College Students' Conceptions of the Role of Rivers in Canyon Formation

Julie M. Sexton[1,a]

ABSTRACT

Rivers are important surficial geologic processes that shape Earth's landscape. Students' conceptions of river features and processes serve as a foundation for their learning of new river concepts. Despite the importance of rivers and students' conceptions of them, little research has focused on identifying students' river conceptions. This study investigated students' conceptions of the role of river processes in canyon formation. In-depth interviews with 18 college students were conducted, and students' responses were analyzed using a modified version of constant comparative analysis. Students' conceptions fell into three categories: incomplete scientific conceptions, alternative conceptions, and incomplete scientific–alternative conceptions. Students with incomplete scientific conceptions thought that rivers carved canyons and did not recognize the connection between surficial processes and base level changes in forming a canyon. Students with alternative conceptions thought that catastrophic processes such as earthquakes form canyons or that canyons do not undergo a formation process at all (i.e., they have always been there). Students with incomplete scientific–alternative conceptions thought that catastrophic processes initiated canyon formation (similar to those students who held alternative conceptions) but also thought that rivers contributed to the process of canyon formation (similar to those students who held incomplete scientific conceptions). These findings add to the growing knowledge base of geoscience conceptions and have implications for improving geoscience teaching strategies. © *2012 National Association of Geoscience Teachers*. [DOI: 10.5408/11-249.1]

Key words: conception, college student, river, stream, surficial process, geomorphology, qualitative research

INTRODUCTION

Research during the past 35 y has demonstrated that students bring their own ideas, or conceptions, of the natural world to the science classroom and use them to organize, interpret, and learn new science topics (Driver et al., 1994; Wandersee et al., 1994; Bransford et al., 2000; Scott et al., 2007). Students' conceptions that agree with accepted scientific explanations are called *scientific conceptions*. Students' conceptions that differ from accepted scientific explanations are called *alternative conceptions* (Hewson and Hewson, 1983, p. 732). When educators know students' conceptions, they can design curricula and classroom instruction that will best modify alternative conceptions and strengthen scientific conceptions (Driver and Oldham, 1986; Wandersee et al., 1994; Vosniadou and Ioannides, 1998).

Most of the research on students' conceptions has been in the field of physics, so an extensive research base on students' physics conceptions now exists (Wandersee et al., 1994; Libarkin and Kurdziel, 2001; Duit, 2004; Duit et al., 2007). In a review of the literature, Libarkin and Kurdziel (2001) concluded that during the 1970s, 1980s, and early 1990s, few studies investigated students' conceptions of geoscience topics. In the past 25 y, the number of published studies to uncover students' conceptions of geology topics has been growing, but there is still a significant lack of understanding in this area (Dove, 1998; Libarkin and Kurdziel, 2001; King, 2008; Cheek, 2010). This study helps to fill this gap by exploring students' conceptions of a geoscience concept, specifically, the role of rivers in canyon formation.

The National Science Education Standards recommends that students understand the water cycle, the role of rivers in that cycle, and the role of surficial processes in forming and destroying landforms (National Research Council, 1996). The Earth Science Literacy Initiative developed a set of ideas that Americans should know about the geosciences (Wysession, 2009). In that set of ideas, the Earth Science Literacy Initiative suggests that Americans should understand river processes and the formation of landscape features. In addition to learning about rivers at the kindergarten to 12th grade (K-12) education levels, college-level, introductory geology classes should also educate students about river features and processes (Kelso et al., 2000; Englebrecht et al., 2005). Despite the recommendations that K-12 students, the general public, and college students should understand river features and processes, little research has investigated what students' conceptions of river features and processes are. This study, as part of a larger initiative, aimed at identifying students' conceptions of river processes. The larger study investigated students' conceptions of river features (e.g., the origin of water in a river and the destination of rivers) and processes (e.g., how rivers form) (the larger study is described in Sexton, 2008). The specific focus of this study was students' conceptions of the role of rivers in canyon formation.

Received 23 June 2011; revised 12 January 2012; accepted 23 January 2012; published online 13 June 2012.

[1]Mathematics and Science Teaching Institute, University of Northern Colorado, 501 20th Street, Box 123, Greeley, Colorado 80639, USA
[a]Author to whom correspondence should be addressed. Electronic mail: Julie.sexton@unco.edu. Tel.: 970-351-2196. Fax: 970-351-1269.

LITERATURE REVIEW

Several studies have investigated students' conceptions of geological processes, including earthquakes (Ross and Shuell, 1993), plate tectonics (Gobert, 2000; Sibley, 2005), and the rock cycle (Stofflett, 1994). In reviews of the geoscience conceptions literature, Cheek (2010) and Dove (1998) found, collectively, about 12 studies that have focused on surficial geological processes. Studies that investigated surficial processes covered a range of processes, including weathering and erosion (Dove, 1997), the water cycle (Bar, 1989; Ben-zvi-Assarf and Orion, 2005), and glacial activity (Happs, 1982).

Previous research on students' conceptions of rivers has focused primarily on 9- to 12-y-old students' conceptions of river features (Sexton, 2008). Three studies described in four articles have investigated students' conceptions of river processes, specifically the formation of rivers: Piaget (1929), May (1996), Cin and Yazici (2002), and Mackintosh (2005). The studies focused on the conceptions held by elementary and middle-school students. The researchers found three general explanations for the formation of rivers and their channels: students did not know how rivers formed, students thought that there were artificial origins to river channels, and students thought that there were natural origins to the formation of the river.

Students described three artificial origins for rivers (Table I). First, some students said that humans created rivers but did not give a specific method by which the humans did so (Piaget, 1929; May, 1996; Cin and Yazici, 2002; Mackintosh, 2005). For example, when asked how a river channel formed, a student said that "some man made it" (Piaget, 1929, p. 327). Second, students thought that humans created the river by digging the channel (Piaget, 1929; May, 1996; Mackintosh, 2005). For example, one student said that the river was dug out using a "mechanical digger" like a backhoe (May, 1996, p. 13). The final artificial origin was that God created rivers (Cin and Yazici, 2002).

Students described several natural origins that they thought created rivers (Table I). Piaget (1929) found that, after age 9 or 10 y, students thought that natural processes created rivers, and he gave one example. One student said that stones rolling along created the river channel. Piaget did not explain this comment, so it is unclear if the student thought that sediment was eroded by river water, thus creating the river channel, or if there was some other meaning. Students in the May (1996) and Mackintosh (2005) studies thought that water "rubbed" the land to create the river channel (May, 1996, p. 13). Other students thought that because the river itself was heavy, it sunk into the earth and created a river channel. The researchers did not analyze what the students meant by these comments. Cin and Yazici (2002) reported that students attributed river formation to natural processes, but they did not list the specific processes.

Students' conceptions about how rivers form are generally incomplete or alternative (Table I). *Incomplete conceptions* are those that are scientifically correct but are missing important components (Harwood and Jackson, 1993). For example, students' conceptions that water rubbed or broke away the land to create a river is an incomplete conception. Students' conceptions that God created a river or that a heavy river sinks into the land and creates a river are alternative conceptions.

This study was conducted to extend the research of K-12 students' conceptions of river processes to college-level students. The questions investigated in this study were What are college students' conceptions of river processes and the role of those processes in landscape evolution, specifically in canyon formation? Which of those conceptions are scientific conceptions and which are alternative conceptions?

METHODS

A basic interpretive qualitative research (BIQR) design was used to address the research questions. The purpose of BIQR is to uncover and interpret the meanings that individuals construct (Merriam, 2002). Students construct conceptions through formal and informal educational experiences, through engagement with the natural world, and through social interactions (Scott et al., 2007). The in-depth data collection and analysis in qualitative designs were the best methods for uncovering individuals' meanings (Crotty, 1998; Merriam, 2002).

Participants

Student participants were recruited from an introductory geology class taught in Spring 2005 and Fall 2005 at a large U.S. research university in Colorado. Students were recruited during two different semesters for the purpose of the larger study. The particular class was selected because the instructor of the class taught a unit on river features and processes. Other introductory geology courses at that university and other prospective universities did not teach river features and processes in introductory geology classes. I, therefore, selected this particular course because it allowed the opportunity for future research to investigate students'

TABLE I: Elementary and middle-school students' conceptions of the formation of rivers.

Conception Origin	Study Source
Artificial origin	
• Nonspecific human activity made the river	Piaget (1929), May (1996), Cin and Yazici (2002), Mackintosh (2005)
• Humans create rivers by digging using non-specific methods, using pickaxes, or using "mechanical diggers"	Piaget (1929), May (1996), Mackintosh (2005)
• God formed the river	Cin and Yazici (2002)
Natural Origin	
• "Stones rolling along, hollow it [the river] out"	Piaget (1929)
• Water rubbed or broke away land	May (1996), Mackintosh (2005)
• "The river is heavy so it sunk in"	May (1996), Mackintosh (2005)
• Nonspecific natural processes created the river	Piaget (1929), Cin and Yazici (2002)

TABLE II: Participant demographic characteristics.

Characteristic	*n*
Gender	
Men	9
Women	9
Ethnicity	
White	15
Hispanic	3
Age	
18–22 y old	14
>22 y old	4
College major	
Science	2
Nonscience	13
Undecided or no answer	3

preinstruction and postinstruction understanding of river features and processes.

About 350 students were enrolled in the course during the Spring, and about 350 students were enrolled in the Fall. All students received the study recruitment statement verbally and via electronic communication. In a pilot study, no incentive was offered in a similar class, and only 1 student volunteered. Therefore, students were offered extra credit in the course for their participation in the study. Twenty-four students volunteered for the larger study. Eighteen of the 24 students were interviewed for this smaller study investigating students' conceptions of the role of rivers in canyon formation. Students were recruited at the beginning of the semester class and were interviewed partway through the semester before they studied rivers in class. Table II summarizes the demographic characteristics of the 18 students interviewed for this study. Demographic data were not collected from the entire 350 students enrolled in the class; therefore, it is not possible to determine how the demographic characteristics of the sample in the study relate to the demographic characteristics of all of the students in the class.

Data Collection

Interviews were conducted to explore students' conceptions. The interviews were open-ended, semistructured, and lasted 15–20 min (the interviews were part of a larger study, with the entire interview lasting 40–60 min). Following the interview methods described by conceptions researchers (e.g., see Bell and Osborne, 1981; Posner and Gertzog, 1982; Brody, 1996), lead-in questions were followed by probe questions that explored students' responses to the lead-in questions. The specific scenario of the role a river plays in forming a solid rock canyon was selected because it allowed investigation of students' understanding of river processes (e.g., erosion and deposition) and their understanding of the role of rivers in landscape formation, specifically a canyon. During the interview, the student was shown a picture of a solid-rock canyon about 450 m deep with a river flowing at its bottom. Students were not told which canyon they were shown or where the canyon was located. The interviewer asked the student how the canyon formed. Probe questions were asked to explore the student's specific response. If the student did not initially describe a river as having a role in forming the canyon, then, after exploring the student's initial response, the student was specifically asked what role the river may have had in the formation of the canyon. An example of the interview protocol is provided in Table III. At the end of the interview, participants completed a questionnaire about their demographic characteristics. The interviews were audiotaped, videotaped, and transcribed verbatim. The videotapes of the interviews were reviewed during analysis for clarification purposes because, in some instances, the participant pointed to a feature in the picture or emphasized their verbal explanation with hand gestures.

Pilot Study

A pilot study was conducted to test the appropriateness of the interview protocol for soliciting students' conceptions of the role of rivers in canyon formation, to test the clarity of the questions, and to determine how long the interviews should last. After the initial interview protocol was developed, five experts—a conception interview expert, a geoscience conceptions expert, and three geoscientists—evaluated the questions. Five of the experts had a PhD and one had an MS in the field of expertise related to this study. The conceptions interview and geoscience conceptions experts evaluated the questions to verify they were appropriate interview questions to elicit responses about students' conceptions. The geoscience conceptions expert and geoscientists evaluated the questions to ensure that the questions adequately probed the river topics. All five experts also evaluated the question order and the clarity of the question wording. Minor changes were made to the questions based on the experts' input. After evaluation by the experts, the interview protocol was piloted with three students who had similar demographic characteristics as those students in the main study. The interview question wording was slightly modified based on the pilot interviews.

Data Analysis

The two research questions guided data analysis. The analysis focused on identifying students' conceptions of the role of rivers in canyon formation and categorizing those conceptions into conception categories (e.g., scientific conceptions and alternative conceptions). The interview data were analyzed using a modified version of constant

TABLE III: Example of interview protocol.

Lead-In Questions
a. Show participant the picture of a canyon and ask: Describe the picture.
b. How did the canyon form?
Follow-Up Questions (Select questions based on how participant responds to main questions)
a. Did the canyon always look like this?
b. How did it look before?
c. Why does it look different now; what happened?
d. Was the canyon always there?
e. What did it look like before the canyon was there?
f. How long did it take the canyon to form?

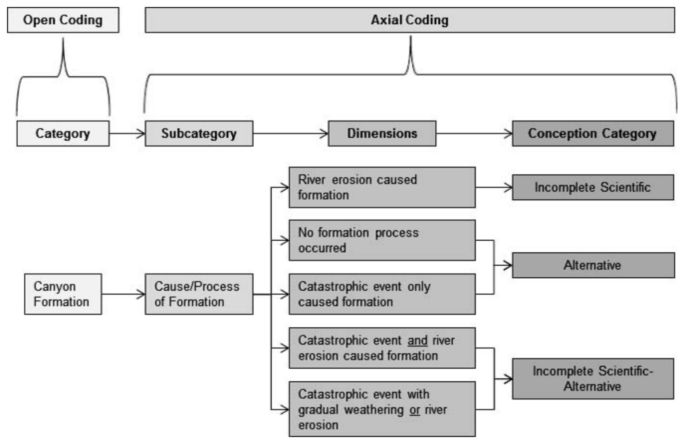

FIGURE 1: Example of coding process. During *open coding*, initial categories (e.g., "canyon formation") were developed. During *axial coding*, subcategories of "canyon formation" were developed. Also, the dimensions of the subcategories were delineated. The delineation of the dimensions allowed for coding students' conceptions into conception categories.

comparative analysis (Strauss and Corbin, 1998). Constant comparative analysis has three levels of coding: open, axial, and selective. During selective coding, a researcher develops a theory associated with the study; because theory development was not a goal of this study, only open and axial coding were used.

In open coding, students' conceptions were coded into general categories, which are phrases, sentences, or paragraphs that express discrete conceptions (Strauss and Corbin, 1998). As additional data were analyzed with each new transcript, they were compared with existing categories. Categories were added or refined to accommodate the new data. Through the process of axial coding, there was an ongoing comparison and revision of the categories created during open coding. In axial coding, subcategory dimensions were delineated. Dimensions describe the range of data along which the subtopics vary (Strauss and Corbin, 1998). The final analysis step was to classify students' responses into conception categories (Fig. 1). This was done by evaluating the range of responses making up the dimensions and developing criteria to place the range of responses into the conception categories. Figure 1 shows an example of the coding process.

Responses that were the same as the scientific explanation were coded as scientific conceptions (Table IV). The scientific explanation for the formation of canyons like the one shown to students includes river processes and base level change occurring over time. A river forms a canyon through solid rock where no canyon had previously existed in response to base level changes caused by tectonic activity or sea-level change. In response to a lowering of base level, river erosion increases. River erosion is the primary river process to form the solid rock canyons like the one in the picture shown to students during the interview. Weathering and mass wasting are also involved in the canyon formation process, but river erosion is the key surficial process.

Responses that were the same as the scientific explanation, but that were lacking key information, were categorized as *incomplete scientific conceptions*. Responses that differed from the accepted scientific explanation were categorized as *alternative conceptions*. Responses that blended the incomplete scientific explanation and an alternative explanation were categorized as *incomplete scientific–alternative conceptions* (Fig. 1 and Table IV).

Trustworthiness and Researcher's Perspective

Several strategies were used in this study to ensure trustworthiness (Creswell, 1998; Merriam, 2002). Experts conducted a peer review of the data collection and analysis processes as well as the findings (Lincoln and Guba, 1985; Merriam, 2002; Ary et al., 2009). During the peer review, six reviewers determined and confirmed that, given the methods and evidence, the findings are appropriate and sound. A person conducting a peer review of qualitative research can be a peer if he or she is not junior or senior to the researcher (e.g., in the case of this study, a peer would have been a doctoral student) (Lincoln and Guba, 1985), an expert in the methodology (Merriam, 2002), an expert in the topic of study (Merriam, 2002), a colleague not familiar with the method or topic (Merriam, 2002), and/or a committee member on a dissertation committee (Merriam, 2002). Four of the peer reviewers were dissertation committee members, one was a doctoral student, and one was a science education research professor not on the committee.

In describing the methodology and findings, thick descriptions were used. Thick descriptions include a description of the research context and demographic characteristics of the participants to allow readers to determine the transferability of the study findings to their own context (Lincoln and Guba, 1985; Merriam, 2002; Ponterotto, 2006; Ponterotto and Grieger, 2007; Ary et al., 2009). Descriptions of the study participants and context were provided to aid with transferability (Ary et al., 2009). Thick descriptions also include use of long interview quotes to support results and interpretation of the data (Ponterotto, 2006; Ponterotto and Grieger, 2007).

The final strategy used to ensure trustworthiness was to provide a description of the researcher's perspective. Qualitative researchers serve as the instrument of data collection and analysis; therefore, it is important for a researcher to report personal, academic, and professional characteristics that are related to the study (Lincoln and Guba, 1985; Patton, 2002). I have several academic and professional characteristics that are relevant to this study. I have undergraduate and graduate degrees in geology and have conducted research in fluvial geomorphology. I have a PhD in geoscience education and have conducted education research to identify students' conceptions of geoscience topics. Influenced by constructionism and interpretivism, I believe that individuals construct knowledge through social interactions and through direct interactions with the natural world (Crotty, 1998). I am aware that students were constructing knowledge during the interviews in this study. As such, I understand that the interactions in the interviews influenced and shaped the conceptions that the students expressed.

RESULTS

Students described four canyon formation processes. These processes were placed into conception categories

TABLE IV: Processes described by participants and conception categories and descriptions associated with the processes.

Process	Process Description	Conception Category	Conception Category Description
• River erosion and base level change	• Student described river erosion as the primary process that forms canyons. • Student described the role of base level change in canyon formation.	Scientific	Student provided a scientific explanation.
• River erosion	• Student described river erosion as the primary process that forms canyons. • Student did not describe the role of base level change in canyon formation.	Incomplete scientific	Student provided a partially correct scientific explanation but missed components that would make the explanation scientific. The missing information could include a student explicitly stating that he or she did not know some of the information.
• Catastrophic process only or • No formation process	• Student had one of the following ideas about the process of canyon formation: 1. Student said that a catastrophic event is the primary process in canyon formation (catastrophic formation group), or 2. Student said that there was no formation process (i.e., canyon had always existed) (no formation process group). • Student did not describe the role of base level change in canyon formation.	Alternative	Student provided a nonscientific explanation (i.e., it differed from that accepted by the scientific community).
• Catastrophic event and river erosion or weathering	• Student had one of the following ideas about the process of canyon formation: 1. Student described a catastrophic event as initiating a canyon, and gradual river erosion as a secondary process that occurs after the catastrophic event to further develop the canyon (*blended conception* group), or 2. Student described two simultaneously contradictory processes that create a canyon (simultaneously contradictory group). • Student did not describe the role of base level change in canyon formation.	Incomplete scientific–alternative	Student blended an incomplete scientific explanation with an alternative explanation.

(Table V). No student held scientific conceptions about the formation of the canyon; most students held incomplete scientific conceptions.

In the results presented below, quotes from student responses are used to emphasize key concepts. Some text in the quotes is highlighted with bold text to indicate a key concept discussed in the results discussion. If more than one key concept occurs in the same quote, then the concepts are differentiated using different modes of highlighting. For example, the first concept highlighted in a quote is indicated with bold text. The next concept is highlighted using underlining.

Incomplete Scientific Conception

Students with incomplete scientific conceptions described river erosion as the primary canyon-formation process (Process 1 in Table V). Students were not assigned to a scientific conception category because they did not describe the role of base level change as a key component to canyon formation.

Participant R05-11 had a typical incomplete scientific conception response. R05-11 described river erosion (bold text in the passage below) as the primary canyon formation process: "[the canyon was] created from a river… this river has cut away at this land mass." With further probing, R05-11 added more detail of how he thought the river formed the

TABLE V: Processes described by participants and number and the frequency percentage of students in each conception category.

Process	Conception Category	Number of Students	Percent Frequency
• Process 1: River erosion	Incomplete scientific conception	11	61
• Process 2: Catastrophic process only • Process 3: No formation process	Alternative conception	4	22
• Process 4: Catastrophic event and river erosion or weathering (*blended concept* and *simultaneously contradictory* groups)	Incomplete scientific–alternative conception	3	17
• Process 5: River erosion and base level change	Scientific conception	0	0

canyon (underlined text in passage below). In the underlined text, the student explained that the river entrains sediment, carries it away, and deposits it downstream.

R05-11

INT: And I'm going to have you first describe the picture, what's in the picture?
RSP: It's a large canyon **and it looks like it was created from a river.** I see a lot of different types of rocks. Some metamorphic rocks, some igneous rocks maybe. Yeah, it looks like just over millions of years **that this river has cut away at this land mass and it's gone down hundreds of feet.** Kinda like the Grand Canyon.
INT: You said it was created by the river, so tell me about how the river created it?
RSP: **Through erosion. As the river goes constantly throughout the year, it picks up sediment and carries it along. Depending on how fast the river is flowing it carries sediment along with it and deposits it further down. So in this picture, it takes millions of years to do this but it cuts away at earth and keeps carrying it away to further distances and deposits it, deposits it . . . and that's how a canyon is formed.**

Alternative Conception

Students with alternative conceptions fell into one of two groups based on their understanding of the processes that form canyons. The first group of students described catastrophic geologic processes (Process 2 in Table V) as the only cause for canyon formation. The second group thought that a canyon had always existed and did not undergo a formation process (Process 3 in Table V).

Process 2: Catastrophic Process Only

The students in the catastrophic process only group said that catastrophic processes, such as earthquakes or volcanic eruptions, formed the canyon. For example, participant R05-19 explained that an earthquake (bold text in the passage below) created the canyon. In response to a follow-up question about the role of the river in the canyon formation process, the student said that she did not think that the river was involved in the formation process. She thought that the river could have existed before or after the canyon was formed by the earthquake and that the river would flow at the bottom of the canyon because that is the lowest elevation. R05-19 did not attribute the canyon formation process to river erosion (underlined text in the passage below).

R05-19

INT: OK. So how do you think the canyon formed?
RSP: **Earthquake maybe, probably**.
INT: And tell me how that occurred?
RSP: How the earthquake occurred?
INT: How the earthquake would form a canyon?
RSP: **If the land splitting apart by the earthquake**, I don't know how to explain it, it would just**—like the earthquake would happen, and then, the earth would kind of like fall into it. Like the land that broke off and form[ed] a canyon**.... I don't know.
INT: And after the earthquake occurred, when do you think the river got into the bottom?
RSP: Depending on when the weather—depending on what the weather was doing, like maybe, there was a river on the ground before the earthquake, and it split it, and then, the river went down into it. Like if it rained, the water from the land up here [pointing to the top of the canyon] would trickle down into this, it would need somewhere to go, and so, obviously, it all just collects. I mean it just goes in the naturally carved-out area where it can go.

Process 3: No Formation Process

One student, R05-14, thought that the canyon did not undergo a formation process (Process 3 in Table V). Several probes were used in the interview to explore the student's conceptions of the canyon-formation process, and consistently, R05-14 gave responses that indicated that she thought that the canyon did not have a formation process.

Initially, when asked how the "canal" formed (R05-14 used the term *canal* to refer to the canyon) and how the river got to the bottom of the canyon, R05-14 said that the water ran off the slope of the canyon under the influence of gravity and gathered at the bottom of the canyon (bold text in the passage below). She did not identify a process that created the canyon.

R05-14

INT: So, how do you think this canal formed?
RSP: **Water came from possibly rain. And the water's obviously not going to stay up here on a steep slope [of the canyon wall] so it has to stay down on the surface, because water's not going to just sit up here on a slant, it has to be down below.**
INT: How did the river get down at that level?
RSP: Well, it's the flattest surface to the ground—and like, where did the water come from?
INT: Yeah, if you look at the picture, it's down kind of at the bottom of the mountain that you described, so why is it down here; how did it get down there?
RSP: **Just because of like gravity forces again. The water, like I said, isn't going to just sit up on a steep slant, it's going to stay down on a flat surface. Most likely, well it is, because of gravity.**

To probe further, R05-14 was asked if she thought that the setting had always looked the way it does in the picture. She said that there have been changes to the canyon setting, but that those changes were minor and included rocks falling from the canyon wall (bold text in the passage below). Again, she did not describe a formation process. The rock falling processes she described were not canyon-formation processes, but only slight modifications to the canyon.

R05-14

INT: Did you think that this setting here always looked this way?
RSP: Like, from a long time ago?
INT: Yes.
RSP: **For a while, but not, like the rocks have obviously like changed. And who knows if there's**

always been water there or not? So maybe once there wasn't even water there . . . .
INT: So, tell me how the rocks may have changed.
RSP: **Just like fallen debris off the rocks, fallen, it changed the formation of the rocks, they're not really moving. I'm just saying like little differences—debris falling off. Not like actually clear movement of them.**

In further probing, R05-14 was asked how the setting in the photograph would look if there had been no water and if there had been an increase in water in the setting in the past. R05-14 said that water does not affect the rocks, so the absence or presence of water in the canyon had no bearing on the canyon setting (bold text in the passage below).

R05-14

INT: So, what would it look like if there wasn't any water—you said there may not have even been water [in the canyon in the past]. So let's assume there wasn't water. How would this picture look?
RSP: **I guess probably just the same, there just wouldn't be water in there. I don't think the water's doing very much to the rocks, so whether it was there or not, I don't think it would make that much of a difference.**

R05-14's responses indicated that she did not think that the canyon underwent a formation process.

Incomplete Scientific–Alternative Conception

Students with incomplete scientific–alternative conceptions combined the processes in the incomplete conception category with processes in the alternative conception category (Process 4 in Table V). The students fell into one of two groups based on how they combined the processes. Students in the blended conception group thought that a catastrophic event followed by river erosion formed the canyon. The student in the simultaneously contradictory group thought that two possible, yet contradictory, processes could form the canyon. Similar to students with incomplete scientific conceptions, students with incomplete scientific–alternative conceptions also did not describe base level change as a component to canyon formation.

Blended Group

Students in the blended group described a catastrophic geologic event, such as an earthquake, as the process that initiated the canyon formation. Following the catastrophic event, they said that river erosion occurred to develop the canyon further. The catastrophic events described by students are the alternative conceptions and the river erosion descriptions are the incomplete scientific conceptions expressed by students in the blended group. Students' ideas were a blend of incomplete scientific conceptions and alternative conceptions.

R05-12 had a typical blended response. She believed that an earthquake caused plates to separate, which initiated the canyon formation process (bold text in the passage below). The student said that after the catastrophic event occurred, a river then played a role in forming the canyon (underlined text in the passage below):

R05-12

INT: How do you think the canyon formed?
RSP: I think that maybe if **there was an earthquake or something happened, and the plates separated there.** But I think that eventually maybe this river wore down, part of some of the bottom and made it more steep. I guess.
INT: So let's start at the very beginning before—tell me like the kind of sequence that would happen to form it.
RSP: To form the canyon? Well, I would think that these two [pointing at both canyon walls] would be together and then something happened, **the plate shifted, or something, and they kind of got expanded apart a little bit**. And they probably move a little bit every year and then, I think, that the river started somewhere and eventually found like a nook in it and helped to wear it down a little bit, but I think **most of it formed from where the plates were moving**.

Simultaneously Contradictory Group

One student, R05-17, held two simultaneously contradictory ideas about canyon formation. The first idea described by R05-17 was that canyons are gradually created by river erosion (bold text in the passage below). This idea aligns with the incomplete scientific explanation of canyon formation. However, he said that he did not personally believe the incomplete scientific conception of canyon formation but instead believed a process similar to that described by the blended group in the incomplete scientific–alternative conception category. He said that the canyon was created by a catastrophic event, in this case, a biblical flood (single underlined text in the passage below). He said that after the flood created the canyon, gradual weathering and erosion would further develop the canyon (italic text in the passage below).

R05-17

INT: How did the canyon form?
RSP: There's a lot of—I know of two theories. **The first one is the widely accepted geological theory: that over a long period of time, this river has carved out this piece of land, and that through millions of years, it's carried the sediment away from its current place as it's dug itself deeper into the mountain.** The other one that I've heard is the one like where it's a giant flood, like in the Bible, and in many cultures, they've described a giant flood. And when you do have a lot of water, it can carve out a massive chunk of land all at once. So if you have a massive amount of water coming through this area all at once, then it can carry a lot of dirt and sediment away very rapidly. So, I would tend to think of the large flood one being true because a lot of societies have described events of a big flood happening, and large chunks of - canyons being formed with that. And I just subscribe to that theory a little bit more.
INT: How long would that process take? You know, like a large flood.
RSP: Probably, just a couple months, very rapidly. *And then, I think what really weathers and opens this up to, is since then, you have a lot of rain and stuff that will continually wear away the sides of these [pointing to the*

> *sides of the canyon], and then, that sediment would go down into the river, obviously, and be carried away.* So, it would look like that you had a long time for something to be worn away, but it's continually being worn away, so. . . .

R05-17 simultaneously held an incomplete scientific conception and an incomplete scientific–alternative conception. Although he said that he only believed the incomplete scientific–alternative conception, he accurately described the incomplete scientific conception of canyon formation. The two conceptions are contradictory because the incomplete scientific conception requires long-term, gradual geologic processes to form a canyon, and the incomplete scientific–alternative conception requires short-term, supernatural forces to initiate a canyon and gradual weathering and erosion to continue the process.

DISCUSSION

This study identified college students' conceptions before instruction. Students had incomplete scientific conceptions, incomplete scientific–alternative conceptions, or alternative conceptions about the process of canyon formation and of the role of rivers in canyon formation. No student described the role of river erosion and base level change; therefore, no student response was categorized as a scientific conception of canyon formation. Several findings emerged in this study.

Comparison of Students' Conceptions in This Study to Other Studies

At the time of submission, there had been no other published work, to my knowledge, investigating students' conceptions of the role of rivers in canyon formation. The most relevant comparative study was conducted by Happs (1982). Both this study and the Happs (1982) study investigated students' conceptions of the surficial processes forming landscape features, canyons in this study and glacial valleys in the Happs study. Happs (1982) investigated 11- to 17-y-old students' conceptions of the origin of a glacial valley. Happs found that some students correctly attributed formation of the valley to surficial processes (glacial activity). This is similar to the students with incomplete scientific conceptions in this study who correctly associated canyon formation to river erosion. Similarly, like the students in this study with incomplete scientific–alternative conceptions and alternative conceptions, Happs found that some students in his study thought that a glacial valley had always existed (i.e., there was no formation process), and other students thought that catastrophic processes, such as volcanic eruptions, created the glacial valley. This study contributes to the few existing studies investigating the role of surficial processes in forming landscape features.

Role of Rivers in Canyon Formation

Most students (61%) thought that river erosion created the canyon. These students had an understanding about the role of river erosion in forming the canyon, even though they had not yet studied rivers in their class. This finding is interesting because most students were nonscience majors, and none of the students were geoscience majors. One explanation for why students held this conception could be that they knew they were being interviewed about rivers and river processes; therefore, when they were asked how the canyon formed, they assumed that the river formed the canyon. However, if that was the case, then students might only have said that the river formed the canyon. In this study, the students were able to explain what river process (e.g., river erosion) specifically formed the canyon, and they provided explanations of how that process formed the canyon. Even if the students had assumed that the river formed the canyon because they were being interviewed about rivers, they still had to be able to explain how the river formed the canyon. This is not something they would necessarily know just because they were being interviewed about rivers.

Another explanation may be necessary to explain how students formed their understanding of canyon formation. Students are not blank slates; they have developed conceptions about the world based on preexisting experiences (Ausubel, 1968; Wandersee et al., 1994; Scott et al., 2007). Students in this study likely developed their understanding of the role of river erosion in forming canyons from previous formal and informal educational experiences.

Catastrophic Events to Create a Canyon

Three students described catastrophic, short-term events (e.g., earthquakes and volcanic eruptions) as the primary processes that created the canyon and did not express awareness about the role of river erosion in canyon formation. Happs (1982) also found that students described volcanic activity as the mechanism to form a valley. It would be important to find out whether the reliance on catastrophic events to initiate or completely form a canyon is transitory and based on students' prior learning or whether it is a well-entrenched idea. Students who think that catastrophic events are the sole cause of landscape features like canyons will need to learn about the gradual, long-term river processes that can create landscape features. This study confirmed findings from the Happs (1982) study that some students describe catastrophic events to create landscape features that typically form from long-term, gradual geologic processes.

Blended Ideas

Some students in this study blended aspects of scientific and alternative conceptions into unique combinations. The conception research field primarily focuses on identifying and modifying students' alternative conceptions. However, students' alternative conceptions represent only a part of their understanding of a topic (Clement et al., 1989; Clement, 1993; Palmer, 2001). Students can have scientific, incomplete scientific, or blended conceptions. This study is not the first study to recognize that students' ideas are more complicated than two categories of conception—alternative or scientific.

Other researchers have found that students hold more diverse conceptions about rivers and other geoscience topics than exclusively scientific and alternative. Piaget (1929, 1930) and Cin and Yazici (2002) found that students had more than two categories of conceptions about river topics. Steer et al. (2005) found that college students had naïve views, limited views, or acceptable views of earth's interior layers. Blake (2005) found that elementary school students had nonscientific, protoscientific, and scientific ideas about several geoscience topics.

It is important to recognize the complexity of conceptions held by students. In instruction, the issue is not solely whether students have scientific or alternative conceptions, but additionally, what aspect of a scientific conception a student holds and what aspect of an alternative conception a student holds.

Students' Understandings of Processes and Complex Systems

Although most students expressed an understanding that river erosion formed the canyon, the students did not express an understanding of complex systems. Identifying students' conceptions of complex Earth systems was not a specific focus of the initial research; however, it emerged during data collection and analysis that students did not express an understanding of complex Earth systems when describing how the canyon formed. For example, one student did not recognize that there was a formation process at all, and the other students, who did identify a change process, did not express an understanding of the interactions of multiple earth processes.

The student who said that the canyon had always existed held a static view of the canyon: the canyon had always existed, and no formation process occurred. Elementary students in the Happs (1982) study thought that a landscape feature (a glacial valley) had always existed, and that there was no formation process. Libarkin and Kurdziel (2006) found that some college students thought that fossils did not have a formation process. Cheek (2010), in a review of the geoscience conceptions literature, found that across several studies, students held conceptions that the earth is "static and unchanging" (p. 123).

Most students in this study did explain a formation process for the canyon. However, none of the students explained how base level change, tectonic activity, and surficial processes operated and interacted over time to create the canyon. Even those students who correctly described the role of river erosion did not express an understanding of the interplay between river erosion and base level change. Students identified single causal processes, such as river erosion or a catastrophic geologic event, as the cause of canyon formation, or they explained two sequential, but unrelated, causal processes (i.e., first a catastrophic event occurred, then river erosion occurred after that to create the canyon) as the cause of canyon formation.

Raia (2005) similarly found that college students failed to recognize complex dynamic systems and instead held linear monocausal explanations, conceptions that did not consider the interactions of components in a system and did not recognize the temporal complexity of complex systems. Raia (2005) found that, over time, students continue to hold linear, monocausal explanations even after instruction, unless students' conceptions are addressed in instruction.

There was no expectation that students would have or should have had an understanding of complex systems in this study. Students had not learned about the role of rivers in forming such a canyon or what role other earth processes, such as base level changes and tectonic activities, have in forming the canyon. However, the findings help with the growing picture of students' conceptual understanding of processes and complex systems.

Implications for Instruction

Although this study did not investigate instructional strategies, the findings have implications for instruction. Most students in this study correctly described the role of river erosion in canyon formation. Students' preexisting scientific conceptions of science topics can serve as a foundation for their future learning (Clement et al., 1989; Clement, 1993; Palmer, 2001). The conception research field primarily focuses on identifying and modifying students' alternative conceptions. However, students' alternative conceptions represent only a part of their understanding of a topic (Clement et al., 1989; Clement, 1993; Palmer, 2001). Instructional strategies that are based on using students' scientific conceptions as a foundation for learning may be effective for teaching the students in the study and other students with similar conceptions (for examples see Clement et al., 1989; Clement, 1993; Grayson, 1994).

The alternative conceptions about canyon formation identified in this study also have implications for instruction. The process students go through to change their alternative conceptions and adopt scientific conceptions can be complex and may require a long time (Driver, 1989; Vosniadou and Ioannides, 1998; Scott et al., 2007). There is debate about the best way to modify students' alternative conceptions (Scott et al., 2007; Vosniadou, 2008). However, there is general agreement that the first place to start in modifying students' alternative conceptions is to understand what the conceptions are before instruction (Driver and Oldham, 1986; Vosniadou, 1991; Dykstra et al., 1992; Wandersee et al., 1994; Vosniadou and Ioannides, 1998; Duit and Treagust, 2003). This study identified several alternative conceptions related to the role of rivers in canyon formation, which can help educators understand the possible conceptions that their students may have.

CONCLUSION AND FUTURE WORK

It is important to contextualize students' responses in this study. This study identified the conceptions held by students about the role of rivers in forming one landscape feature: a solid rock canyon with a river at the base. Student responses were specific to the feature they were shown. In this study, most students held incomplete scientific conceptions and understood that a river had a role in forming the canyon in the photo shown to them. Some students held blended conceptions that combined aspects of scientific and alternative conceptions about the role of a river in creating a canyon. Some students thought that there was no formation process or that a catastrophic process formed the canyon. Future areas of research stem from this study.

First, future work should investigate students' conceptions of the role of rivers in forming other canyons and landscape features. Because students' responses were specific to the canyon they were shown, more study is needed to know if the same processes would be described by students for other canyons in other settings. Also, future research should investigate what role students think rivers have in modifying and creating other landscape features.

Second, future research should investigate how students' conceptions change over time. This study investigated students' conceptions at one point in time and did not investigate how students' conceptions changed over time or to what extent the conceptions were well entrenched or easy to change. Future research should investigate whether students' conceptions are well entrenched and resistant to change or whether they are transitory (Taber, 2008). Students may express conceptions that are developed in situ during research interviews, or they may bring with them well-developed ideas (Taber, 2008). Both in situ ideas and preexisting conceptions may be either well entrenched or transitory (Taber, 2008). To help inform instruction, educators need to know how students' conceptions change over time and whether the conceptions are easy to change with instruction or are difficult to change.

Finally, future research should investigate what instructional strategies best help students build on the scientific conceptions identified in this study and modify their blended and alternative conceptions. Of particular importance for geoscience is to investigate how to modify students' conceptions that no change occurred or that catastrophic processes created the canyon.

Few existing studies investigate students' conceptions about the role of rivers in forming landscape features. This study serves as a foundation for future investigations into this topic.

Acknowledgments

I would like to thank the students who participated in this research. I would also like to thank Erin Dokter, Ingrid Novodvorsky, Becky Morlier, two anonymous reviewers, the Associate Editor, and Editor-in-Chief for providing feedback to improve this article. This study was approved by the Colorado State University Human Research Committee (Protocol 04-269H).

REFERENCES

Ary, D., Jacobs, L.C., and Sorensen, C. 2009. Introduction to research in education. Independence, KY: Wadsworth Cengage Learning.

Ausubel, D.P. 1968. Educational psychology: A cognitive view. New York: Holt, Rinehart and Winston, Inc.

Bar, V. 1989. Children's views about the water cycle. *Science Education,* 73:481–500.

Bell, B., and Osborne, R. 1981. Interviewing children—A checklist for the I. A. I. interviewer, Working Paper 45. Hamilton, New Zealand: University of Waikato, Learning in Science Project. p. 18.

Ben-zvi-Assarf, O., and Orion, N. 2005. A study of junior high students' perceptions of the water cycle. *Journal of Geoscience Education,* 53:366–373.

Blake, A. 2005. Do young children's ideas about the Earth's structure and processes reveal underlying patterns of descriptive and causal understanding in earth science? *Research in Science and Technological Education,* 23:59–74.

Bransford, J.D., Brown, A.L., and Cocking, R.R. 2000. How people learn: Brain, mind, experience, and school. Washington, DC: National Academy Press. p. 374.

Brody, M.J. 1996. An assessment of 4th-, 8th-, and 11th-grade students' environmental science knowledge related to Oregon's marine resources. *Journal of Environmental Education,* 27:21–27.

Cheek, K.A. 2010. Commentary: A summary and analysis of twenty-seven years of geoscience conceptions research. *Journal of Geoscience Education,* 58:122–134.

Cin, M., and Yazici, H. 2002. The influence of direct experience on children's ideas about the formation of the natural scenery. *International Research in Geographical and Environmental Education,* 11:5–14.

Clement, J. 1993. Using bridging analogies and anchoring intuitions to deal with students' preconceptions in physics. *Journal of Research in Science Teaching,* 30:1241–1257.

Clement, J., Brown, D.E., and Zietsman, A. 1989. Not all preconceptions are misconceptions: Finding 'anchoring conceptions' for grounding instruction on students' intuitions. *International Journal of Science Education,* 11:554–565.

Creswell, J.W. 1998. Qualitative inquiry and research design: Choosing among five traditions. Thousand Oaks, CA: Sage Publications, Inc. p. 403.

Crotty, M. 1998. The foundations of social research: Meaning and perspective in the research process. Thousand Oaks, CA: Sage Publications. p. 248.

Dove, J. 1997. Student ideas about weathering and erosion. *International Journal of Science Education,* 19:971–980.

Dove, J. 1998. Students' alternative conceptions in earth science: a review of research and implications for teaching and learning. *Research Papers in Education,* 13:183–201.

Driver, R. 1989. Students' conceptions and the learning of science. *International Journal of Science Education,* 11:481–490.

Driver, R., and Oldham, V. 1986. A constructivist approach to curriculum development in science. *Studies in Science Education,* 13:105–122.

Driver, R., Squires, A., Rushworth, P., and Wood-Robinson, V. 1994. Making sense of secondary science: Research into children's ideas. New York: RoutledgeFalmer. p. 210.

Duit, R. 2004. Bibliography: Students' and teachers' conceptions and science education. Available at http://www.ipn.uni-kiel.de/aktuell/stcse/stcse.html (accessed 19 January 2006).

Duit, R., Niedderer, H., and Schecker, H. 2007. Teaching physics. *In* Abell, S.K., and Lederman, N.G., eds., Handbook of research on science education. Mahwah, NJ: Lawrence Erlbaum Associates, p. 599–629.

Duit, R., and Treagust, D.F. 2003. Conceptual change: A powerful framework for improving science teaching and learning. *International Journal of Science Education,* 25:671–688.

Dykstra, D.I., Boyle, C.F., and Monarch, I.A. 1992. Studying conceptual change and learning physics. *Science Education,* 76:615–652.

Englebrecht, A.C., Mintzes, J.J., Brown, L.M., and Kelso, P.R. 2005. Probing understanding in physical geology using concept maps and clinical interviews. *Journal of Geoscience Education,* 53:263–270.

Gobert, J.D. 2000. A typology of causal models for plate tectonics: Inferential power and barrier to understanding. *International Journal of Science Education,* 22:937–977.

Grayson, D.J. 1994. Concepts substitution: An instructional strategy for promoting conceptual change. *Research in Science Education,* 24:102–111.

Happs, J.C. 1982. Glaciers, Working Paper 203. Hamilton, New Zealand: University of Waikato, Science Education Research Unit. p. 34.

Harwood, D., and Jackson, P. 1993. Why did they build this hill so steep?: Problems of assessing primary children's understanding of physical landscape features in the context of the UK national curriculum. *Geographical and Environmental Education,* 2:64–79.

Hewson, M.G., and Hewson, P.W. 1983. Effect of instruction using students' prior knowledge and conceptual change strategies on science learning. *Journal of Research in Science Teaching,* 20:731–743.

Kelso, P.R., Brown, L.M., Mintzes, J.J., and Englebrecht, A.C. 2000. Key concepts in geoscience subdisciplines, teaching strategies, and core course requirements: Results of a national survey of geoscience faculty. *Eos, Transactions, American Geophysical Union,* 41:304.

King, C. 2008. Geoscience education: An overview. *Studies in Science Education,* 44:187–222.

Libarkin, J.C., and Kurdziel, J.P. 2001. Research methodologies in science education: Assessing students' alternative conceptions. *Journal of Geoscience Education,* 49:378–383.

Libarkin, J.C., and Kurdziel, J.P. 2006. Ontology and the teaching of earth system science. *Journal of Geoscience Education,* 54:408–413.

Lincoln, Y.S., and Guba, E.G. 1985. Naturalistic inquiry. Newbury Park, CA: Sage Publications Inc.

Mackintosh, M. 2005. Children's understanding of rivers. *International Research in Geographical and Environmental Education,* 14:316–322.

May, T. 1996. Children's ideas about rivers. *Primary Geographer,* 29:12–13.

Merriam, S.B. 2002. Qualitative research in practice: Examples for discussion and analysis. San Francisco, CA: Jossey-Bass. p. 439.

National Research Council. 1996. National science education standards. Washington, DC: National Academy Press. p. 262.

Palmer, D. 2001. Students' alternative conceptions and scientifically acceptable conceptions about gravity. *International Journal of Science Education,* 23:691–706.

Patton, M.Q. 2002. Qualitative research and evaluation methods. Thousand Oaks, CA: Sage Publications. p. 688.

Piaget, J. 1929. The child's conception of the world. London, UK: Routledge and Kegan Paul. p. 432.

Piaget, J. 1930. The child's conception of physical causality. London, UK: Kegan Paul, Trench, Trubner & Co., Ltd. p. 309.

Ponterotto, J.G. 2006. Brief note on the origins, evolution, and meaning of the qualitative research concept "thick description." *The Qualitative Report,* 11:538–549.

Ponterotto, J.G., and Grieger, I. 2007. Effectively communicating qualitative research. *The Counseling Psychologist,* 35:404–430.

Posner, G.J., and Gertzog, W.A. 1982. The clinical interview and the measurement of conceptual change. *Science Education,* 66:195–209.

Raia, F. 2005. Students' understanding of complex dynamic systems. *Journal of Geoscience Education,* 53:297–308.

Ross, K.E.K., and Shuell, T.J. 1993. Children's beliefs about earthquakes. *Science Education,* 77:191–205.

Scott, P., Asoko, H., and Leach, J. 2007. Student conceptions and conceptual learning in science. *In* Abell, S.K., and Lederman, N.G., eds., Handbook of research on science education. Mahwah, NJ: Lawrence Erlbaum Associates, p. 31–56.

Sexton, J.M. 2008. A qualitative study of college students' conceptions of rivers [PhD dissertation]. Fort Collins: Colorado State University. p. 289.

Sibley, D.F. 2005. Visual abilities and misconceptions about plate tectonics. *Journal of Geoscience Education,* 53:471–477.

Steer, D.N., Knight, C.C. Owens, K.D., and McConnell, D.A. 2005. Challenging students' ideas of Earth's interior structure using a model-based, conceptual change approach in a large class setting. *Journal of Geoscience Education,* 53:415–421.

Stofflett, R. 1994. Conceptual change in elementary school teacher candidate knowledge of rock cycle processes. *Journal of Geological Education,* 42:494–500.

Strauss, A., and Corbin, J. 1998. Basics of qualitative research: Techniques and procedures for developing grounded theory. Thousand Oaks, CA: Sage Publications, Inc. p. 312.

Taber, K.S. 2008. Conceptual resources for learning science: Issues of transience and grain-size in cognition and cognitive structure. *International Journal of Science Education,* 30:1027–1053.

Vosniadou, S. 1991. Designing curricula for conceptual restructuring: Lessons from the study of knowledge acquisition in astronomy. *Journal of Curriculum Studies,* 23:219–237.

Vosniadou, S., and Ioannides, C. 1998. From conceptual development science education: A psychological point of view. *International Journal of Science Education,* 20:1213–1230.

Wandersee, J.H., Mintzes, J.J., and Novak, J.D. 1994. Research on alternative conceptions in science. *In* Gabel, D.L., ed., Handbook of research on science teaching and learning: A project of the National Science Teachers Association. New York: Macmillan Publishing Company, p. 177–210.

Wysession, M. 2009. Earth science literacy principles. Available at http://www.earthscienceliteracy.org/document.html (accessed 22 September 2009).