Water Towers, Pump Houses, and Mountain Streams: Students' Ideas about Watersheds

Daniel P. Shepardson — Departments of Curriculum and Instruction, 100 North University Street, Purdue University, West Lafayette, IN 47907-2098 dshep@purdue.edu

Jon Harbor — Earth and Atmospheric Sciences, 100 North University Street, Purdue University, West Lafayette, IN 47907-2098

Bryan Wee — Departments of Curriculum and Instruction, 100 North University Street, Purdue University, West Lafayette, IN 47907-2098 dshep@purdue.edu

ABSTRACT

The watershed concept is important in many areas of geology and environmental science, and the purpose of this study was to investigate students' ideas about watersheds and how these ideas change across grade level. A total of 95 students were sampled: 28 sixth graders, 25 seventh graders, 22 eight graders, and 23 ninth graders. To elicit students' ideas about watersheds a task was developed that required students to draw a picture of a watershed and explain their drawing. In general, students understand a watershed from a very limited scientific perspective. For sixth and some seventh grade students a watershed is a water storage facility or a facility that supplies water. Eighth and ninth grade students' ideas about a watershed focused on a mountainous stream. Older students also incorporated the hydrologic cycle, but rarely represented linkages between land and watercourses. For all students, humans do not appear to be a part of a watershed, but separate from it. The implications of these findings are also explored.

INTRODUCTION

Although a number of studies have been conducted that investigate students' ideas about the Earth's shape and gravity (e.g., Nussbaum, 1985; Baxter, 1989), lunar phases (e.g., Baxter, 1989; Stahly et al., 1999), rocks and rock cycle (e.g., Happs, 1985), and seasons (e.g., Baxter, 1989), a breadth of research in the area of students' conceptions about geoscience concepts is lacking (Manduca et al., 2002). Furthermore, little research has been conducted that investigates students' ideas about watersheds, despite the fact that the watershed concept has wide ranging application in environmental and sedimentary geology and environmental science. Therefore, the purpose of this study was to investigate students' ideas about what a watershed is, adding to the extant literature base on students' geoscience learning. Specifically, the research questions guiding this study were:

1. What are students' ideas about a watershed?
2. In what ways might students' ideas about a watershed change from sixth grade to ninth grade?

An understanding of the watershed concept is essential to comprehending issues about water quality, point and nonpoint source pollution, and the impact of land use and personal actions or behavior on water quality. This is particularly important considering the rapid pace of urbanization in the U.S. as well as the pressure that population growth is placing on water resource management. How well students understand issues about groundwater and groundwater contamination may also be dependent on their understanding of the watershed concept. Therefore, if teaching is to promote students' learning about watersheds, it is essential to determine what students' ideas are about watersheds, what and why they think that way (Osborne and Freyberg, 1985). By understanding students' ideas, potential impediments to learning may be identified (Ausubel et al., 1978) and insight toward planning curriculum, designing instruction, and developing assessments that build on students' ideas is gained (Driver et al., 1994; Shepardson, 2002).

BACKGROUND ON LEARNING

Constructivist theory frames learning as an active, continuous process whereby students construct meaning based on prior ideas and experiences (Driver and Bell 1986; Duit, 1991), through physically and mentally acting on objects (Piaget, 1970). This knowledge construction is shaped through social interactions with members of the community and culture (Vygotsky, 1986). Thus, students construct understandings for themselves, but not in isolation from others (Bishop, 1985; Rogoff, 1990). Learning involves both a personal construction of meaning and a socially negotiated meaning (Cobb, 1990).

Studies of students' ideas indicate that students hold common notions about natural phenomena that influence their science learning (Driver et al., 1985; Driver, et al., 1994; Duit, 1991; Hodson, 1991; Munson, 1994). The research literature has noted that student conceptions are: (a) based on their observations, social interactions, and language, (b) similar across age, ability, gender, and culture, (c) not easily changed, and (d) influence science learning in unintended ways (Wandersee et al., 1994). Over time, students' conceptions become entrenched in cognitive structures such that they become consistent with everyday language and observations (Eaton et al., 1983). In other words, students tend to retain a misconception that makes sense rather than accept scientific explanations that are in conflict with their common sense beliefs (Stepans et al., 1986).

In order to understand the world and its phenomena, students construct internal representations or mental models that are based on their prior knowledge, existing ideas, and past experiences; these mental models are useful or functional in that they allow students to make predictions or explain phenomena or events (Greca and Moreira, 2000). These mental models are always under construction and based on new knowledge, ideas, and experiences; they are personal, idiosyncratic and often unstable (Greca and Moreira, 2000). On the other hand, scientific or conceptual models

Categories	General Science (Sixth grade) n=28	Life Science (Seventh grade) n=25	Life Science (Eighth grade) n=22	Biology (Ninth grade) n=23
Water tower/shed (water storage)	11 (39%)	2 (8%)	0	0
Well/pump house (water delivery)	10 (36%)	5 (20%)	2 (9%)	1 (4%)
Hydroelectric plant	3 (11%)	0	0	0
Water purification plant	1 (3%)	3 (12%)	0	0
Soil/sand holding water	2 (7%)	0	0	0
Creek/river	3 (11%)	2 (8%)	2 (9%)	0
Mountainous stream	1 (3%)	8 (32%)	9 (41%)	7 (30%)
Mountainous stream with hydrologic cycle	0	5 (20%)	9 (41%)	12 (52%)
Branching stream diagram	0	0	0	3 (13%)

Table 1. Categories of student responses to the watershed task.

are precise, complete, and simplified representations of phenomena based on scientifically accepted knowledge; they are external representations shared by the community (Greca and Moreira, 2000).

Because students come to science classrooms with different cultural, educational, and personal experiences they come with different mental models (Glynn and Duit, 1995). Learning science, in part, requires students to reflect on their existing mental models and build conceptual models (Glynn and Duit, 1995; Greca and Moreira, 2000; Libarkin et al., 2003). This model building process is dependent on the sophistication of the students' existing mental model (Libarkin et al., 2003). Well developed and organized mental models allow students to place new knowledge into existing models while poorly developed mental models may be easily modified based on new experiences (Libarkin et al., 2003).

METHOD

A constructivist perspective also guided this qualitative study. Constructivism, as a research referent, aims to understand the meanings constructed by students participating in context-specific activities using language (Schwandt, 1994). Central to this study is the language used by students for transmitting meanings (Holstein and Gubrium, 1994), how students interpret the world and what it means to them (Patton, 1990). Similarly, the authors interpret and construct an understanding of the student's language for explaining their understandings about watersheds-the authors create constructions about the student's constructions.

This study seeks to understand how students, within a specified group, conceptualize the term "watershed." This is done by having students respond through writing and drawing to written prompts in the Watershed Task. The students' responses are based on their experiences with and understandings about the phenomenon. Students' responses are then analyzed for their ideas about the phenomenon, grouping or categorizing their responses. This approach is hermeneutic in that it analyzes students' written and drawn responses in the context in which they were created and interpreted.

Sample - The sample for this study came from four randomly selected, intact classrooms in a rural junior-senior high school. A total of 95 students participated: 28 sixth graders, 25 seventh graders, 22 eight graders, and 23 ninth graders. All students came from a rural, agricultural community in Indiana and were predominately Caucasian, 95% for the school. Because the students were from different grade levels, they had different educational experiences. The school and its district are on a till plain with subtle topography and extensive agricultural drainage. Although watersheds are important for issues of local environmental management, drainage divides are not distinct features of the landscape.

Data Collection and Task Development - The Watershed Task was administered to the students the first week of March. Students were given a full class period, approximately 40 min., to complete the task. The Watershed Task was designed as an idea eliciting task and was based on the interviews about instances task (Osborne and Freyberg, 1985) and the draw and explain protocol (White and Gunstone, 1992); using written prompts to elicit student responses that emphasized the students' thinking. The Watershed Task required students to draw a picture of a watershed and explain their drawing using language as writing.

The students' drawings are conceptual visualizations or representations of their understandings about watersheds. Drawings as representations are an active, deliberate meaning-making process; drawings like words are embodied with and carry meaning (Kress et al., 2001). The students' drawings, then, are representations of their mental models (Glynn and Duit, 1995) and "reveal qualities of understandings that are hidden from other procedures" (White and Gunstone, 1992, p. 99). Furthermore, it allows students who have difficulty expressing their ideas verbally or in writing an opportunity to reveal their ideas (Rennie and Jarvis, 1995). The written portion allows students to describe the drawings in their own words, and clarifies their understandings of a watershed for the researchers. Moreover, other geoscience educators (e.g., Dickerson and Dawkins,

Figure 1. A sixth grader's "water shed" drawing and explanation illustrating the water storage category.

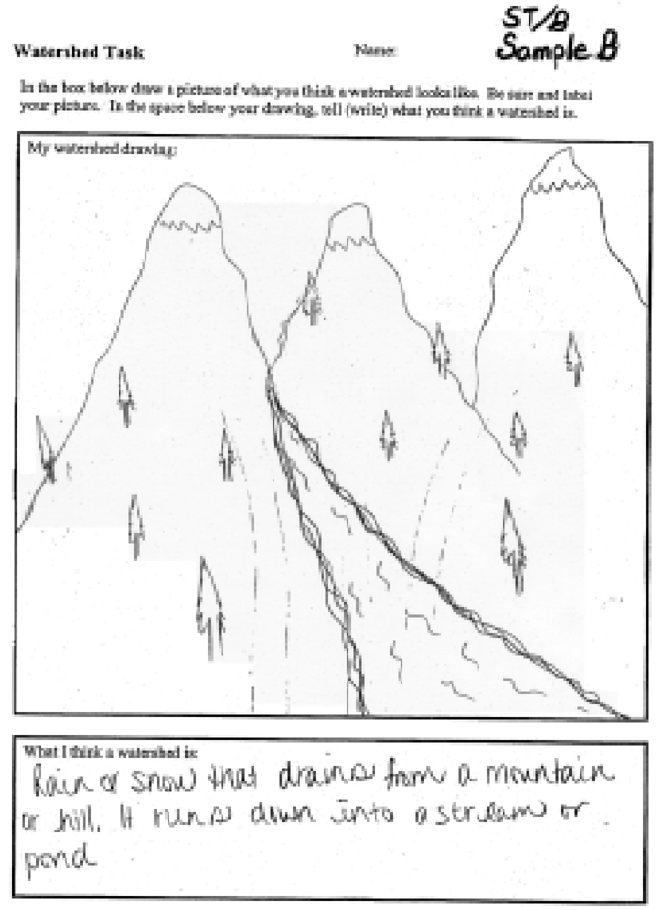

Figure 2. An eighth grader's mountains and stream drawing and explanation illustrating the mountainous stream category.

2004; Trop et al., 2000; Patterson and Harbor, in press) have used draw and explain tasks to make explicit students' ideas about geoscience concepts.

A prototype of the Watershed Task was administered to a sample of 20 seventh grade students, as a field test. These students were also primarily Caucasians from a rural school in an agricultural community. As a part of the field test students were interviewed about the task and their responses. Based on this field test the task was modified slightly in its wording.

Data Analysis - The data were analyzed using methods of inductive analysis (Patton, 1987; 1990). All data were coded by the first author. The data were searched for patterns or themes versus the imposing of predetermined codes on to the data (Patton, 1987; 1990). Specifically, the codes and categories emerged from the drawings and explanations. From the first reading of the data, initial codes were constructed reflecting the students' ideas about watersheds. Revision of the emergent codes occurred during the second reading. The data sources were read a third time whereby students' ideas about watersheds were placed into the final categories. This data analysis process is similar to the procedure described by Rubin and Rubin (1995). Descriptive themes were constructed based on the core ideas that emerged from the different students, at the different grade levels. The data were analyzed for confirming and discrepant situations to ensure credibility in the data analysis process (Erlandson et al., 1993). Student responses were checked against each other, providing a degree of triangulation. Students' ideas were also triangulated across grade-level experience.

RESULTS

Results from the analysis of the students' drawings and explanations are shown in Table 1. Sixth grade students tended to draw and explain pictures of water storage, water delivery, or water purification facilities (81%); only 21% drew and explained a picture that reflected some aspect of a watershed (e.g., mountainous stream, creek/river). The sixth grade students literally represented the word "watershed" by drawing a shed that stores or delivers water and explaining their drawings, for example, as "a shed that holds water" (Figure 1). The water storage result is similar to the findings of Patterson and Harbor (in press), who investigated the impact of a watershed and E. coli curriculum on middle school students' geoscience learning. Although seventh, eighth and ninth grade students also drew "water towers" or "well houses;" this percentage was greatly reduced from the sixth grade. Based on the responses, it seems that every day language guided students' thoughts (Duit, 1991) and how they represented their ideas, especially in the sixth grade.

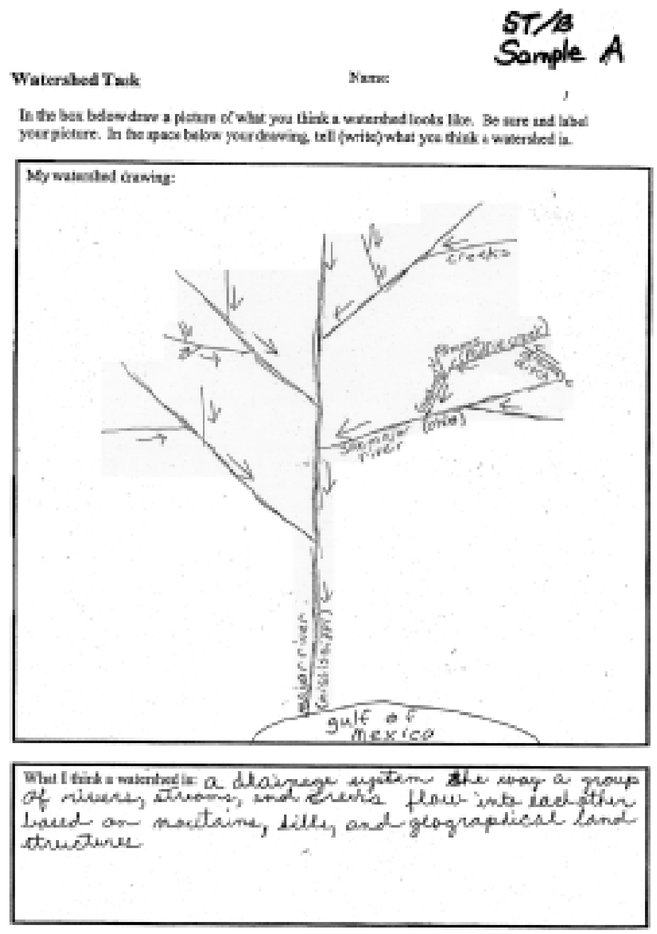

Figure 3. A ninth grader's branching stream drawing and explanation illustrating the branching stream diagram category.

Further, 52% of students in the seventh grade and 82% in the eighth and ninth grade conceptualized a watershed to exist in mountainous terrain, suggesting that watersheds are either confined to mountainous areas or limited to land areas of high relief and elevation. One eighth grader, however, did indicate that a watershed could be defined by a hill, "Rain or snow that drains from a mountain or hill" (Figure 2). The concept of the hydrologic cycle as a component of a watershed increased by grade level; more ninth grade students (52%) than eighth grade students (41%) or seventh grade students (20%) included the hydrologic cycle in their drawings and explanations. No sixth grade student drawings or explanations included the hydrologic cycle.

The students' drawings and explanations also emphasized a single river or stream, with the exception of 3 (13%) ninth grade students, who drew a branching stream network (Figure 3). As shown in Figure 3, only one student identified specific streams and rivers in his drawing, even including the local drainage ditch; labeling them "Parrie [sic] creek," "Wabash," "Ohio," and "Mississippi," with the Mississippi flowing into the "gulf of mexico [sic]." This student was the only one to draw streams and rivers that flowed into the ocean, the Gulf of Mexico, and to explain a watershed "based on mountains, hills, and geographical land structure."

All of the drawings depicted natural areas versus human developed areas, suggesting that watersheds only occur in natural areas and that humans are not immediately thought of as being a part of a watershed. Even though seventh, eighth and ninth grade students indicated that water runs off a land area (e.g., mountain) into a stream or pond, none of the students linked specific land area conditions or uses to a stream's quality or to a watershed.

DISCUSSION

These students' ideas about watersheds were limited to mountainous terrain, land areas of high relief and elevation. Watershed hydrology for the most part was restricted to precipitation, evaporation, and condensation; climate and biology (e.g., vegetation, animal life) were not accounted for, and watershed structure was equated to streams and rivers for the most part. Thus, these students' ideas about watersheds displayed fundamental gaps in understanding. The mountainous watersheds drawn by these students reflected the prototypical watershed example shown in many textbooks, magazines, and other resources (see Figure 4 for an example), and do not resemble the topography of watersheds in areas the students live. Additionally, these students' ideas about watersheds focused on a single river and only on natural areas. None of the students indicated that water or other materials on the land would be carried into the rivers and further transported through the watershed. Thus, students did not see the connection between point and nonpoint source pollution and watersheds or the applications to sedimentary geology and environmental science. The almost complete absence of ideas about land areas supplying water and other materials to a stream and river system is of particular significance.

The fact that some students in the upper grade levels exhibited similar ideas about watersheds as sixth and seventh grade students reinforces the notion that students' conceptualizations are resistant to change. At the same time, these students' ideas about watersheds are not much different than that of adults, suggesting that education is contributing little to the development of a citizenship knowledgeable about watersheds. Most citizens are not knowledgeable about the watershed concept, nor fully understand the hydrologic connection (Schueler and Holland, 2000). For example, only 41% of adults have any idea what a watershed is and only 22% knew that stormwater runoff was a major cause of stream pollution (NEETF, 1999). Thus, designing a curriculum based on students' ideas and that builds toward a scientific perspective is essential (National Research Council, 1996). Effective learning experiences requires a geoscience curriculum that is sequenced in a way that moves students toward scientific understanding-curricular continuity (Driver et al., 1994). The findings suggest that the following concepts need to be developed in order to improve students' understandings of watersheds and to enhance students' geoscience learning:

- A watershed is a land area that provides runoff that feeds rivers and streams.
- Every place on land is a part of a watershed, including the places where we live, work and play.
- Smaller streams flow into larger rivers forming a river system, a network of tributaries that flow into a major river.
- Watersheds consist of a river system, which drains water from the land within the watershed.

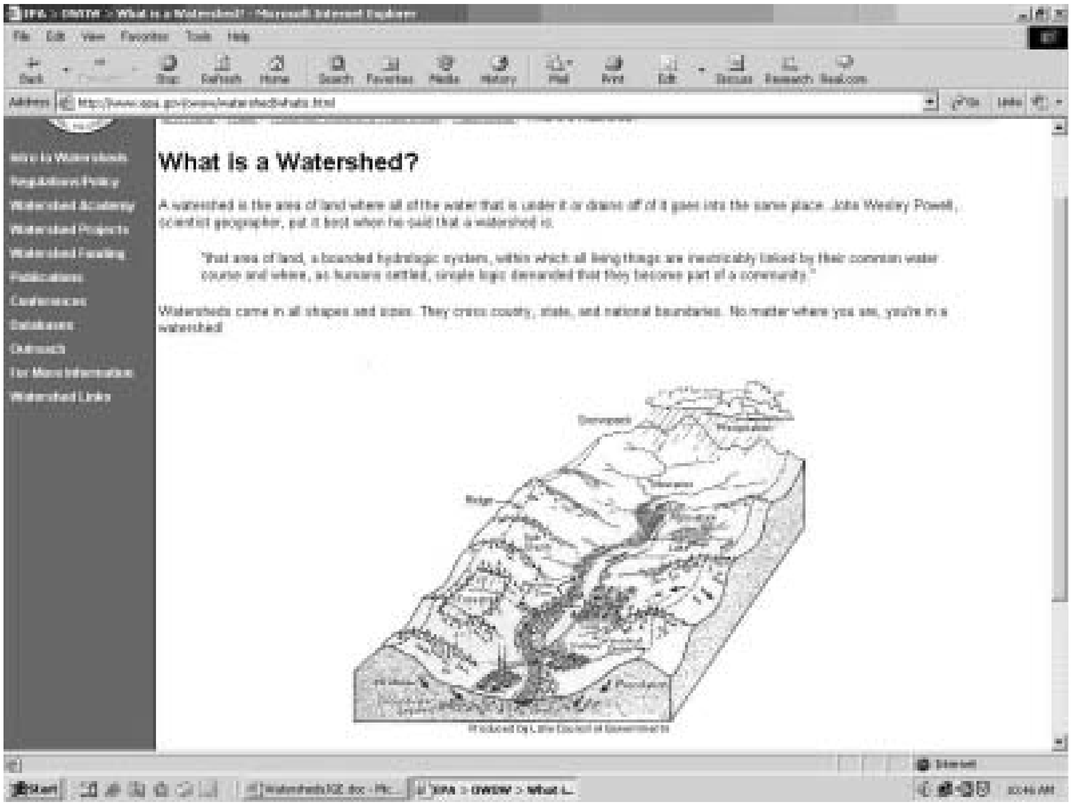

Figure 4. Screen capture of the U.S. EPA web site definition and example of a watershed (http://www.epa.gov/owow/watershed/whatis.html)

- Watershed boundaries are defined based on elevation. The elevation or divide determines the direction water flows or which basin precipitation flows into. In other words, a watershed can be defined for any and every point on a stream, river, or body of water.
- The earth's surface consists of numerous nested and joining watersheds that drain into lakes or oceans. These sub-watersheds, which may be further divided into smaller watersheds as defined by the elevation at a given location.
- Sediment and other substances and contaminants on land are transported into the stream through runoff and then transported through the watershed by the river system and into joining watersheds, lakes or oceans. The contaminants transported off the land area and through the river system are often referred to as nonpoint source pollution: fertilizer and pesticide runoff for example.

If students' ideas about watersheds are incomplete or poorly developed, instruction should assist students to construct conceptual models by building from the students' existing ideas. Students need opportunities to explore their existing ideas in an effort to build more scientifically accepted models. For example, if students hold a mountainous stream model it may be fruitful to show them a physical model of a watershed with low relief and elevation (see Patterson and Harbor, in press) and have students draw the physical model and compare it to their original mountainous stream drawing. Students could take a field trip, exploring the land use practices within their local watershed and then re-draw their watershed diagram; comparing and contrasting their initial drawing to their new drawing. Older students could compare and contrast topographic maps with different relief and elevation patterns as a means for exploring different watersheds or students could outline connecting watersheds as a way of seeing the relationship between watersheds, branching streams, and land use practices. Analogies between school bus routs, road systems and a branching stream and drainage basin could be made. Finally, students could conduct a stream monitoring study within a watershed and land use context. In these ways, students come to construct a more scientific understanding about watersheds, how their personal actions impact their local watershed, and how watersheds connect sediment source areas to depositional areas. If students are to develop a watershed ethic and become the informed future decision-makers about watershed management issues, they need to learn about watersheds and that learning builds from their existing conceptions.

REFERENCES

Ausubel, D.P., Novak, J.D., and Hanesian, H., 1978, Educational Psychology: A Cognitive View, New York, Holt, Rinehart, and Winston, p. 733.

Baxter, J., 1989, Children's understanding of familiar astronomical events, International Journal of Science Education, v. 11, p. 502-513.

Bishop, B., 1985, The social construction of meaning-a significant development in mathematics education, For the Learning of Mathematics, v. 5, p. 24-28.

Cobb, P., 1990, Multiple perspectives, in Steffe, L.P. and Wood, T., editors, Transforming Children's Mathematics Education: International Perspectives,

Hillsdale, NJ, Lawrence Erlbaum Associates, p. 200-215.
Dickerson, D. and Dawkins, K., 2004, Eighth grade students' understandings of groundwater, Journal of Geoscience Education, v. 52, p. 178-181.
Driver, R. and Bell, B.F., 1986, Students thinking and the learning of science: a constructivist view, School Science Review, v. 67, p. 443-456.
Driver, R., Guesne, E., and Tiberghien, A., 1985, Some features of children's ideas and their implications for teaching, In: Driver, R., Guesne, E., and Tiberghien, A., editors, Children's Ideas in Science, Buckingham, England, Open University Press, p. 191-201.
Driver, R., Squires, A., Rushworth, R. and Wood-Robinson, V., 1994, Making Sense of Secondary Science: Research into Children's Ideas, London, England, Routledge, p. 210.
Duit, R., 1991, Students' conceptual frameworks: consequences for learning science, In: Glynn, S.M., Yeany, R.H., and Britton, B.K., editors, The Psychology of Learning Science, Hillsdale, NJ, Lawrence Erlbaum, p. 65-85.
Eaton, J. F., Anderson, C. W. and Smith, E. L., 1983, When students don't know they don't know, Science and Children, v. 20, p. 6-9.
Erlandson, D.A., Harris, E.L., Skipper, B.L., and Allen, S.D., 1993, Doing Naturalistic Inquiry: A Guide to Methods, Newbury Park, CA, SAGE Publications, p. 198.
Glynn, S.M. and Duit, R., 1995, Learning science meaningfully: constructing conceptual models, in Glynn, S.M. and Duit, R., editors, Learning Science in the Schools: Researching Reforming Practice, Mahwah, NJ, Lawrence Erlbaum, p. 3-34.
Greca, I.M. and Moreira, M.A., 2000, Mental models, conceptual models, and modeling, International Journal of Science Education, v. 22, p. 1-11.
Happs, J.C., 1985, Regression in learning outcomes: some examples from Earth sciences, European Journal of Science Education, v. 7, p. 431-443.
Hodson, D., 1991, Philosophy of science and science education, In: Matthews, M.R. editor, History, Philosophy, and Science Teaching: Selected Readings, Toronto, OISE Press, p. 19-32.
Holstein, J.A. and Gubrium, J.F., 1994, Phenomenology, ethnomethodology, and interpretive practice, In: Denzin, N.K. and Lincoln, Y.S., editors, Handbook of Qualitative Research, Thousand Oaks, CA, SAGE, p. 262-272.
Kress, G., Jewitt, C., Ogborn, J., and Tsatsarelis, C., 2001, Multimodal Teaching and Learning: The Rhetorics of the Science Classroom, London, Continuum, p.188.
Libarkin, J.C., Beilfuss, M. and Kurdziel, J.P., 2003, Research methodologies in science education: mental models and cognition in education, Journal of Geoscience Education, v. 51, p. 121-126.
Manduca, C., Mogk, D., and Stillings, N., 2002, Bringing Research on Learning to the Geosciences. Report from a Workshop Sponsored by the National Science Foundation and the Johnson Foundation, p. 36.
Munson, B.H., 1994, Ecological misconceptions, Journal of Environmental Education, v. 25, p. 30-35.
National Research Council, 1996, National Science Education Standards, Washington, DC, National Academy Press, p. 262.
National Environmental Education Training Foundation, 1999, National Report Card on Environmental Knowledge, Attitudes, Behaviors: Seventh Annual Roper Survey of Adult Americans, Washington, DC, NEETF, p. 30.
Nussbaum, J., 1985, The Earth as a cosmic book, in Driver, R., Guesne, E., and Tiberghien, A., editors, Children's Ideas in Science, Buckingham, England, Open University Press, p. 170-192.
Osborne, R. and Freyberg, P., 1985, Children's science, In: Osborne, R. and Freyberg, P., editors, Learning in Science: The Implications of Children's Science, Auckland, New Zealand, Heinemann Publishers, p. 5-14.
Patterson, L.A. and Harbor, J.M., in press, Using assessment to evaluate and improve inquiry-based geoenvironmental science activities: case study of a middle school watershed E. coli investigation, Journal of Geoscience Education.
Patton, M.Q., 1987, How to Use Qualitative Methods in Evaluation, Newbury Park, CA, SAGE, p. 176.
Patton, M.Q., 1990, Qualitative Evaluation and Research Methods, Newbury Park, CA, SAGE, p. 532.
Piaget, J., 1970, Genetic Epistemology, New York, Columbia University Press, p. 84.
Rennie, L.J., and Jarvis, T., 1995, Children's choice of drawings to communicate their ideas about technology, Research in Science Education, v. 25, p. 239-252.
Rogoff, B., 1990, Apprenticeship in Thinking: Cognitive Development in Social Context, Oxford, England, Oxford University Press, p. 242.
Rubin, H.J. and Rubin, I.S., 1995, Qualitative Interviewing: The Art of Hearing Data, Thousand Oaks, CA, SAGE, p. 302.
Schueler, T.R., 2000, On watershed education, in Schueler, T.R. and Holland, H.K., editors, The Practice of Watershed Protection, Ellicott City, MD, Center for Watershed Protection, p. 629-635.
Schwandt, T.A., 1994, Constructivist, interpretivist approaches to human inquiry, in Denzin, N.K. and Lincoln, Y.S., editors, Handbook of Qualitative Research, Thousand Oaks, CA, SAGE, p. 118-137.
Shepardson, D.P., 2002, Bugs, butterflies, and spiders: children's understandings about insects, International Journal of Science Education, v. 24, p. 627-643.
Stahly, L, Krockover, G, and Shepardson, D., 1999, Third grade students' ideas about the lunar phases, Journal of Research in Science Teaching, v. 36, p. 159-177.
Stepans, J. I., Beiswenger, R. E. and Dyche, S., 1986, Misconceptions die hard, The Science Teacher, v. 22, p. 65-68.
Trop, J.M., Krockover, G.H., and Ridgway, K.D., 2000, Integration of field observations with laboratory modeling for understanding hydrologic processes in an undergraduate earth-science course, Journal of Geoscience Education, v. 48, p. 514-521.
Vygotsky, L.S., 1986, Thought and Language, Cambridge, MA, MIT Press, p. 287.
Wandersee, J.H., Mintzes, J.J., and Novak, J.D., 1994, Research on alternative conceptions in science, In: Gable, D., editor, Handbook of Research on Science Teaching and Learning, New York, Macmillan, p. 177-210.
White, R. and Gunstone, R., 1992, Probing Understanding, London, England, Falmer Press, p. 196.

National Association of Geoscience Teachers

Membership Application or Renewal Form

Name: ___________________________ Phone: ___________________________

Mailing Address: ___________________________________ Fax: _____________________

____ Email: ____________________

City: ______________________________ State: ________ Zip: ______________________

___College/University Professor @ ______________

___Precollege Teacher @ ____________________

___Other @ ______________________________

Checks, MasterCard, or VISA (US funds only) are payable to:National Association of Geoscience Teachers. Mail to: NAGT, PO Box 5443, Bellingham, WA 98227-5443

Membership	**Rates (US funds)**
Regular USA	$35 _____
Outside USA	$47 _____
Student–USA	$20 _____
Student–outside USA	$32 _____
Retired NAGT member	$30 _____
Library Subscriptions	
Regular USA	$55 _____
Outside USA	$67 _____
_______New	_______Renewal

- ❑ Check
- ❑ Credit card: MC/VISA (circle one) Number: ___________________________

Signature: _____________________________ Exp. Date _____________________________

The *Journal* and membership year runs from January to December. Subscriptions received after June 1 will begin receiving the *Journal* in January of the following year. Back issues are available for $15 (foreign $18) each.

*To qualify for student rate, indicate and obtain verification from a NAGT member:

___Undergraduate ___Graduate ____

Signature of NAGT member School