers wrote. In combining areas of both affect and cognition, the question (SIR Q3) asked teachers, "Did the group re-write increase your confidence in your conclusions?" Susan responded, "Yes, because it allowed for us to analyze the metacognition of the entire group." Joanna's response was, "we were able to build off each others' conclusions and make a powerful one in our final copy." Both of these responses were rated as partially reflective responses. Karen's response was, “Yes!” This was rated as a non-reflective response. While the question did not ask for an elaboration of one’s thinking, because most of our teachers did choose to elaborate, we found this to be an indicator of a teacher’s natural tendency to use SRL strategies. While those who did not receive a full score may possess these skills, they chose not to employ these strategies when responding to these questions.

Examples of Teachers’ Learning of Flooding Content

The most difficult question on the test (see Appendix), Q8: “Which station will most likely have recorded the highest discharge after the storm?” displays the range of difference between the participants’ gains from pre- to post-PD. On the pretest, Susan had the wrong answer and the wrong explanation, “because it is a wash and received the most rain.” While she recognized that water gathers in a wash, she had not accurately interpreted what was happening and why a specific wash may have more water than another. On the post-test she selected both the correct answer and provided a correct explanation, “because this is the area where all the rivers/washes converge downstream.” Susan connected the big picture of the region into the runoff patterns for a specific region. Joanna started with the wrong answer and had written “guess,” for her initial explanation. In the post-test, she still had the wrong answer; however her explanation was accurate, “downhill from station B.” Consequently, she recognized that water flowing down from one source will contain more water, but she appeared to have misinterpreted what was downhill topographically on this map. Karen started with the wrong answer and explanation, “because the Rowe Wash had the highest amount of rainfall.” This was similar to Susan’s initial ideas that the wash was where water gathers for a flood. However, in the post-test, her answer was also incorrect, “the area with the most rainfall would logically have the highest rainfall.” This is circular logic as Karen appears to be equating runoff with rainfall. It appears that she has replaced one incorrect idea with another.

Another example of the differences between these participants and one that demonstrates resistance to change is question Q10. This item presented a series of images from Mars and required the teachers to select which image represented a river-based deposit. This was not explicitly taught, and only some of the participants interacted with the images due to their selection of self-designed inquiry projects in Lessons 3 and 4, one of whom was Karen. Karen started with the right answer, but in her explanation, she said “Guessed!” On the post-test, she shifted to an incorrect answer and still wrote “I guessed,” for her explanation. Of the three participants, she was the only one who selected the wrong answer on the post-test. Susan started with a partially correct explanation “because it appears there is significant erosion (possibly caused by water),” in which she hints toward a water-based erosional process. However, in the post-test her response was more succinct and accurate “because of the type of erosion pattern.” Joanna had the correct answer, but in the pre-test indicated “guess” for her explanation and in the post-test simply wrote a question mark.

An example in which the teachers incorporated academic language from the seminar, somewhat to their detriment, was in question Q11. Teachers were asked to identify a specific flooding pattern on a hydrograph. All three had the correct answer both pre- and post-activity. However, both Susan and Joanna started with a correct explanation (e.g., in the pre-test Joanna wrote "two peaks") and shifted to a partially correct answer, as both used the descriptor of the type of flood instead of simply describing the hydrograph. Susan wrote "because it shows two storm surges," and Joanna wrote "Shows 2 storm surges, but 1 with greater discharge." Both teachers demonstrated an application of academic terminology, albeit an inaccurate use of the term, and did not entirely answer the question. Storm surges are associated with coastal flooding events; this hydrograph was from a desert region indicating a flash flood. Karen started by employing circular reasoning in her pre-test answer, "[it] seemed logical," to an accurate response, "the graph shows two peaks, one larger than the other." Here she has learned how to describe the hydrograph, but may not have the same degree of comfort with applying the academic language. This became clearer in the last question, which was an open-ended question about two types of hydrographs. This item asked the teachers to describe the differences between the two floods based on the hydrograph data provided.

Karen's pre-test response was "I don't have any idea," and in her post-test proceeded to describe the hydrograph in painstaking detail, but ultimately said very little that indicated any real comprehension of content:

> Figure IX shows the amount of discharge in cubic feet on the Verde River near Scottsdale. It begins around 10 feet between 19:00 and 21:00 hours on July 31, 2007. It shows a sharp, sudden increase from July 31 at 23:00 hours and August 1st at 1:00 hours. The decrease it shows is fairly sudden also. Taking place from 1:00 to 5:00 hours and going to a low point of 500 cfs.

Joanna also showed a very low pre-test understanding of the content layered with low self-efficacy, when she stated, "I have no idea where to even begin," and yet in her post-test response (scoring a one out of four possible points) she attempted to incorporate the academic language into the response "[Second] shows a "live" river that has constant water flow. [First] shows a dry river that has a sudden increase in water (flash flood)." While the flash flood aspect did not improve her post-test score, it did accurately represent the type of flood that occurs in that particular hydrograph.

Susan started with a detailed Venn diagram explaining the differences and similarities between the two hydrographs of flood events in Arizona and Missouri. In her pre-test response, Susan provided the following:

> Verde River, Scottsdale, AZ
>
> This river is in the desert with land that doesn't readily absorb the water, much less discharge (1,000s'), Over 1 month data 2007 (drew a sketch of hydrograph, pointed to initial part of low cfs. and labeled it as drought, then labeled peak as "large storm hits," labeled back end of hydrograph as "storm has stopped and discharge subsides"), because it has happened in early August it is safe to assume this was a monsoon. Monsoons come from the south and usually happen fast.

> Mississippi River, St. Louis, MO
>
> This river is in an area more adapted to rainfall, and had river banks that are [used] to surges and flooding of the banks, much more discharge (100,000s'), over 4 months data 1993, continuous rainfall through the months (draws hydrograph, labels initial part, "a pretty good size of rainfall (consistent) in May," labels second half of hydrograph, "more storms in July/August"), rainfall here could also be swelling from other areas up the river.

In her post-test response Susan also drew a Venn diagram and wrote the following:

> Verde River, Scottsdale, AZ
>
> Desert, Flash flood, 1 day, discharge between 0 and 6000 cfs.
>
> Mississippi River, St. Louis, MO
>
> Wet area, Regional flood, 4 months, discharge between 300,000 and 1,100,000 cfs.

Below the Venn diagram, Susan wrote:

> The Verde river flood is a flash flood, and happens quickly over 1 day. The Mississippi river is a regional flood, happening over 4 months. The Mississippi river has a much more significant discharge.

Susan's score did not change from pre- to post-test; however, she did incorporate the terms "regional" and "flash floods" into the post-response. This indicated an accurate incorporation of academic language into her response that was not present in her pre-test. In fact, on the pre-test explanation of Q9, she stated "I don't know what a Regional Event is," but later she applied it accurately on the post-test for the final question. While application of these terms did not change Susan's score, it did indicate an increase in her academic language comprehension.

Sustained Lack of Understanding and Areas of Learning Gains

When participants were asked "What were the causes of flooding?," Susan had a detailed and accurate representation of one type of flooding. However, she also conveyed an erroneous idea about ground material, "When the land is too dry it will not soak up moisture as quickly as rain falls," and then later contradicted herself within the same passage by saying that "soils [*sic*] is too saturated to absorb any more water." She recognized that ground material plays a role, but was unclear how it specifically works. This also became clear in her Science Investigation Report (SIR), in which she described flooding to be less likely to occur when the ground is saturated. This may have been because Susan was focused on the amount of material transported rather than the amount of water transported at different intervals. In the post-lesson reflection of the flooding activity, Susan did not describe how she would change her answer; rather, she described the different types of floods that she had learned about. While her understanding of causes of floods did not seem to change, Susan's perspective on what constituted a flood had expanded.

Joanna initially described causes of floods as a general list of terms "Earthquakes, broken levees, rain, drought, [and] wet winters." She also stated an incorrect idea in that she regarded dry ground as a significant contributor to flooding. In the post-activity reflection Joanna offered "I feel like my response from yesterday was vague, yet correct." However, she did not go on to describe what had made her previous responses vague. In the SIR, this trend continued as she described the events that occurred, but offered very little in terms of interpreting events.

Karen focused on flooding events that could occur in the Phoenix, Arizona area by mentioning broken dams and flooding in the desert "In the desert area around Phoenix there isn't anywhere for water to go, so significant amounts of rain cause flooding." She did not make connections to the ground material; however, it is clear that Karen recognized a difference in Phoenix relative to other regions. In the post-activity reflection, she admitted that "The causes are not as clear to me as I'd like, but the varieties are clear." Consequently, Karen learned more about new types of flooding but was still trying to connect the relationship of the factual information to the larger concept of flooding.

Discussion

Pre–Post Test Results

A summary of each question item using the elementary teachers' learning gains is presented in Table A-1 in the Appendix using the coding matrices. The pre- and posttest scores were used to determine learning gains along a spectrum of no knowledge to a normative scientific view. We then interpreted these learning gains using the primary data analysis to synthesize and categorize teachers' performance. By examining the teachers' prior knowledge and their gains on the flooding assessment, we found that the teachers' results were clustered in 7 of the 16 potential categories of learning (Table 9). Seven (41.2%) of the teachers achieved a normative view of flooding concepts from a strong prior knowledge base. One teacher also achieved a normative view from partial prior knowledge. Another teacher, while she did not obtain it, did make a considerable shift toward a normative view from partial prior knowledge. Two other teachers (11.7%) also made considerable 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 and three (17.6%) with weak prior knowledge, showed no change. For the teacher, who already knew a great deal about flooding, there was little room for improvement at this introductory level of flooding concepts. For two of the three teachers with little prior knowledge, neither teacher answered the Tier 2 test questions; consequently the measure of their improvement was limited to their multiple-choice scores. Overall, it appeared that having stronger prior knowledge before starting the unit 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. Length of teaching experience did not appear to directly affect teacher learning.

In reviewing the degree of teachers' use of SRL as it related to learning gains, we found that 9 of 11 (82%) teachers who achieved a normative view of flooding demon-

Table 9. Summary of teachers within specific learning profiles

Change profile	# of teachers	Percent
Normative view achieved from strong prior knowledge base	7	41.2
Normative view achieved from partial prior knowledge base	1	6
Considerable shift toward normative view from partial prior knowledge base	1	6
Considerable shift toward normative view from weak prior knowledge base	2	11.7
Some positive shift from partial prior knowledge base	2	11.7
Little to no shift from strong prior knowledge base	1	6
Little to no shift from weak prior knowledge base	3	17.6

strated a higher degree of SRL. This further underscores the importance of employing self-regulatory learning strategies in PD activities to help participants learn content.

Challenges in Learning about Flooding and Related Earth Science Concepts

Skill challenges. From the pre- to post-test, the most frequent persistent errors concerned a difficulty in reading an aerial photo of channels and river systems, specifically being able to interpret the sun's angle and resulting shadows, and graph interpretation, comparing different axis scales and interpretation. This persistence suggests the lack of direct experience with these skills. Graph reading skills were necessary to understand the case study lesson, and the low scores were probably due to the lack of direct instruction provided or assessment of the teachers' skill level in these discrete areas.

The analysis question (Q8) that was the most difficult on the pre-test and resulted in the least improvement in understanding required greater depth of knowledge to accurately identify the runoff patterns and the resultant flooding processes. 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 correct, however, she selected the wrong location, resulting in a misinterpretation of the map itself and how rivers flow. These map reading skills are aspects of the content that could be inferred during the PD activities but were not explicitly taught.

Lastly, some of the responses, while not indicating a considerable change in understanding by the standards established in this paper, still indicate a partially correct understanding. For example, on item Q10, one teacher (S10) answered, "[this] looks like rivers where 'A' looks like land," on the pre-test, which was the correct explanation. On the post-test, her 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 activity of rivers on Mars. The vagueness of the response could indicate that the teacher's understanding decreased or that she was simply less explicit on the post-test.

Terminology challenges. The highest frequency of confusion and the greatest amount of learning gains occurred as teachers attempted to add new academic language to their prior understandings. There were times when teachers used terms out of the accurate context in a type of hybrid comprehension. Teachers equated discharge with rainfall on the post-test when most were previously unfamiliar with the term discharge. Teachers increased their use of, but more frequently misused, the term "storm surge" to describe a general event rather than using it appropriately. Teachers demonstrated the greatest improvement on Questions 3, 4, and 9, all of which required term recall. However, it is unknown how long terms will be remembered after the seminar because of the low cognitive demand of term recall. Before we began Lesson 2, we developed a word wall with the teachers to support their development of academic language and increase term recall. The word wall vocabulary provided the words needed to read the primary literature in the geoscience research of the case studies in Lesson 1. Words like paleoflood and isohyetal became a part of teachers' working language before they engaged in activities that used such terms.

Another example, on the pre-test for question Q12, one teacher (S23) wrote, "I seriously don't know." Whereas, in the post-test, this same 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 shifted from having no idea to engaging with the academic language and scientific ideas from the seminar, which hints at a greater awareness, if not a normative view, of flooding. This represents a partial change in understanding but not in a way that changes the score on the post-test result. Without interviews, it is impossible to know exactly how much of a change in her ideas has occurred since the post-test response is still too vague to accurately answer the question.

Challenges related to lack of background knowledge. The most common misconceptions that led to evidence of teachers' normative understanding were the probability of flooding and the role of ground conditions in flooding events. Both topics were specifically addressed with PD activities that required teachers to process data and consider how these variables affected their interpretation of a potential flood zone. The probability of flooding was one that was particularly well-illustrated since the seminar occurred at the same time as major flooding in the Midwestern region of the USA. An incorrect idea that emerged frequently in the pre-activity written prompt responses concerned ground saturation. Both over- and under-saturated ground were identified as causes of flooding. Many teachers identified excessively dry land as a cause of flooding. In the post-test, 12 teachers went into more detail than was required of the two-tier response on question Q6 that highlighted the comprehension change and use of academic language to support their understanding. For example, in the pre-test Joanna responded "guess," but in the post-test, she responded, "if absorption goes down that leaves more water to stay above ground." As a result her score went from zero to full credit. Susan initially responded "Because the more building, the more run off issues," and in her post-response she replied, "The concrete does not absorb the water and therefore increases run off." In this case, Susan's initial response is worth full credit; however, the detail she provides in her post-test response is more insightful as to the cause of localized flooding due to runoff. However, other teachers appeared to continue to confuse ground material with saturation levels. In the final open-ended question Q12, three teachers mentioned dry ground or a dry wash as a factor in the type of flooding. For example, Joanna's post-test response was "[Second] shows a 'live' river that has constant water flow. [First] shows a dry river that has a sudden increase in water (flash flood)." It is unclear from her response if she considers the dry riverbed to be a factor in defining the event as a flash flood or not.

Supports for learning. These data indicate that improved understanding was facilitated by some prior knowledge of flooding. Additionally, the data suggest that it is essential for teachers, and PD providers, to spend time building background knowledge with students before starting a unit of a study.

Self-regulation of Learning

Teachers, who possessed stronger prior knowledge at the beginning of the PD, were more likely to achieve a normative view than those with weaker prior knowledge. In addition, those who were more reflective and had more insights into how they as individuals learn were more likely to be successful in retaining information (Weinstein et al., 2000). Teacher reflections indicated that there were different levels of self-awareness (i.e., executive control) of their own learning process.

Table 10 indicates the relationship between the different factors that may have influenced a teacher's degree of improved understanding. While it is clear that prior knowledge plays an important role, there also appears to be a correlation between the degree of SRL and normative view acquisition. There appeared to be no relationship between previous science courses taken and concept acquisition for the teachers at this seminar.

In the reflection prompt asking participants to reflect on which posters they found most helpful, Susan assimilated what she saw from another group's presentation to how she as an individual could better learn the content. Joanna focused more on what she needed to make better for the future in a more general manner. Unfortunately, Karen was not present on the day of this reflection, so there is no basis for comparison. However, more importantly, her absence also meant that she did not have the opportunity to reflect on her learning, which may ultimately have been an important factor in her lack of learning gains.

Table 10. Selected examples of comparison of prior knowledge, change, past exposure to science content, years of teaching experience and level of self-regulation

Teacher code ID	Prior knowledge	Change	ES classes	Other science classes	# of reflective SRL prompts	% of max number of prompts (9)	Change – science background–SRL relationship
S03	Strong	Normative	3	5	9	100	Achieved a normative view from a strong prior knowledge base, many science courses, and high degree of SRL.
S04	Partial	Normative	1	0	8	89	Achieved a normative view from a partial prior knowledge base, few science courses, and high degree of SRL.
S22	Strong	Normative	0	2	9	100	Achieved a normative view from a strong prior knowledge base, few science courses, and high degree of SRL.
S11	Partial	Some positive shift	0	1	3	33	Some positive shift toward normative view from a partial prior knowledge base, few science courses, and low degree of SRL.
S21	Weak	Little to no shift	1	0	2	22	Little to no shift toward normative view from a weak prior knowledge base, few science courses, and low degree of SRL.
S24	Weak	Little to no shift	0	0	3	33	Little to no shift toward normative view from a weak prior knowledge base, no science courses, and low degree of SRL.

Amount of reflective or partially reflective responses: 66–100% = high SRL, 33–66% = moderate SRL, < 33% = low SRL.

In the second reflective prompt about their learning process, "Were the poster session and the SIR helpful with your overall content comprehension?" we gained more insight into each participant's learning process. As Susan described, "I think that the SIR really held me accountable individually and made me apply the information gathered in the lab. The poster session was semi-helpful. It provided different perspectives but was difficult to maintain focus." Here, Susan pinpointed what helped her to learn and how it did so, as well as how it prevented learning. Joanna replied, "The poster session was helpful, however the SIR seemed to confuse me some because it is new." Here she mentioned that the poster session was helpful but did not specify why or how. On the other hand, it is clear that not only is she learning new content, but that the methods used were new to her, which is why it is important to reinforce new approaches to learning with students because operational cognitive processing can sometimes impede content comprehension (Mayer & Moreno, 2003).

Karen also provided a vague description of what was helpful, "The poster session was helpful and the carousel format is something I plan to do with my students. At first I didn't think the SIR helped with content comprehension but after writing I see that it does help." Here, she indicated that she was surprised that she learned from her writing process. This realization may indicate that she lacked some knowledge of what strategies are most effective for her own learning. If she is still developing her own skill set, this may limit her ability to act as a SRL model for her own students.

Research and Professional Development Implications

The added benefit of the two-tier test design was that it revealed teachers' reasons for their choices, degree of understanding of the science concepts, and better informed the instructors and PD program as to the effectiveness of the instruction and how to modify lessons for future use. Teachers demonstrated considerable growth in their understanding of flooding concepts through scaffolded inquiry lessons during CISIP PD. However, most teachers' understanding of flooding remained in a partial comprehension stage by the end of the seminar. Teachers who began the PD seminar with greater prior knowledge demonstrated more complete change toward a normative view of flooding. While delayed post-testing after the PD would establish the robustness of the change, regardless, this speaks to the importance of building teachers' background knowledge before initiating PD with complex science concepts. This may be especially important when the PD introduces new instructional practices at the same time as content is introduced. Elementary teachers, who often have weak prior scientific knowledge in particular, may need iterative PD to achieve normative scientific views.

Within the course of this research, there were some ideas that appeared to indicate possible misconceptions, for example, teacher understanding about infiltration rates as it pertains to ground material. The degree to which we had access to teachers' thoughts was limited. As a result, the theoretical framework and associated claims we can make about misconceptions and conceptual change are limited at this time.

However, we would strongly recommend future research in this important area of natural disasters to add to the literature on formal misconceptions in the geosciences.

Lessons Learned

From our experiences, teaching and observing the PD flooding lessons with these 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 undertaken to build teachers' background and skill level before engaging in flooding activities that require these skills. The pre– post assessment instrument of the flooding science content should include a new item to specifically address the concept of ground saturation levels. Additionally, some of the two-tier questions that were basic fact-recall items did not take full advantage of the two-tier test format and should be revised to test higher levels of application and comprehension. Teachers clearly understood from the PD activities that ground material plays a more significant role in flooding, rather than the role of ground saturation in flooding. These ideas should be addressed more specifically in the future.

Conclusion

In geoscience education research, we need to expand our understanding of how people's lack of understanding of specific concepts affects their larger understanding of their natural environment and their daily lives. As elementary teachers, these study participants demonstrated a range of understanding about flooding, but through carefully constructed PD most teachers were able to improve their understanding of the science content under study. The explicit modeling and participation in inquiry-based science activities, as well as teachers' written responses to SRL prompts supported their concurrent learning of the science content. Providing PD that allows teachers to employ SRL strategies may be a productive facet of such programs.

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Appendix

Table A-1. Summary of frequencies of learning categories by question item n = 17 matched pre- and post-tests)

Change	Two-tier response	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12
Most consistent and correct, highest prior knowledge, no 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; 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, 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 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 change. (8)	Pre-test incorrect choice and incorrect justification to post-test correct choice and incorrect justification		1	4	2	2	1			4	1		

Continued

Table A-1. (*continued*)

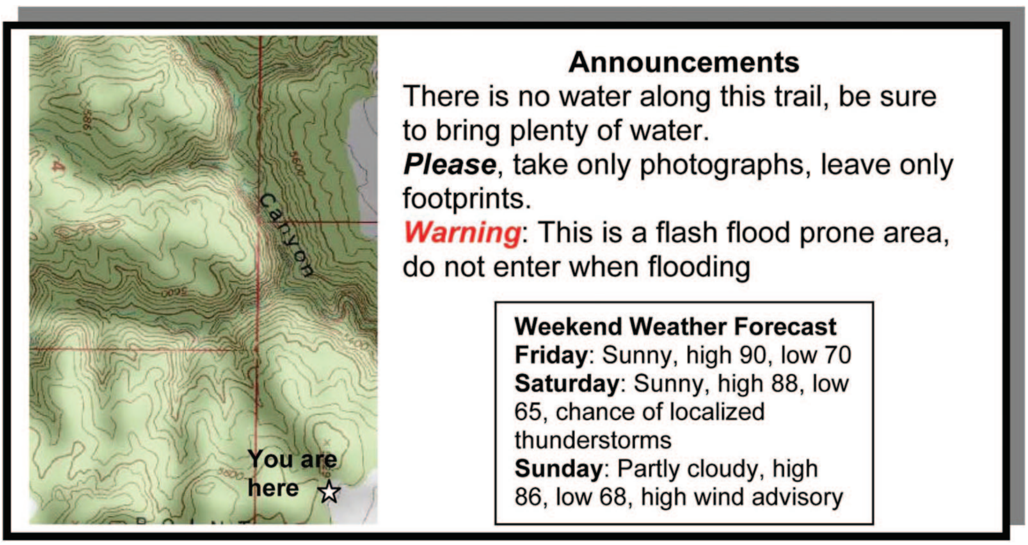
Change	Two-tier response	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12
Partial confusion, move from completely correct to partially correct. (9)	Pre-test correct choice and correct explanation to post-test incorrect choice and correct explanation	1									1		
Partial assimilation of new information into prior 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 change. (12)	Pre-test incorrect choice and incorrect explanation to post-test incorrect choice and correct explanation	1							3	1			2
Greatest negative 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 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 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

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:



1. Looking at the map, what kind of terrain might you expect for this region?

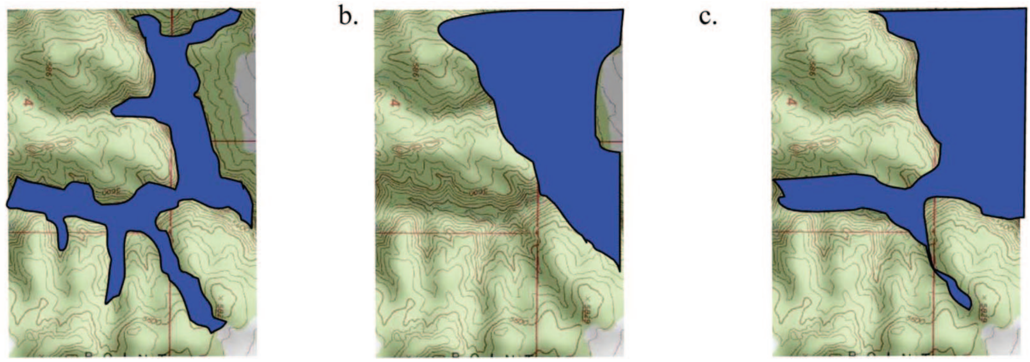
    a. Steep, continuous hill to a plateau.
    b. Narrow, steeply sloped walls.
    c. Wide open spaces along a dry wash.
    d. I don't know, I can't read maps

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?

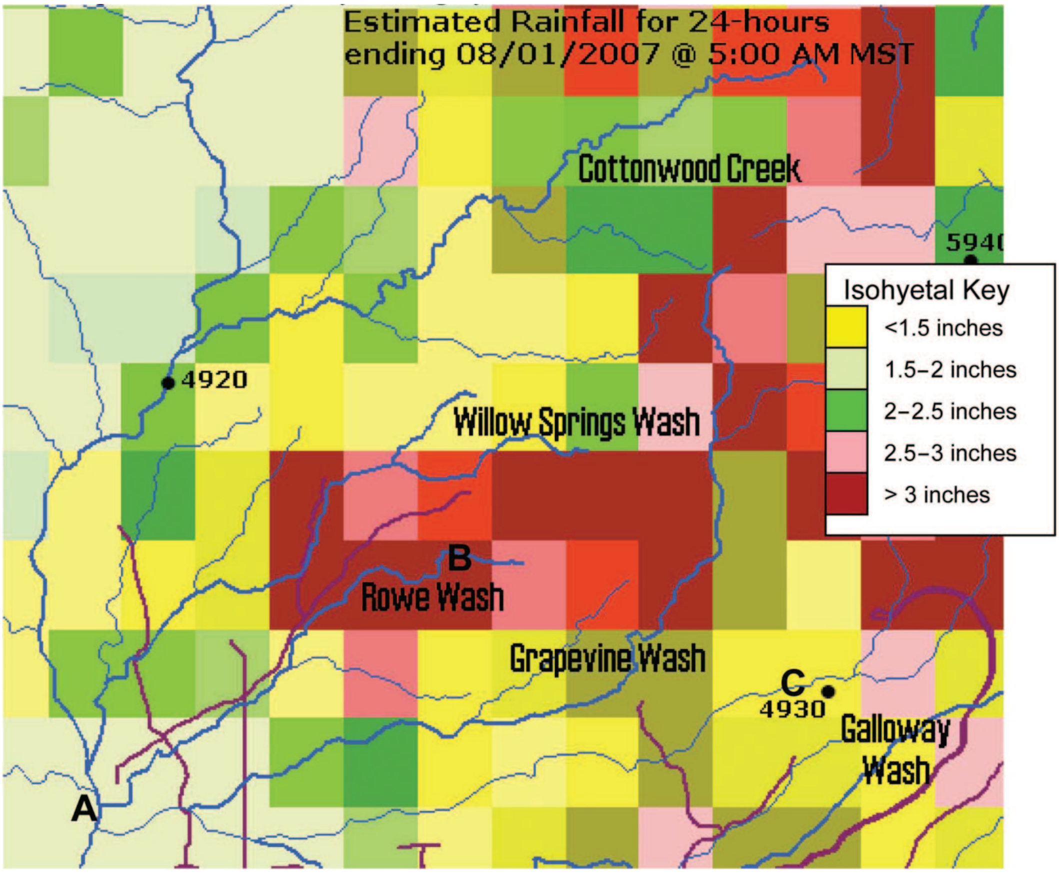
   a. Paleofloods show that flooding has occurred and therefore could occur in the same area.
   b. A paleoflood indicates areas that this area once flooded but is no longer susceptible to flooding.
   c. Paleofloods imply nothing about future or past flooding events.

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. 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.



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?

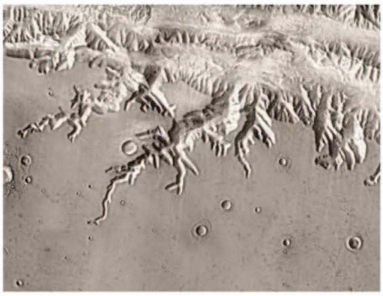
a. Station A
b. Station B
c. Station C

9. What kind of storm tracking could **not** be represented by this map?

a. Flash Flooding
b. Regional Event
c. Storm Surge

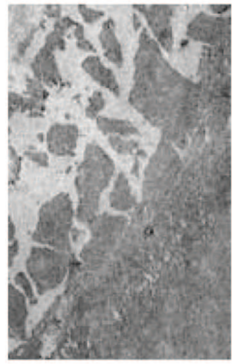
10. The year is 2064, and you are selected to be one of the people to head to Mars. If you were to look out over the planet as you came in for a landing, which area would you most likely expect to see river deposits?

a.



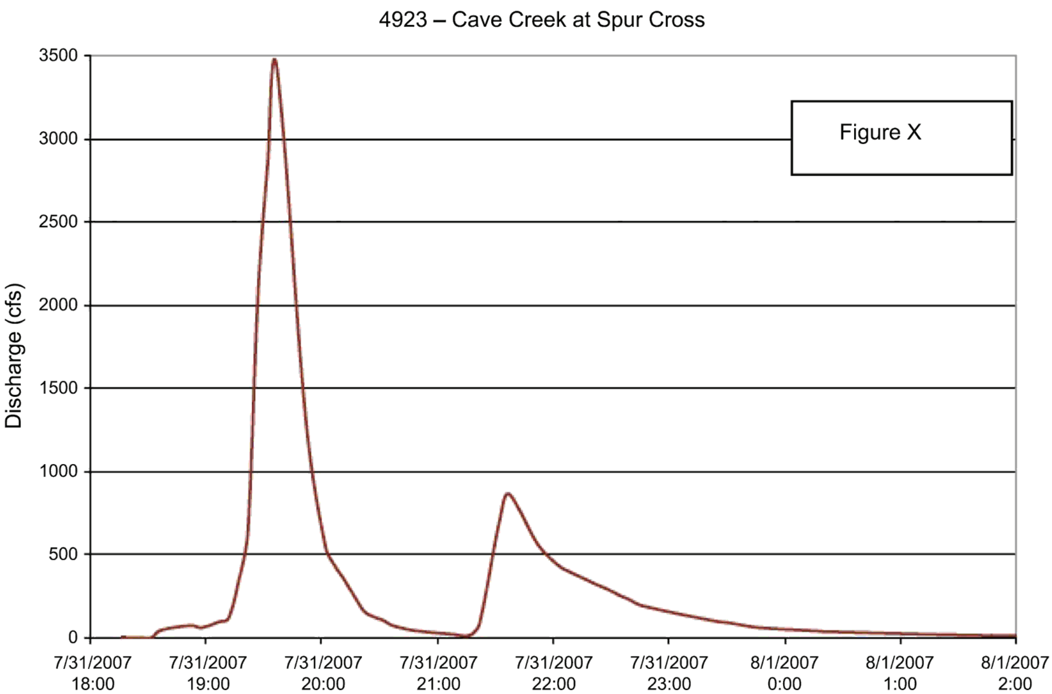
b.

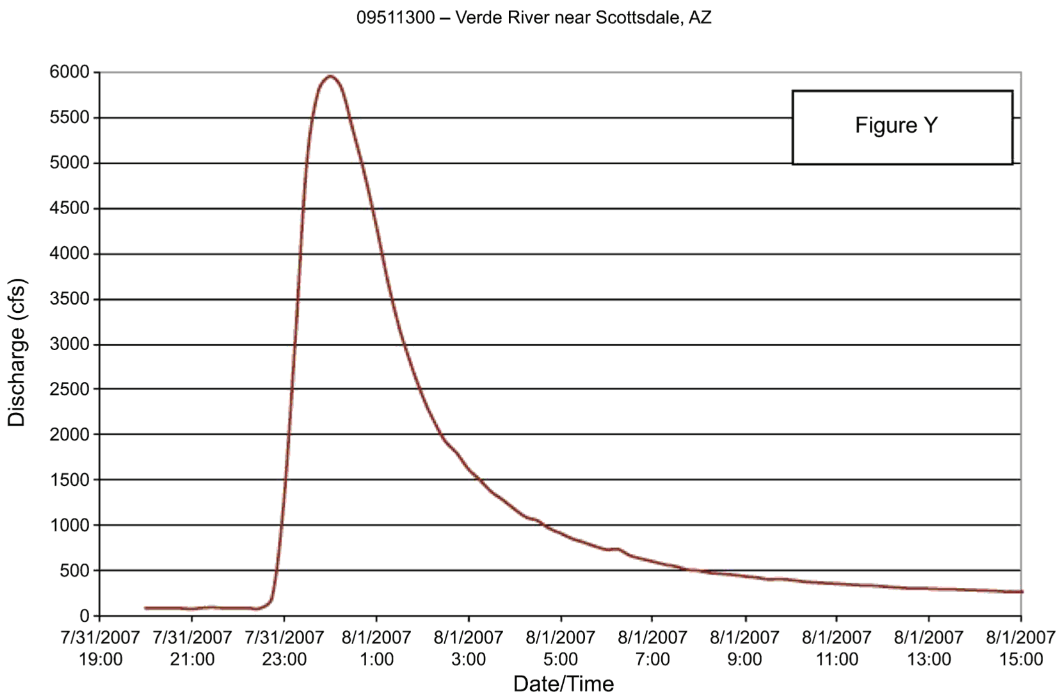
c.

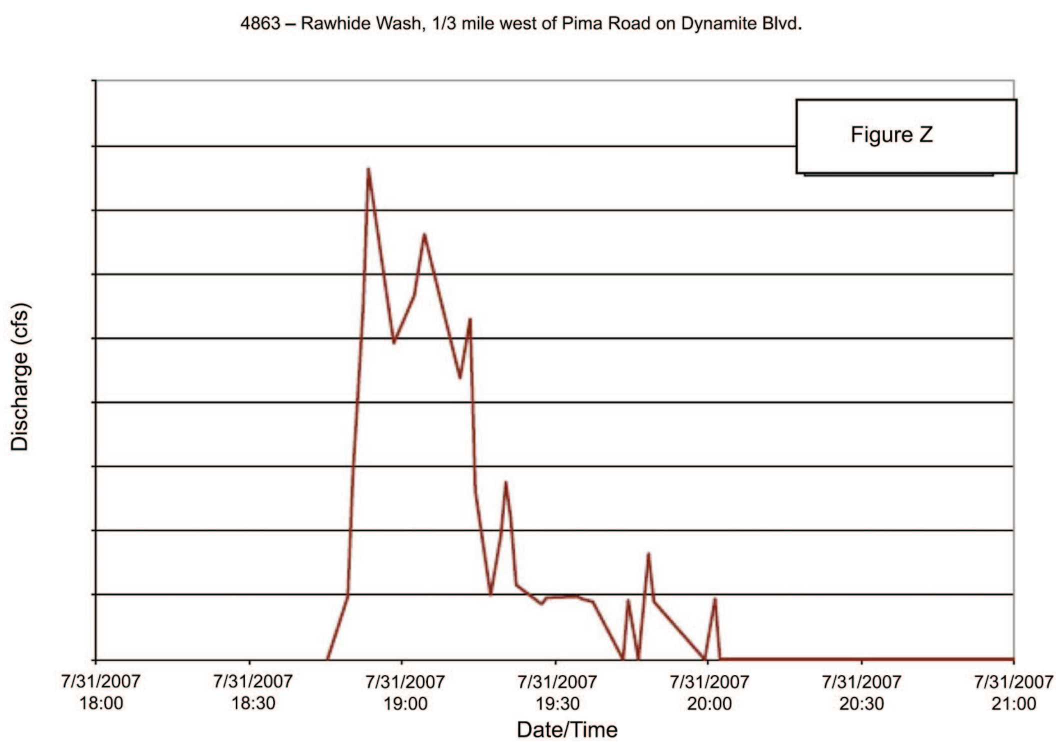


11. A summer storm hits in Maricopa County, which of the following hydrographs best describes the following scenario? A thunderstorm has a very rapid release of precipitation which causes the stream to rapidly increase discharge. The discharge lessens as the storm subsides, and resurges as a second storm 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)
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.