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Engaging Students to Learn Through the Affective Domain: A new Framework for Teaching in the Geosciences

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ABSTRACT

To motivate student learning, the affective domain—emotion, attitude, and motivation—must be engaged. We propose a model that is specific to the geosciences with theoretical components of motivation and emotion from the field of educational psychology, and a term we are proposing, "connections with Earth" based on research in the fields of environmental education and art education. When all three of these components (motivation, emotion, and connections with Earth) are combined in the classroom, students may experience greater interest in and connection to the content. This interest and connection may lead to greater motivation to learn and value the content. We use our model to evaluate three practices in geoscience education and show that their demonstrated success in achieving student learning lies in the attention to students' affective needs as well as to delivery of content. We propose a future research agenda using currently developed, validated instruments that can measure these motivational and attitudinal shifts to determine what practices work best for our students from both cognitive and affective perspectives. Although this was conducted in both Europe and the United States, the implications of this research may extend across cultures and nationalities. Additional research needs to be conducted to understand these implications. © 2011 *National Association of Geoscience Teachers*. [DOI: 10.5408/1.3543934]

INTRODUCTION

How many geoscience instructors have walked into their introductory class on the first day and asked the students something along the lines of: "What is your interest in the geosciences?"—only to be met with a deafening silence? How are we to interpret this silence? Is it students' lack of experience with geoscience prior to college (Ridky, 2002; Willyard, 2008), lack of interest in science in general, a fear of standing out, or is it that most students enroll in the introductory classes only out of necessity, in order to fulfill a science requirement (Gilbert *et al.*, 2009)? As experts, we are aware of the excitement of geology and the fundamental concepts we want our students to learn, but how effective are we at helping our students *want* to learn these topics? One of our goals as educators is to engage students in learning geoscience so they are motivated to continue learning on their own in informal settings, through additional coursework, or as geoscience majors. In this article, we define geoscience to include any discipline that pertains to studies of Earth, including geology, physical geography, meteorology, and oceanography.

Although recent efforts to determine geoscience curriculum for undergraduates in the U.S. (e.g., Fuhrman *et al.*, 2005; Earth Science Literacy Initiative, 2010) and the European Union (e.g., Bologna Process, 2010; Boyle *et al.*, 2009) have been an important conversations about what we teach our students, *how* we teach in order to engage and motivate students has been shown to be as important as choice of content (Bransford *et al.*, 2000; Patrick *et al.*, 2003; Brophy, 2004). Research on what motivates students to learn provides insight into why certain pedagogical practices are effective for capturing student attention and changing attitudes. For example, students who perceive course content to have less value show lower levels of motivation to learn (Wigfield and Eccles, 2002). Compelling a student to take a science course would seem to contradict his or her desire for control over the learning process and devalue what is taught. Further, research has shown the more students have a clear sense of their future goals, the less they value the content in introductory general studies courses; e.g., introductory geoscience courses (Husman *et al.*, 2007). These findings help us understand our sense that geoscience educators in introductory courses are fighting an uphill battle from the first day of class.

The purpose of this article is to develop a practical model for the multiple factors that motivate student learning, which can be used by educators to design effective learning opportunities. Perhaps the single most important factor is interest, or what psychologists call "intrinsic value." Research shows that the best predictor of students taking a second class in a topic is not their performance in the first class, but their interest in the subject (Harackiewicz *et al.*, 2000). Thus, our model not only incorporates what we know about enhancing student performance with learning outcomes, but also includes what we know about enhancing student interest in geoscience.

A MODEL OF THE AFFECTIVE DOMAIN FOR THE GEOSCIENCES

We propose a model (Fig. 1) that incorporates three aspects of the affective domain as an effective construct to

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enhance student understanding and valuing of geoscience content (Fuhrman *et al.*, 2007). The integration of cognition and affect in learning has been championed as a needed movement in educational curriculum reform (Brophy, 2008). The affective domain (Krathwohl *et al.*, 1964) incorporates aspects of learning that include feelings, emotions, attitudes, motivations, and values (for more information see the Cutting Edge Workshop website, http://serc.carleton.edu/NAGTWorkshops/affective/intro.html). The three affective elements of our model—*motivation, emotion*, and *connections with Earth*—are not independent but overlapping (Fig. 1). For example, interest is both an emotional and cognitive response that may be aroused by a sense of connection with Earth, and indicates a motivation for learning more about Earth (Renninger and Hidi, 2002). In Fig. 1, the different regions of overlap represent opportunities to engage our students in the classroom and in the field. This may include opportunities for students to interact with one another, to learn from one another, and connect the content to places of meaning.

Although the model components, motivation and emotion, apply to any learning situation, what makes our model unique to the geosciences is the third element: connections with Earth. The center of Fig. 1, where the circle representing connections with Earth overlaps with emotion and motivation, is the "sweet spot" of optimal engagement in learning about Earth and where a student may begin to internalize the content as a part of his/her identity (Table I).

There is not enough room in this article to review the research conducted to date on motivation, emotion, and connections with Earth in educational settings. We have narrowed the focus to those aspects that are most appropriate for teaching introductory-level geoscience courses, typically to nonscience majors. The references cited herein provide access points to the extensive literature for the reader interested in deeper investigation.

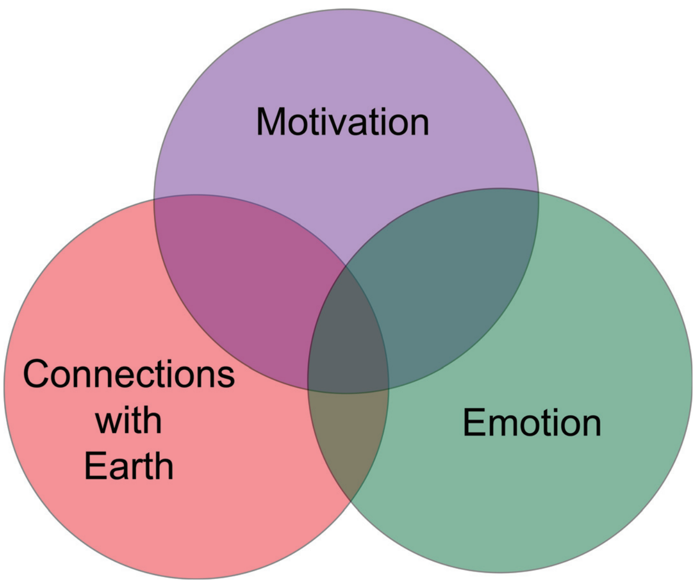

FIGURE 1: (Color online) The three domains in which geology is most likely to influence student attitudes toward learning the geosciences is through motivation, emotion, and connections with Earth.

Motivation Theory

Motivation is an important area of research on student learning. For example, motivation was a focal point of a 2007 "On the Cutting Edge" workshop dedicated to the affective domain in geoscience learning (Science Education Resource Center, 2007). Overviews of the theoretical framework and empirical support for motivation theory are provided by Brophy (2004) and Schunk *et al*. (2008). However, relatively few researchers have connected motivation theory with geoscience education (Baker and White, 2003; Jarrett and Burnley, 2003; Fuhrman *et al*., 2007; Posnanski, 2007; Srogi *et al*., 2008; Stokes, 2008; Stokes and Magnier, 2008; Stokes and Boyle, 2009).

Self-determination theory (SDT), one aspect of motivation theory, is a useful starting point that describes students' willingness to engage based on fulfilling three fundamental psychological needs: autonomy, competence, and relatedness (Ryan and Deci, 2000). These needs influence students' responses in the form of goals and self-regulation. Students who are able to have some control over their learning experiences (autonomy), who feel capable of succeeding in a task (competence), and who feel part of a classroom community (relatedness), are more likely to be *intrinsically motivated* to learn within that classroom. Students who are intrinsically motivated have a positive affect toward learning, are active learners, and are more likely to manage their own learning (Deci and Ryan, 2008). In other words, the kind of students we would like to have in our classes are those who are intrinsically motivated.

Conversely, a student who engages in a task only in order to receive rewards such as grades, rather than for the learning experience itself, is described as being *extrinsically motivated*. Extrinsically motivated students may remain focused on rewards and outcomes rather than on learning itself. SDT helps to explain some student attitudes and provides a key insight: that is, how instructors meet students' needs strongly influences how students approach their learning experiences. However, SDT does not necessarily tell us what makes students value and want to learn the content, and provides only limited notions of the ways that students cognitively construct value. The focus on intrinsic versus extrinsic motivation brings us to an impasse as educators; some argue that students will never achieve complete intrinsic motivation (Brophy, 2004) because, in the classroom setting, their autonomy has limits and their sense of competency is challenged.

Rather than focus on the notions of intrinsic motivation, it may be more appropriate to examine how we can make our students sustain interest in the content. Interest comprises affective response and focused attention to content over a sustained period of time and may result in a desire to re-engage with the content based on predispositions (Hidi and Renninger, 2006). Hidi and Renniger (2006) define four phases of interest, starting with "triggered situational interest" and ending with well-developed "individual interest" (Hidi and Renninger, 2006). Triggered situational interest requires an external agent (like an instructor) to excite one about a topic, but in order for interest to be sustained and become self-driven it must become internalized into individual interest. Although students may come to geoscience courses with few opportunities for the development of interest due to their lack of prior exposure to the geosciences (Willyard, 2008; Ridky, 2002), educators can provide

TABLE I: The overlap of the different domains from Fig. 1 and how those overlaps are applied in the classroom.

	Motivation	Emotion	Connection to Earth
Motivation	*Self-efficacy*: Students who expect to be successful at a task in which they are engaged are more likely to be motivated to learn.	*Prosocial opportunities*: For students who value the opportunity to engage in social interactions with their classmates, peer interaction can increase student desire to persist and learn.	*Modeling appreciation*: As experts, we must model for our students how to think about connections with Earth, and ask them to replicate the thinking process.
Emotion	*Interest*: Attributes of engaging student interest include keeping students actively engaged with the content, which allows them to feel they have control over their learning; supporting their expectations for success on a task, and providing opportunities for them to value what they are learning.	*Postive and negative emotions*: Students who experience positive emotions such as joy, hope for success, and pride and low levels of negative emotions like boredom, anxiety, and shame are more likely to persist and learn.	*Place attachment*: Individuals attach self-identity to a place through emotion. If we support students to make connections between the content and their own place attachments, it may increase a desire to learn the content.
Connection to Earth	*Identity (sweet spot)*: If students start to identify with the content as personally meaningful and valuable, their interest may change from temporal to sustained individual interest, which could lead to a greater desire to learn more.		*Connections to aesthetic*: Students who have opportunities to connect content to their aesthetic appreciations may begin to value the content.

opportunities to trigger "situational interest" and create "maintained situational interest" (the next phase in the Hidi and Renninger model), which can lead to an enduring personal connection to geoscience. Moving students from "triggered" to maintained situational interest requires exposure to content and specific supportive feedback that allows students to experience success and relate the content to their own experiences (Hidi and Renninger, 2006). The movement from triggered situational interest to "emerging individual interest" may be gradual, require multiple triggers, and may regress (Renninger, 2009). Enjoyment is distinct from interest, being more dependent on the individual student's predispositions, whereas interest is more dependent on the environment and culture of the classroom (Harackiewicz *et al.*, 2000). Research on the development of interest also underscores the importance of creating a positive learning environment; students who have positive associations with the content may begin to develop individual interest, which is the greatest predictor of choosing to register for another geoscience course (Harackiewicz *et al.*, 2000).

One compounding difficulty of working with students who may be new to a field, and only at the first phase of interest development, is the likelihood that these students will also have low self-efficacy (Hidi and Renninger, 2006). Self-efficacy, belief in the ability to succesfully complete a task, and the accuracy of that belief, is a critical component to student motivation (Bandura, 1977; Zimmerman, 2000). Understanding self-efficacy can help instructors make better choices when it comes to previewing academic tasks, structuring academic tasks, and providing feedback. Although our students come with little exposure to the content of geosciences, they likely still have an initial preconception of their own self-efficacy. Students' assessment of their self-efficacy can change over the course of a semester (Husman and Hilpert, 2007); as that assessment changes so will the amount of effort students choose to put into a class, their willingness to persist in the face of difficulties, and their willingness to choose to engage in geoscience in the future (Schunk and Pajares, 2005).

Theories of Emotion

Research shows that emotion is fundamental for learning; a high level of intrinsic value and positive emotions like enjoyment of learning, hope for success, and pride of a given task result in more effective learning (Schutz and Pekrun, 2007). Students are likely to engage in more adaptive learning strategies such as elaboration, organization, and critical thinking when in an emotionally supportive learning environment (Turner *et al.*, 2002). In addition, students with positive emotions will choose to engage in a task and are more likely to persist when they encounter difficulties or are faced with failure (Pintrich and DeGroot, 1990; Pekrun *et al.*, 2002). Conversely, researchers from both Germany and the U.S. have demonstrated that students with negative emotions (e.g., anxiety, anger, and shame) may learn less, because they are more likely to use poor processing skills such as memorization or rehearsal of content, and are more likely to withdraw from a class when faced with difficulties and failure (Pekrun *et al.*, 2002; Shell and Husman, 2008; Turner *et al.*, 2002). Therefore, it is critical for instructors to understand the emotional experiences of their students specifically within the context of their geoscience class (Goetz, Frenzel *et al.*, 2006; Goetz, Pekrun *et al.*, 2006). Emotionally supportive environments can be fostered by creating a community of learners, providing helpful feedback, and creating opportunities for peer interactions that limit competition (Turner and Patrick, 2004). Although positive emotions are commonly associated with positive learning outcomes, recent research indicates that this connection is much more complicated that initially proposed (Linnenbrink, 2008).

Motivation and emotion are two dimensions of educational psychology research that frequently are examined together (e.g., Schunk *et al.*, 2008). More specifically, much of the work conducted in Greece (Efklides and Petkaki, 2005), Germany (Hidi *et al.*, 2004), Australia (Ainley *et al.*, 2005), and the U.S. (Renninger and Hidi, 2002) on interest has focused on the interplay between student interest and positive emotion. Although both negative and positive emotions have been related to triggered situational interest, positive emotions toward learning experiences have been shown to support interest development over time (Ainley *et al*., 2002).

Connections with Earth

We have chosen a general descriptor—*connections with Earth*—for this aspect of our model because there are many ways in which people connect with Earth; for example, an aesthetic appreciation for the beauty of a landscape; a sense of awe or wonder at the power of geological processes; or a profound feeling of personal attachment to a particular place on Earth. The same range of responses that we combine as "connections with Earth" is termed "aesthetic appreciation," "values of life," "beauty," "sublime," or "sublimely cool" by other authors (Dewey, 1934; Pestrong, 1994; Kellert, 1996; Neumann, 2005; Kieffer, 2006; Wong, 2007), who posit that direct sensory experiences and a sense of awe or wonder can lead to increased meaning and value, engagement of the emotions, and a deep sense of caring about Earth. In philosophy, however, the meaning of "aesthetic" is subject to some debate (e.g., Carlson, 2000; Parsons, 2006; and references therein); therefore, we use connections with Earth to convey our meaning and avoid disciplinary controversies.

A number of studies from environmental sociology, psychology, and education address people's attitudes, beliefs, values, and behaviors concerning the environment (e.g., the recent review by Dietz *et al*., 2005). Several survey instruments have been developed, including those by Rokeach (1973), Schwarz and Bilsky (1990), Stern *et al*. (1995; 1998), and Dunlap *et al*. (2000). Recent advances in this research incorporate consideration of a person's sense of identity as it pertains to his/her relationship with the natural world; variably termed the "ecological identity," (Thomashow, 1995), the "ecological self, " Wilson (1996), or "environment identity," (Stets and Biga, 2003). All of this work is written from an environmental—not a geological—perspective and is heavily weighted toward the biological realm. For example, biologist E. O. Wilson has argued that humans have a genetically determined tendency to focus on and bond with other living organisms, and termed that tendency "biophilia" (Wilson, 1984).

Connections with Earth may also be viewed as a more geologically focused counterpart to the affinities people variously hold for other components or aspects of nature or the physical environment. From his extensive synthesis of the environmental perceptions and values held by a panoply of ancient and modern cultures, geographer Yi-Fu Tuan (1974) posited the existence of "topophilia," which he defined as "all of the human being's affective ties with the material environment," (Tuan, 1974, p. 93)—encompassing the anthropogenic or "built" environment as well as natural surroundings. (We would have similarly proposed geophilia to mean connections with Earth, but the term is already used to describe organisms that inhabit the soil). Scholarly work on the sense of place—the combined set of meanings and attachments people or groups affix to places (Brandenburg and Carroll, 1995; Williams and Stewart, 1998)—which is discussed in more detail below, is another more human-centered area of research into connections with Earth. What has not yet been done, to our knowledge, is to assemble a complete picture of how people's attitudes, beliefs, values, and affinities (the human affective domain) intersect with the physical reality of the geological world, the conceptual constructs of the geosciences (e.g., Earth Science Literacy Initiative, 2010), and the direct experience with and exploration of geology. As of yet, there is no all encompassing, validated instrument that measures connections with Earth. This remains as future work, and we intend this section to be an introduction to the many different and overlapping facets of connections with Earth currently in the literature and demonstrate future avenues for developing a complete measurement tool within the geosciences based on work in other fields.

A session at the 2008 Annual Meeting of the Geological Society of America (GSA), "The Human Connection with Planet Earth: What is it and Why is it Important?" explored emotional, place-based connections and the aesthetic. Several presenters at this session (Mogk, 2008; Moores, 2008; Nuhfer, 2008; Smaglik, 2008) expressed convictions that there is some inherent and special affinity of people for the Earth, that this affinity is essential for our well-being, and that it is part of our motivation for learning geoscience. Some scientists have described the importance of connections with the natural world to scientific creativity and effective science teaching, (Fox Keller, 1983; Pestrong, 1994; Neumann, 2005; Kieffer, 2006; Eerola, 2008; Shick, 2008), but this is often the "hidden" aspect of science: why we as geoscientists love what we do, but rarely emote this feeling to our introductory students as a dimension of science (Flannery, 1992).

By contrast, many 19th-century scientists and naturalists seamlessly integrated aesthetic and emotional connections with Earth into their scientific observations. Thoreau (1841) eloquently expressed the sense of unity and harmony with nature when he desired, "to be nature looking into nature with such easy sympathy as the blue-eyed grass in the meadow looks in the face of the sky," (p. 36–37).

In writing about the Galapagos Islands, Darwin (1845, p. 398–399) used emotional language and invoked the sense of mystery that is considered by some (e.g., Godlovitch, 1994) to be an essential element of the aesthetic experience of nature:

> "October 8th—The archipelago is a little world within itself, or rather a satellite attached to America, whence it has derived a few stray colonists, and has received the general character of its indigenous productions. Considering the small size of these islands, we feel the more astonished at the number of their aboriginal beings, and at their confined range. Seeing every height crowned with its crater, and the boundaries of most of the lava-streams still distinct, we are led to believe that within a period, geologically recent, the unbroken ocean was here spread out. Hence, both in space and time, we seem to be brought somewhat near to that great fact—that mystery of mysteries—the first appearance of new beings on this earth. "

Aesthetic connections were emphasized in the May 2000 issue of the *Journal of Geoscience Education* devoted to "Teaching Earth Science with Art," in which Rosenberg (2000) and Montgomery (2000) asserted that some artists portray geological landscapes and materials with such interpretive insight that they should be considered "founders" of geology. Several authors have proposed that artists, poets, and scientists have in common certain cognitive approaches, uses of language and metaphor, and observational methodologies (Flannery, 1992; Pestrong, 1994, 2000; Wright, 2000; Rule *et al*., 2004), but have diverged over time due to changing perspectives of objectivity [science] versus subjectivity [art] (Bedell, 2001).

Carlson (2000) and many geoscientists argue that scientific knowledge is a valid, even essential part of the aesthetic or sublime experience (e.g., Wong, 2007), particularly as it increases the meaning and value found in nature, and concern for its sustainability. A strain of philosophy called "scientific cognitivism" posits that scientific knowledge (at least at a basic level) is required for aesthetic responses to the natural world beyond that of a basic sensory appreciation (e.g., Rosario and Collazo, 1981; Carlson, 2000). This is the position we are taking for our introductory geoscience classrooms; however, it is a viewpoint not always shared by others working in aesthetics, education, and environmental studies (e.g., Carroll, 1993; Godlovitch, 1994; Brady, 2003; Budd, 2002).

The educational role of human connections with the natural world is complex, and almost all of the published work comes from an environmental, rather than a geological perspective. For example, college environmental curricula now incorporate different approaches to the aesthetic of the natural environment (Carlson, 2000; Brady, 2003) as a result of the movement that began in 1966 to include aesthetics in environmental ways of thinking (Hepburn, 1984). For example, Brady *et al*. (2004) describe creating a field-based course in the UK in which students experience the landscape in a multisensory fashion and reflect upon those experiences. This approach is important for students to begin to develop a notion of the ecological identity (Thomashow, 1995) or ecological self (Wilson, 1996).

Fostering students' connections with Earth as part of their human development process has become established in environmental education, which commonly has an explicit goal to produce knowledgeable citizens motivated to act in environmentally responsible ways. Thus, environmental educators are deeply involved in describing and measuring students' attitudes and behaviors toward the natural world. A common approach is to categorize attitudes and behaviors as anthropocentric, biocentric, or ecocentric (e.g., Withgott and Brennan, 2009), using value-based terms derived from the environmental ethics literature concerning altruism (Dietz *et al*., 2005). As noted by Hayes-Conroy and Vanderbeck (2005), attitudes alone tend to be a poor predictor of environmentally aware behaviors, and more recent studies incorporate concepts and instruments related to identity development. Modern sociological theories hold that a person's identity is dynamic rather than fixed, and is "constructed and reconstructed in relation to socio-cultural contexts" (Hayes-Conroy and Vanderbeck, 2005). Thomashow (1995, p. 3) used the term ecological identity to describe "how we extend our sense of self in relationship to nature," and considered one role of environmental education to be helping students in their identity work on their evolving relationship with nature. Stets and Biga (2003) conducted a detailed and quantitative study of 437 college students, incorporating instruments to measure values, attitudes, environment identity, and gender identity, and found that environment identity—and not ecological worldview attitude—significantly influences proenvironment behavior. In a qualitative study involving in-depth, semistructured interviews of 13 students, Hayes-Conroy and Vanderbeck (2005) found that students do indeed undertake significant work on their ecological identity in two multidisciplinary college environmental courses. They describe students' initial attitudes and values, and the complex ways in which the students articulate their environmental identity, delineate the boundaries of that identity, and situate that identity within their perceived social context. In a qualitative study involving structured interviews of 46 currently active environmentalists (Chawla, 1999), formative experiences in natural areas were identified as the most important reason for their dedication to their current work. These environmentalists also indicated that people are most likely to become involved if they become fully informed. These studies provide insight into how to create meaningful experiences for students to engage and connect with Earth. In addition, these approaches to understanding connection to place pose possible research pathways in which a mixed methodology of qualitative interviews and quantitative measurements may provide insight into student connections to Earth from a geoscience theoretical framework.

An important caveat: for students whose connections with Earth are strongly influenced by cultural or religious contexts, scientific information can seem irrelevant, contradictory, alien, or even threatening (Aikenhead, 1996, 1997; Aikenhead and Jegede, 1999; Dagher and Boujaoude, 1997; Semken, 2005). In addition, what geoscience educators consider to be developing a connection to Earth may need to be expanded beyond the realm of natural landscapes, if we are to create a more inclusive environment for all of our students (Gruenewald, 2003b). While many geoscientists feel a connection with Earth most strongly while we are in the natural landscape (camping, hiking, etc.), many students feel discomfort and a disconnect when out of their comfort zone (Orion and Hofstein, 1994). If we are to develop a broadly encompassing measure of connections with Earth, it must allow for encounters with nature in urban, human-dominated settings as well as rural or wilderness settings. These connections include those of place attachment, an emotional attachment to personally meaningful places (Williams and Vaske, 2003).

We propose that appropriate learning opportunities in geoscience classrooms provide our students with opportunities "to expand their sense and perception of life, and to widen and sharpen their connections with the world around them," (paraphrased from Donaldson, 2001; Dewey, 1934); but how can those connections be defined from a geological (rather than ecological) perspective, and how can they be measured? As seen from the presented examples, determining how to measure geoscience affect are among the critical questions for future work, and the many facets of connections with Earth described above (including place attachment, an engagement of emotions, a deeper connection through the combination of knowledge, beauty, increased creativity, and environmental identity) provide a foundation for this work. The importance of integrating research on human connections with Earth and research on motivation is illustrated by the insight that it is not a question of the public having sufficient scientific *knowledge*, but whether they have "sufficient *interest in engaging* in such appreciation," (Parsons, 2006, p. 183, italics added).

In the following sections, we examine how specific educational best practices—field-based experiential learning and place-based learning—can foster students' connections with Earth and how these connections relate to students' emotions and motivations in our geoscience classrooms.

CURRENT BEST PRACTICES: WHAT WE KNOW AND WHAT WE NEED TO KNOW

Three strategies commonly used to enhance student learning in geoscience education: (1) peer instruction with formative assessment using ConcepTests; (2) field-based experiential learning; and (3) place-based learning; have been shown in some test cases to enhance student geoscience-content learning (McConnell *et al.*, 2006; Elkins and Elkins, 2007; Semken and Butler Freeman, 2007). Content learning alone, however, is not sufficient if educators want to engage students' interest in geoscience to maximize learning in and beyond a course. Below we use the affective-domain elements in our proposed theoretical framework (motivation, emotion, and connections with Earth) as lenses to clarify why these best practices are successful, and what aspects of student affect may yet need to be explored.

ConcepTests with Peer Instruction and Other Cooperative Learning Strategies

ConcepTests are a recently developed formative assessment designed for use with peer instruction (McConnell *et al.*, 2006). They exemplify cooperative learning strategies (i.e., activities intended to be carried out collectively by small groups of learners for mutual benefit) that provide structured opportunities in class for students to discuss concepts and course content with each other, and have been shown to be effective for improving both student learning and attitudes (Crouch and Mazur, 2001; McConnell *et al.*, 2006; Smith *et al.*, 2009). ConcepTests allow students to check their comprehension by providing mastery experiences that build their confidence in their ability to successfully complete the task (self-efficacy), which leads to a higher expectation of success.

A potentially fruitful line of investigation is whether ConcepTests can trigger and sustain student interest in geoscience topics. This is a critically important question because the greatest predictor of students selecting another class in a particular content area is if they sustain individual interest in the content (Harackiewicz *et al.*, 2000). There are activities and strategies that are commonly employed in the classroom (e.g., fun videos, entertaining lectures), which may trigger, but not maintain situational interest. In order to sustain interest, students must be engaged in meaningful tasks, learning content that they find relevant, in which they are actively engaged (Harackiewicz *et al.*, 2000; Renninger and Hidi, 2002). Cooperative learning strategies provide opportunities for active engagement, and students who are in the first two phases of interest development will especially benefit from the self-reflective support of ConceptTests and cooperative learning (Renninger, 2009). Instructors must consider the likely phase of interest of their students carefully and tailor instructional materials accordingly.

Viewing peer interactions through the affective lens of emotion reveals many reasons why cooperative learning strategies work. Encouraging positive interdependence among students (Johnson *et al.*, 1991), described as a prosocial goal in the motivation literature (Wentzel, 1998), is essential for creating a classroom community and is valued by the students (Summers and Svinicki, 2007). Students have multiple goals when they enter our introductory classrooms, not all of which may be content specific, or even academically focused. Recent evidence supports that students from the UK (especially women) have goals of interacting with others in an effort to develop connections (Boyle *et al.*, 2009; Stokes and Boyle, 2009), which are referred to by motivation researchers as prosocial goals (Summers and Svinicki, 2007). Table I indicates how interest and prosocial goals are examples of overlap between the motivational and emotional lenses of our model in Fig. 1. Student interactions typically slow the pace of a course; if the instructor responds by reducing detail, emphasizing the essentials, and allowing students to take time for speculation and investigation (Flannery, 1992), the result may be enhanced interest, engagement, and learning. Using peer discussion to encourage more holistic thinking with not as much separation of subjective and objective perspectives opens geoscience content to different kinds of learners. Creating community and encouraging different kinds of thinking may be especially successful approaches for engaging women and minority students traditionally under-represented in science (Flannery, 1992; Levine *et al.*, 2007).

Learning often involves discomfort, confusion, and frustration; both instructors and peers can help foster positive emotions to counter those that may lead students to disengage and transform the journey of the learning experience as described by Dutch researchers, Boekaerts and Minnaert (2006). We view this process from the emotion perspective, although several of the authors cited here have described this as an aesthetic experience. Wong (2007, p. 73) describes intense learning as a sublime experience, "on the bridge between what is within and what is beyond our grasp, we are filled with ideas and imagination inspired to reconsider about what is and what could be." Flannery (1992, p. 11) makes the critical point that in order to transform feelings of frustration, helplessness, confusion and intimidation into feelings of competence and joy, "for affective change to occur, feelings must be allowed to surface in the classroom; the objective must be joined to the subjective, the rational to the intuitive and aesthetic." Having students work together in a carefully structured environment of cooperation and support (Johnson *et al.*, 1991) can allow feelings to emerge and both cognitive and affective change to begin.

Research has consistently demonstrated the importance of modeling and scaffolding along with clear expectations and constructive and timely feedback to the development of self-efficacy and adaptive motivation (Zimmerman, 2000; Schunk and Parajes, 2005). In helping our students to understand how to engage in the content and value what they are learning, it is important to model that behavior (Chi *et al.*, 1981) and then scaffold the process for our students through specific opportunities to reflect on their own affective response (Pugh, 2002). Collaborative learning, therefore, does not automatically support student motivation; only when students receive constructive feedback, have an opportunity to witness coping as well as mastery models, and feel supported in their own explorations will collaborative learning support student motivation (Zimmerman, 2000).

A virtually unexplored area of research is the extent to which collaborative peer interactions and our third affective domain component, connections with Earth, intersect in geoscience education. How do peer interactions influence instructor attempts to build student connections with Earth? Conversely, is a sense of connection with Earth a motivating factor for students to collaborate in learning geoscience?

Field-Based Experiential Learning

Field-based learning remains a hallmark of undergraduate geoscience education, recently evidenced by a special interactive poster session at the 2004 GSA Annual Meeting, a special issue of the *Journal of Geoscience Education* (v. 54, 2006) dedicated to "Teaching in the Field," and a *GSA Special Paper* (Whitmeyer *et al*., 2009). Field experiences can build confidence and, if students can expect to do well in field experiences, they may find more value in the content they are learning (e.g., Gonzales and Semken, 2006, 2009; Hemler and Repine, 2006; Tedesco and Salazar, 2006). But field experiences can take students farther and be truly transformative events in their lives. Even students with relatively limited background in geoscience classes can make quantum leaps in understanding, skills and sense of themselves as geoscientists (e.g., Hemler and Repine, 2006). Hemler and Repine (2006) provide a number of different measures of students' growth during an inquiry-based field experience (although it should be noted that this was a small-scale investigation that may not be generalizable to larger groups of formal or informal learners). The eight participants in this program could see themselves as geoscientists (Hemler and Repine, 2006) and appreciate the beauty in the complexity of Earth. Field-based learning can provide an opportunity for the kind of identity development that may lead to emerging personal interest (Renninger, 2009). This is what we might consider the ultimate "sweet spot" in our model where all three of our theoretical dimensions overlap (Fig. 1). So while Hemler and Repine's study is not generalizeable, the program and approach to student learning of the geosciences bears further study in light of this model.

At their most successful, field experiences provide opportunities for students to feel what Polanyi (1962) describes as the "passion" of science: a merging of an appreciation of scientific value (or a deep interest in learning about Earth) with the students' sense of their capacity for discovering scientific knowledge. In a larger scale example, Stokes and Boyle (2009) describe student experiences in an extended field activity for geology majors in the U.K. While the focus of their research is about how the affective domain influences their cognitive gains (including interest and motivation), students also mention the experience of the outdoors as a positive component to their learning experience.

Geologists tend to view field experiences as a rich opportunity for cognitive learning, but also for prosocial opportunities; this appears to be a common overlap for our student needs and geologic perspectives, and most likely indicates an overlap between the emotion and motivation components of our model. Evidence supports that even when students are anxious about working in the field, the prosocial interactions generated during field experiences lead to a positive learning experience (Hemler and Repine, 2006; Boyle *et al*., 2007; Stokes, 2008; Stokes and Magnier, 2008; Stokes and Boyle, 2009).

Doing geology in the field is a potentially obvious way to connect students with Earth, as scientists and as stewards. Some studies provide evidence for significant shifts in students' attitudes as a result of field experiences. For example, Hemler and Repine (2006) interpret aspects of their students' work as indicating a deeper understanding of the nature of science as a human construct. This critical element, commonly ignored in the science curriculum (Abd-El Khalick and Lederman, 2000), may be brought out more clearly in inquiry-based field studies, especially if we hope to help our students understand how to think geologically and to start to make the connections between the formal classroom setting and the informal learning opportunities in their everyday lives (Girod *et al*., 2003). There has been a call for teaching geoscience in a context that includes environmental and humanitarian issues in order to strengthen students' connections to and sense of responsibility for Earth (e.g., Pestrong, 1994; Smaglik, 2008). There is limited evidence that increased knowledge of geoscience leads to this outcome (Wandersee and Clary, 2008; Kirk and Thomas, 2003). Tedesco and Salazar (2006) use excerpts from student reflection papers following a field-based service-learning project to illustrate attitudinal change leading to increased understanding of the importance of the environment and a greater sense of responsibility. However, this outcome is by no means universal. For example, Hill and Daniel (2008) found that increased information about the ecological benefits of a dense woodland landscape did not change people's preference for an open savannah landscape as having greater "scenic beauty," although this result could have been skewed by the quality of their photographic images (Tinio and Leder, 2009). Clearly, there is still ample opportunity for research to explore our students' connections with Earth and how those inform, and are informed by, the field (both real and virtual) experiences in our geoscience curricula. Most environmentalists (and children) report a greater connection to Earth based on positive experiences in the outdoors from their childhood (Sobel, 1996; Wilson, 1996). Are these positive feelings we can help to recreate for our students?

We assert that for most geoscientists scientific knowledge increases meaning and value and motivates learning (e.g., Carlson, 2000; Wong, 2007)—an overlap of the motivation and connections with Earth portions of our model—but is this true for our students? Consider a concrete example: when a geologist looks at the Grand Canyon, she sees not only the beauty of the canyon, but also the time and processes involved in forming that canyon, the power of the forces involved; the cognitive framework knowledge that she possesses helps her to value her aesthetic and emotional connection all the more powerfully (Carlson, 2000). However, this assertion has not been thoroughly researched; as Smaglik (2008) asked: "is there a link between our curiosity about how Earth works and our desire to be connected to it?" For the purposes of this paper, let us assume that the knowledge that informs our "expert" perspective deepens our affective connections with Earth. This brings us to the more important question of how we transfer this experience and mindset to our students with their "novice" perspective. Introductory students in particular lack the expert framework (Chi *et al.*, 1981; Petcovic and Libarkin, 2007), and so are less likely to have cognitively informed emotional connections with geoscience. In a more quantitative example, Leopold (1969) applied a diverse set of factors (physical, biologic and water quality, and human use and interest) to classify different river systems which resulted in a uniqueness score based on these different factors. He determined that reaches of river systems that held greater aesthetic values (e.g., Grand Canyon) also tended to possess larger uniqueness values (Leopold, 1969).

One approach is for instructors to *model* their thinking processes and appreciation (Table I). Sharing our passion for the beauty and awe we feel as we explain how we, as experts, see and think about a given outcrop on a given field trip, would theoretically help students to further value the content knowledge (motivation) and feel the connections with Earth (Bransford *et al*., 2000). Pugh (2002) describes some success in helping students to value content when the instructor shares his/her excitement and enthusiasm with the students, models how s/he thinks about the content in application to everyday observations, and then scaffolds that thinking by asking students to do the same. This develops the students' own expert framework (Chi *et al*., 1981) upon which they can better learn to think as a geoscientist (Bransford *et al*., 2000; Petcovic and Libarkin, 2007) and understand why the content is valued. However, other workers have found that modeling is not enough to evoke a sense of harmony and connectedness in students. For example, Shane Cavanaugh (in Wong, 2007) designed her classroom research specifically to develop a sense of connection with the environment in her middle school students, by modeling, sharing evocative stories, and showing how science ideas enhanced her sublime experiences. However, this did not succeed: "in a discussion on the deep sense of quiet harmony she had felt on a recent walk in the woods, Cavanaugh's students were more concerned about the various dangerous or dirty things that might be encountered in a remote spot," (Wong, 2007, p. 81). One promising avenue of future research is the extent to which instructor modeling and scaffolding support in how we connect with Earth as experts can be successful in building college-level students' connections with Earth, and whether this also increases their sense of value of geoscience content.

Place-Based Learning

Place-based learning (Gruenewald, 2003a; Sobel, 2004; Gruenewald and Smith, 2008) situates curriculum in local environments and communities through the use of local features, phenomena, and issues as context and scaffolding for content. Such curricula typically emphasize experiential learning in the field or service learning in the community, and often both (Gruenewald and Smith, 2008). Place refers to any locality given meaning by human experience (Tuan, 1977). People not only imbue places with diverse scientific and humanistic meanings; they also typically develop emotional attachments to them. The sense of place, as noted above, is defined as the set of all of the meanings and attachments affixed to a place by an individual or group (Brandenburg and Carroll, 1995; Williams and Stewart, 1998). Hence, sense of place encapsulates both the cognitive and the affective connections between people and places. The place attachment component of sense of place corresponds to the emotional connections with Earth in our model (Table I).

Leverage and enhancement of a student's sense of place are authentic and assessable learning outcomes of place-based teaching (Semken and Butler Freeman, 2008). These outcomes are met when students are enabled to find personally relevant meanings and develop attachments to the places they study. For example, in learning about surface water and groundwater systems, common subjects in most introductory geoscience courses, students should know whence their own water supply comes and where wastewater goes (Orr, 1992). Such understanding may result in a feeling of empowerment, which in turn can lead to political action in support of sustainable water use in their communities. In this way, the content is made personally relevant and a part of the student's identity (Table I). Findings from a recent qualitative study (employing ethnographic methods) of a place-based Earth science course presented to a diverse group of in-service teachers indicate that the approach can enhance personal relevance of the discipline, and appreciation for surrounding geological features, systems, and processes (Semken and Williams, 2008; Williams and Semken, in press).

As shown by Tedesco and Salazar (2006), developing students' emotional feelings for a place and linking those feelings to the course content may result in students having greater value for what they are learning, and therefore develop a greater motivation to learn (an overlap of connections with Earth, emotion, and motivation). For nonscience majors, who may feel intimidated or bored by traditional science teaching (Hill, 2000; Wright, 2000), the place-based approach may be more successful. Science majors also benefit, since their schedules leave little room for all but the most superficial exploration of the humanities (Shick, 2008), and they can learn from the "real-life" applications of science knowledge and methods (Hill, 2000). Place-based approaches would seem to have added value for the students both from learning at a deeper level but also enjoying the learning experience. However, we need to explore beyond general attitudes to investigate how students value the content, in order to truly assess if there is a long-lasting impact on student attitudes and motivations (the "gestation time" problem: Wright, 2000).

An interesting question for future research is how this connection of place to the geoscience content ties into students' sense of their future goals as a source of motivation (Shell and Husman, 2001). Psychologists call students' belief that a task is instrumental to achieving future goals their "perceptions of instrumentality." Students who have high endogenous (internally generated) perception of instrumentality believe that the *process of learning* the course material, rather than simply completing the course or making a good grade, is necessary for achieving valued future goals. If students are able to internalize these ideas and connect the task to their own future goals, they are more likely to value the task and as a result, will improve their attitudes toward the content of the course (Husman and Lens, 1999). A cautionary note for this future-goals research is sounded by Wong (2007), who points out that educators and parents tend to focus more on students' future lives, while, for students, "school *is* life, not merely preparation for it" (p. 84). For Wong (2007), it is important for students to value the learning process in the here-and-now, and not just for what it might mean for their futures. Our role as faculty is to help students set both proximal goals to help with self-efficacy (Zimmerman, 2000), but also in connecting these goals to longer term, future-distal goals (Husman and Lens, 1999) which amplify the outcomes of the course. As faculty we need to help students see that setting future goals does not preclude attaching a value and instrumentality to the present.

INSTRUMENTS FOR ASSESSING MOTIVATION, EMOTION, AND CONNECTIONS WITH EARTH

There are well-validated instruments from the educational psychology community already in place that we recommend should be examined and amended as appropriate for the geoscience community. The Motivated Strategies for Learning Questionnaire (MSLQ), originally described by Pintrich and DeGroot (1990) and later modified for validity and reliability by Pintrich *et al.* (1993) assesses student values, expectancies for success, and emotion. There is ongoing research in order to gather a baseline of student attitudes and motivations in the geosciences across institutions around the United States (McConnell *et al*., 2006, 2009). The Self-Efficacy Questionnaire (SEQ) is very task and topic specific, so there is currently no geoscience specific SEQ; the guidelines for creating a SEQ are described by Bandura (2006). The Perceptions of Instrumentality, originally described by Husman *et al.* (2000), is used to assess student connection between course content and future goals. Interest has been assessed by Harackiewicz *et al.* (2008) in a validated survey administered both pre- and postinstruction.

A valid generalizable instrument for measurement of place attachment (Williams and Vaske, 2003), the affective component of sense of place, has been adapted from the environmental psychology literature for use in assessment of place-based learning in an introductory geoscience course (Semken and Butler Freeman, 2008) and in the characterization of sense of place in different populations (Perkins and Semken, 2008; Perkins, 2008; Semken *et al*., 2009). There are several examples of surveys that have been used to assess student appreciation of landscapes by looking at photographs (e.g., Balling and Falk, 1982; Tinio and Leder, 2009), which have been found to be internally reliable; but the external validity may still be in question. A number of survey instruments have been developed to measure environmental attitudes, values, or commitments to the environment, including those by Rokeach (1973), Schwarz and Bilsky (1990), Stern *et al.* (1995; 1998), and Dunlap *et al.* (2000). Modifying one or more of these instruments to incorporate more specifically geological items could be an important direction of future research.

With all of these instruments available we propose a future research direction to validate this theory empirically as follows:

(1) Develop an instrument for connections with Earth by modifying current instruments previously mentioned in place attachment (William and Vaske, 2003); appreciation of the natural world (Balling and Falk, 1982; Stets and Biga, 2003; Tinio and Leder, 2009), values of Earth (Dunlap et al, 2000; Rokeach, 1973; Schwarz and Bilsky, 1990; and Stern *et al.*, 1995, 1998) and possibly in conjunction with quantifying landscapes and regions (e.g., Leopold, 1969);

(2) Measure the key motivations and goals of students in introductory (and upper division) geoscience courses by using currently validated instruments like the MSLQ (Pintrich *et al*., 1993) such as the work currently in progress by McConnell *et al.* (2006; 2009), the Perception of Instrumentality Instrument (Husman *et al*., 2000), or by developing a geoscience specific Self-Efficacy Questionnaire (Bandura, 2006) specific to the geosciences; and

(3) Extend emotional measurements beyond simple test anxiety (measured as a subscale within the MSLQ) by examining positive emotions such as interest, for which the instrument developed by Harackiewicz *et al*., 2008 would be an appropriate instrument to modify and validate for the geoscience community. The validation of not-yet-developed instruments may require qualitative investigations of experts (as demonstrated by Chawla, 1999, and Hayes-Conroy and Vanderbeck, 2005, in which interviews helped to develop categories and themes) to determine common elements across disciplines and career pathways.

(4) Last, testing of this model in the U.S., as well as in other countries, will be needed to ensure that this theory is valid internationally.

CONCLUSIONS

Measuring how students respond to our practices in the classroom and ultimately to the content they learn can only be done if we measure for the components from the affective domain. For example, recent work indicates that the more students have a clear sense of their future goals (that are not related to the geosciences), the less they value the content provided in their introductory geoscience courses even if they are highly motivated and academically succesful (Husman *et al*., 2007). It is important to figure out how to motivate our students to value the content while adhering to their future goals. This may require a reanalysis of how we teach introductory geoscience classes and what content we cover within that domain. Recent work in the U.S. and the European Union has focused on this very topic in examining what is truly essential for a student to learn about geoscience (Fuhrman et al., 2005; Earth Science Literacy Initiative, 2010; Boyle *et al*., 2009); both the content and the context need to be considered in this process (Lewis and Baker, 2010).

Future directions for understanding connections with Earth include the need for an empirical study to examine ways of measuring students connections (or disconnections) with Earth. The dearth of literature on this subject illustrates an overall lack of conceptual framework to explain student experience with connections with Earth. The research agenda we propose here may be the beginning steps toward developing this important explanatory framework. Future research may address whether cooperative learning in the classroom can help to support student connections with Earth; if the notions of connections with Earth may be a way to help student move from what Hidi and Renninger (2006) discuss as "situationed" to "individual interest;" if engaging in field work helps students to develop a greater connection with Earth; and if modeling our own connections with Earth can help students to start to develop a similar expert framework. We invite our European colleagues to test this model in non-U.S. settings to determine if this model subsumes culture.

There have been recent calls for changes in how we as a community of geoscience educators can encourage students to become majors as enrollments in geoscience programs decline across the U.S. and the world (Ridky, 2002; Czujko, 2007; Boyle *et al.*, 2009). The current approach is not generating the numbers our society will need to replace retiring teachers in the K–12 system (Lewis, 2008) and within the workforce as a whole (see Associated Press, 2009). Another area of research would be to investigate if there are ways to engage this model with a younger population, in an effort to determine how we may be able to reach students at a critical time in the geoscience "pipeline" model (Levine *et al.*, 2007). As geoscientists, we need to work harder at recruiting students who may be initially less than attracted to the idea of geoscience (Tobias, 1990; Lewis and Baker, 2010). As geoscience educators, our goal should be to emphasize where some of the common goals and values between geoscientists and students overlap, (e.g., prosocial goals, sense of place, etc.) so students will value the topic they have been "forced" to learn as an introductory science. Examples posed within this paper—cooperative learning experiences in the classroom, field experiences, and place-based learning—are proposed as possible future directions for empirical research to determine if this model is valid for enhancing both student learning of the content and valuing the content they are learning.

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