Developing Student Interest: An Overview of the Research and Implications for Geoscience Education Research and Teaching Practice

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ABSTRACT

Interest is a complex interplay between affective and cognitive components that drive motivation. Over decades of work in the educational psychology community, a theoretical framework has emerged that explains this complex interplay. Interest is initially externally triggered (triggered situational interest), which, through support, can become maintained situational interest, ultimately leading to individual interest progressing from emerging to well-developed. Student interest tends to be triggered from an external agent (e.g., an engaging instructor or experience), but will not develop into a more sustained, individual interest unless it is repeated, engaging, and intellectually stimulating. This literature review provides an overview into how interest has emerged as a motivational theory and provides examples as to how it has been applied (or misapplied) in the science education and geoscience education literature. The geoscience education research (GER) community has tended to couch interest as a global phenomenon rather than as a part of a progression; as such, there are not many examples of the appropriate application of interest in the GER literature. If we apply the framework presented in this literature review to the themes identified by the larger Discipline-Based Educational Research community for future research, including our ability to best determine student content comprehension and approaches to problem-solving, the most effective instructional strategies, along with emerging categories of research such as metacognition, self-regulation, and other affective components; interest may be an important lens for considering what and how we teach, as well as how we choose to measure student experiences in the geosciences. © *2017 National Association of Geoscience Teachers*. [DOI: 10.5408/16-215.1]

Key words: Situational Interest, Individual Interest, affect, motivation

INTRODUCTION

Ella, a student in an introductory oceanography class, is introduced to acidification in the ocean as a result of human-induced climate change and is horrified to think that human action could result in a possible collapse of the ocean biosphere. Following the introduction to this topic, the instructor provides students an option to do research on a local problem as it pertains to oceanography. Ella chooses to focus more on the ocean acidification issue by looking at the local oyster beds. After reading about a local oyster farm needing to import their "seeds" from Hawaii, she talks to the oyster farmers and finds that the challenges are even greater than she'd realized and wants to delve beyond just the class project. She approaches her instructor about doing an independent learning contract for the following quarter to study this more closely through an internship at the local oyster farm. She finds herself talking about oysters and the challenges that are facing the local business to her friends and family. She talks to her instructor and advisor on how to pursue this as a career path, and starts rearranging her future class schedule to take courses leading toward an oceanography degree.

OVERVIEW OF INTEREST

The scenario previously presented is an idealized representation of how a student may progress through the continuum of interest as presented by the educational psychology researchers, Renninger and Hidi (2016). Few would dispute the assertion that developing an interest in geoscience is critical for students to enter into the geoscience pipeline or for engaging to learn the content in a geoscience course. As a geoscience community, it is important to recognize that interest has its own field of researchers with a complex and nuanced way of viewing the term. In the everyday meaning of the word, interest can function as a preference for an object or a subject area, and even an everyday way of thinking in which no further stimulus is needed beyond the initial interest (Prenzel, 1992). Interest is a blend of both affective and cognitive components that drives motivation and involves some form of an interaction between the individual and the environment (Hidi, Renninger, and Krapp, 2004; Renninger and Hidi, 2011). In addition, interest is content-specific, which means one must have an interest in something specific in order for interest to develop. Interest is a challenging field of study because there have been multiple working definitions found within the literature base stemming from various theoretical frameworks and in different fields of education research. However, most interest researchers have begun to coalesce around one framework initially described by Hidi and Renninger (2006) and further refined by them in 2016 (Renninger and Hidi). The provided scenario with Ella illustrates the progression of interest from externally triggered to one that is internally sustained.

In this literature review, I provide a brief history of interest research development and review the interest research from three literature fields: Educational Psychology, Education, and finally Science Education and Geoscience Education. The perspectives of these fields are then followed

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by an exploration of how student interest can be supported and developed through pedagogical interventions, which result in new questions to be addressed by the Geoscience Education Research (GER) community.

HISTORY OF INTEREST RESEARCH

Interest has been a part of educational research for well over a century. In the late 1800s and through the turn of the century, interest was largely a philosophical debate of which Dewey was an outspoken proponent for interest in educational contexts (Arnold, 1906a; 1906b; Dewey, 1913). Dewey described interest as primarily an inherent trait from within, but could be facilitated to expand beyond one's initial interest by making connections to one's existing interest. He described a scenario in which one might not initially like math, but when put in the context of engineering, it becomes interesting to the student (Dewey, 1913). After the first World War, interest research started to move toward the experimental as there became a strong desire for students to be interested in learning (and for jobs to not be boring) and understand what drove that motivation. Yet through most of this work researchers still viewed interest through the lens of an inherent trait of one's personality (Berlyne, 1949). As psychology became more nuanced to recognize multiple frameworks to explain motivation, the role of interest began to advance in understanding. Initially, interest was and in some cases continues to be, a part of several different educational frameworks including Self-Determination Theory (SDT), Social Cognitive Theory (SCT), and ultimately becoming its own distinct framework (Renninger and Hidi, 2016).

INTEREST IN EDUCATIONAL PSYCHOLOGY LITERATURE

Although there may be more than one theoretical framework from which interest is conceived, in general, interest has been identified as both an enduring disposition and as a motivational state for a given circumstance (Hidi et al., 2004). The philosophical underpinnings of what drives interest and what results can help to distinguish the different approaches to studying interest within the motivation literature.

SDT describes how one is motivated to engage in a task based on three fundamental innate psychological needs: autonomy, competence, and relatedness (Ryan and Deci, 2000). These needs can influence how one may develop values and set goals. For example, in an academic context, if a student has control over his/her learning experience (autonomy), feels capable of completing a task (competence), and feels as though they are a part of their learning community (relatedness), s/he will be more likely to be intrinsically motivated. Interest is commonly associated with, but distinct from, intrinsic motivation. Interest is tied to feelings of satisfaction, enjoyment, and involvement, which can ultimately lead to self-realization (Ryan and Deci, 2000; Schiefele, 2001). Interest from the SDT framework is commonly operationalized through the notion of the Person-Object theory of Interest (POI). In POI, the individual interacts with an object, where object is a generic term for environment, topic, or activity that may generate interest (Krapp, 2002a; 2002b). Interest in the construct of POI deepens as autonomy, competency, and relatedness needs are met with an object that is identified as a part of one's self-concept (Krapp, 2002b). The challenge is that most classroom settings are ones in which students do NOT have full autonomy. As a result, it is a generally less applicable context for studies on interest in the classroom, but can still apply to aspects for interest outside of the classroom like hobbies or informal learning experiences (Hofer, 2010).

SCT is based on the construct that what motivates individuals is more than just their own internal drives, but how these internal drives interact with peers and the environment (Bandura, 1986). In this case, interest is driven by both internal processes as well as through the interaction of external processes through feedback (in opposition to SDT, where the environment informs the individual, but not vice versa). From an educational standpoint, a SCT approach to interest provides more power to the instructor. There are opportunities for the instructor to design an environment that provides conditions favorable for fostering positive motivation through this feedback process, which can lead to developing and deepening interest. It is stemming from SCT that Hidi and Renninger (2006) developed a four-phase model of interest in which the four phases are a continuum from triggered situational interest, maintained situational interest, emerging individual interest and finally, to well-developed individual interest (it should be noted that those from the SDT standpoint also apply notions of situational and individual interest, it is in what drives that process that differs; Krapp, 2002a; Krapp and Prenzel, 2011). An individual can move through these phases as they engage in content; as it becomes internalized, the level of interest increases and sustains. This model starts as a more emotional component, based on external triggers (e.g., stimulating classroom environment) but develops into a more knowledge-based component as it becomes internalized (e.g., finding relevance from course content to everyday lives). As interest becomes more developed, emotion is still important, but value also begins to play a role (Hidi and Renninger, 2006). The more one develops interest, the more they choose to repeatedly engage in the content. Lastly, interest drives effort, self-regulation, goal-setting, and self-efficacy. Figure 1 illustrates a simplified version of this model and what changes over time for an individual if and when they move through these four phases.

In the scenario provided at the beginning of this review, Ella was progressing through the continuum of interest. When she first learned about ocean acidification, her first reaction was that of horror, but it triggered her situational interest. This was triggered because of an external agent (her instructor/oceanography course content). Later, when she chose to focus on ocean acidification for her class project, her situational interest was maintained as she was choosing to deepen her understanding with guidance from the class structure and the instructor. Once Ella took the initiative to reach out to the local oyster farm and determine if there were ways to follow up with an ongoing project, she transitioned to an emerging individual interest, she took initiative but still required some guidance from her instructor and a program to support the process. As she shared her thoughts and ideas with her friends and family, her brain was forming new connections and pathways that were helping her to further develop her interest. Later, when she started to think about the future coursework that could lead

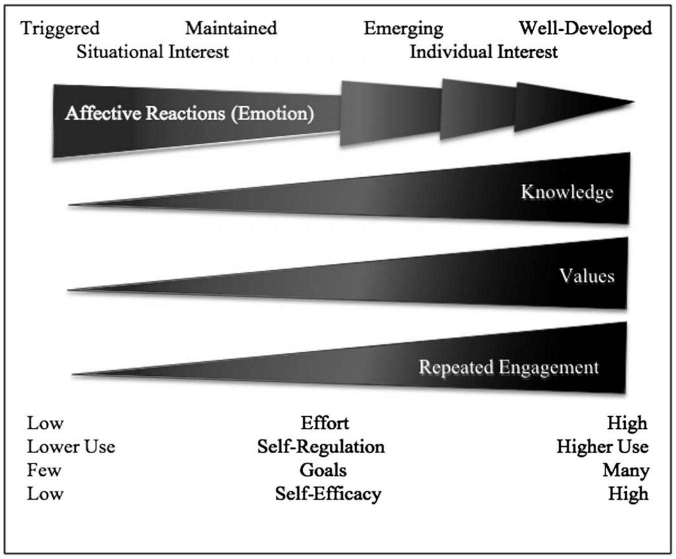

FIGURE 1: Model illustrating factors that influence development of interest based on work described by Hidi and Renninger (2006). Note that as interest becomes more individually developed, emotional reactions may not be as frequent, but are (and must) still be triggered on occasion in order to continue the desire to pursue and engage (Renninger and Hidi, 2016).

to a major and a possible career path, this was an example of moving into maintained individual interest. If she is able to maintain her direction through coursework that is seemingly unrelated, she will have securely developed a maintained individual interest, requiring fewer interventions and support for maintaining that interest.

As an individual's interest is triggered situationally, it may wane without external support beyond the initial trigger. Situational interest is typically identified by an individual who has few goals for further pursuit, does not have much of a gauge for how effective they will be at a given task, and is less likely to regulate their own motivation, emotion, or engagement (Hidi and Renninger, 2006). However, as one's interest becomes more of an individual interest, his/her effort is likely to persist in the face of difficulty, will continue to regulate the process, the number of goals s/he will set increases, the neural pathways in the brain will deepen, the content comprehension increases, and the internal and external feedback through this process develops increasing perceptions of efficacy (Hidi and Renninger, 2006; Renninger, Nieswandt, and Hidi, 2015; Renninger and Hidi, 2016).

Returning to Ella, there are plenty of times where she could have had her interest thwarted. Her school may not have had individual learning contracts, the oyster farm could have ignored her attempts to learn more, she could have had structural barriers of an unstable living situation, or her instructor and or peers telling her she was not capable of pursuing a path in this direction. All of these scenarios could have stifled her interest or resulted in frustration or a lack of self-efficacy at a time when the interest was not developed enough to sustain through those periods of setbacks and as such did not allow the full continuum to develop.

Not all agree that these phases are distinct. Hofer (2010) argues that rather than phases of interest development, it proceeds along a continuum in which interest grows through the cycle of exploration, feedback, and selection. In initial interest, individuals explore the topic, subject, or activity more. Based on the feedback (internal or external) from engaging in that task determines whether one selects to continue to engage based on their own notions of self-concept. As interest develops, the cycle continues in deeper and more meaningful ways with longer time and energy exerted as one progresses toward sustained interest. So while Hofer (2010) may not be convinced of the distinct phases described by Hidi and Renninger (2006), he does not dispute the discrepancy between situational (initial) interest and individual (sustained) interest.

The existence of situational interest and individual interest has been empirically supported through case study methods (Renninger and Hidi, 2002) through a combination of self-reports, behavior, and performance (Ainley et al., 2002; Harackiewicz et al., 2002), direct observations (Renninger and Bachrach, 2011), and measuring brain activity (Renninger and Hidi, 2016). The methods of measuring interest are as varied as the definitions. Renninger and Hidi (2002) based their work from interviews developing case studies. Many rely on different forms of self-report commonly mixed with other methods, including rankings of preferences (Häussler and Hoffman, 2000), Likert scales and performance (Harackiewicz et al., 2002; Ainley and Ainley, 2011; Hong and Lin-Siegler, 2012), surveys and interviews (Palmer, 2004; 2009), and written responses (Hulleman and Harackiewicz, 2009). Although others have used behavior as a metric of interest, such as questions self-generated on the internet (Baram-Tsabari and Yarden, 2009), behavior on computers (Ainley et al., 2002), to continuing to take courses in a particular subject area given a choice (Harackiewicz et al., 2000; Harackiewicz et al., 2002). Recent work has further supported the existence of different degrees of interest by measuring the neural activity in the brain through functional magnetic resonance imaging (fMRI) and from dopamine levels (Hidi, 2016; Renninger and Hidi, 2016). Most of these findings can still be tied back to the model of situational and individual interest to varying degrees.

Part of the challenge of measuring interest is that it is commonly measured at a more global level rather than at an intra-individual scale. As interest can be very topic specific, this can lead to misleading and sometimes contradicting results where students may report a lack of interest in science, but be very interested in specific topics that are scientific (Häussler and Hoffman, 2000). It is evident that interest emerges from prior experiences and knowledge and builds over time (Krapp, 2002a; Krapp and Prenzel, 2011). It can be "unexpected and ephemeral" (Renninger and Bachrach, 2015) where students do not know their interest has been triggered. So while individuals may have predisposed interests, it can also trigger from an external influence. Once established, well-developed interest demonstrates great stability over time. Interest in science can be found to be stable in children as young as four (Alexander et al., 2012). It should be noted that triggered situational interest is distinct from curiosity (even though it has been conflated in past research) in which triggered interest leads to a desire to know more, whereas curiosity once satisfied does not (Renninger and Hidi, 2016). How interest progresses and develops (or diminishes) depends on the type and quality of continued exposure over time.

INTEREST IN EDUCATIONAL LITERATURE

Dewey was one of the earliest prominent advocates for supporting student interest. His own definition evolved over time from 1896 to 1913 in which he originally argued that interest is only from within and cannot be stimulated externally, to later recognizing that interest can develop externally when linked to an already existing interest (Dewey, 1913; Archambault, 1964; Jonas, 2011). Dewey argued that adults forcing their goals onto children was artificial and would often result in an only surface learning rather than a deeper more meaningful interaction with content (Dewey, 1913). Although we now know that interest can be externally triggered to develop into individual interest, most of his ideas still hold true to today including the notions of joy and pleasure sustained by interest that was later confirmed by fMRI results (Renninger and Hidi, 2016).

More recent educational interest research has examined student interest around reading activities (e.g., Ainley et al., 2002), writing activities (e.g., Hulleman and Harackiewicz, 2009), science projects (e.g., Renninger and Hidi, 2002; Maltese and Harsh, 2015), and math problems (e.g., Renninger et al., 2002). Although the ages range from 11–16 years old for these studies, the common themes that emerged were that the more a student is supported and or scaffolded in his/her learning experience, and the more s/he can connect course content to their own preexisting interest, the more likely interest in a topic will develop into an individual level.

Focusing on the college setting, a similar story emerges. Several different studies with introductory psychology students indicate that interest is a predictor of enrollment in future courses, choices to become majors, better academic success, and setting mastery goals (Harackiewicz et al., 2000; 2002; Harackiewicz et al., 2008).

Although interest may drive motivation to learn more and persist within the subject area, it is not necessarily linked to academic achievement. Although a correlation exists between interest and achievement, which is stronger in the sciences than in the humanities, performance alone neither guarantees increased interest nor does it predict future actions, e.g., continuing on as a major (Shiefele et al., 1992; Harackiewicz et al., 2002). But in order to develop an individual interest, one must gain a deeper and greater understanding of a given topic (Alexander, 1997; Krapp, 2002a; Renninger and Hidi, 2011). If that interest diverges from what is taught in the classroom and what is assessed, students can perform poorly, but still have interest for a given topic (Sansone and Thoman, 2005). However, without encouragement, feedback, or an alternative approach when continually faced with poor performance one may begin to lose interest even if it is at the individual level (Renninger and Hidi, 2016).

A common theme in developing interest, and with it a growing level of expertise, was providing opportunities for freedom and choice in certain aspects of the curriculum (e.g., Alexander, 1997; Renninger et al., 2015a). These opportunities could include providing problems where there is more than one solution, opportunities for undergraduate research as a freshman, all within a supportive community (Alexander, 1997). In general, best practices for student learning are also beneficial for developing student interest such as, creating opportunities for social interaction within learning, creating novel, surprising, or discrepant (in which students are forced to confront misconceptions) experiences for students to explore, opportunities for laughter, and even experiencing learning with food (Bergin, 1999).

INTEREST IN SCIENCE AND GEOSCIENCE EDUCATION LITERATURE

There is not a clear operational definition of interest within the science education literature, including the geosciences, due to the fact that it has been partnered with different philosophical underpinnings (Krapp and Prenzel, 2011). It has been presented as a form of intrinsic value where there is a choice involved (Yuretich et al., 2001; Zoldosova and Prokop, 2006; Baram-Tsabari and Yarden, 2009; 2010), a development of intrinsic and extrinsic goals as defined by career choice (Maltese and Tai, 2010), as a value-based construct (Miller et al., 2007; Hulleman and Harackiewicz, 2009), as form of motivation (Palmer, 2009; Hong and Lin-Siegler, 2012), as a motivational construct that is associated with positive affect (Baber et al., 2010; Swarat et al., 2012), as a critical incidence (LaDue and Pacheco, 2013), and as the same framework as that posed by Hidi and Renninger, 2006 (Palmer, 2004; Alexander et al., 2012; Maltese and Harsh, 2015; Kortz and van der Hoeven Kraft, 2016). It may be situated within a broader definition including notions of cognition, self-concept, and emotion (Häussler and Hoffman, 2000; Hoffman, 2002). In other cases, it has been identified as a component of one's attitudes toward science (Osborne et al., 2003; Yuretich et al., 2001). Although there is empirical evidence that enjoyment (an emotion rather than an attitude) of science influences individual interest in that science (Ainley and Ainley, 2011), this is not the same as attitudes. It is possible for one to have a negative attitude (e.g., horrified by effects from pollution and climate change), yet still have interest to study a topic (Krapp and Prenzel, 2011; Renninger and Hidi, 2011).

Regardless of these varying definitions, the key commonality is that there is a desire for knowledge gained, which is critical for developing and fostering interest. This is evident through the work of Baram-Tsabari and Yarden (2009) in which they looked at what questions students asked (primarily) unprompted on websites like, "Ask a Scientist." Older students' (middle school and high school) question topics became much more in line with those covered in school (e.g., physics, chemistry), compared with the questions from younger children, which focused on observational phenomena (e.g., why is the sky blue?). In addition, Häussler and Hoffman (2000) and Maltese and Tai (2010) both indicate that students' interests in science typically have little to do with what is typically taught within the classroom (also known as "school science"); as a result, their interest in science tends to decline as they reach the ages of middle school and high school, where the science curriculum becomes much more restrictive with less exposure to content that supports interest. If student learning does not include content that supports development in interest, then it will not lead to continued interest. This becomes particularly salient as the gender gap for interest in science grows as children get older; specifically, boys tend to be more interested in physical sciences, and girls in biology (Baram-Tsabari and Yarden, 2010) and school science is what is more likely to trigger initial interest for girls because there are fewer opportunities afforded (and or selected) to girls outside of the school setting (Maltese and Tai, 2010).

As such, a global notion of interest in science would be inappropriate. It is clear that interest is very domain-, even topic-, specific (e.g., Häussler and Hoffman, 2000). Domain learning, which is generally described as the knowing of what, when, how, and why of a given domain, is not directly connected to the individual topics within a domain (Alexander, 1997; Alexander et al., 1997). For example, with Ella, she was not necessarily interested in oceanography as a whole, but the specific topic of ocean acidification triggered her interest and desire to learn more. As interest develops into the sustained individual phase, one is much more likely to be able to apply strategies across a given domain more successfully than when initially exposed to content (Hidi and Renninger, 2006).

One of the limitations of this literature review is that a limited amount of research published in the geoscience community has directly measured interest as a function of a construct beyond a global measure. As such, when we examine interest in pedagogical context, we must look both within and outside of the geoscience domain to learn how to best proceed with future practices when attending to interest.

SUPPORTING STUDENT INTEREST THROUGH PEDAGOGICAL INTERVENTIONS

The learning environment may impact the development of interest as much as what the students bring into the classroom. In order to trigger situational interest, much less to maintain it toward an ultimate goal of individual interest, students must be in an environment that fosters and supports student interest (Krapp, 2002a; Harackiewicz et al., 2008; Renninger, Nieswandt, et al., 2015).

Throughout the interest continuum (Fig. 1), the key to development of interest in the classroom is facilitating student learning in an engaging way that helps them to make connections between the content and their own goals (Hulleman and Harackiewicz, 2009; Hofer, 2010), provides opportunities for students to be engaged with one another, and with content that appropriately challenges them (Renninger and Hidi, 2011). Knowing how to appropriately achieve a classroom with these components is where the expertise of the instructor plays a role. When engaging students in active-learning environments that are most conducive to facilitating situational interest, the teacher's role is critical in fostering interest through expertise in facilitating student learning through the use of scaffolding and appropriate support structures (Rotgans and Schmidt, 2011; Renninger, Nieswandt, et al., 2015). The greatest restriction on this development is that students enter the classroom with many prior experiences and goals, which can influence what s/he may find interesting.

For example, there is strong evidence to support that there is a distinct difference between interest in science (content that is not necessarily structured within a specific curriculum, e.g., exploration of the outdoors or Science Olympiad type events) and an interest in school science (Häussler and Hoffman, 2000; Osborne et al., 2003; Maltese and Tai, 2010). So the prior knowledge of a topic and personal values and experiences can influence interest development (Hidi and Renninnger, 2006). Cultural values may also impact what drives interest based on how a topic is valued (Ainley and Ainley, 2011). One's interpretation of the drivers of interest, affect, and cognition, is likely to change with age and context (Hofer, 2010). Students who are highly self-regulated already entering the classroom require fewer support structures and may do very well to maintain an already existing individual interest in a lecture-based class and may even have interest triggered or sustained from a lecture environment, as they are able to make connections from content to their own prior experiences provided students have an opportunity to engage and re-engage in the content (Ainley and Ainley, 2015).

Triggering Situational Interest

Research indicates that there are ways to trigger situational interest, activities that support a more sustained situational interest, and there are other factors that may help move students to individual interest. Table I describes a series of possible interventions to illustrate how the development of interest may be possible. It should be noted that not all authors use the model/language proposed by Hidi and Renninger (2006), so the placement in the table is based on interpretation from the author's definition of interest.

Creating an environment that fosters the triggering of situational interest is particularly important for novice students who lack the full spectrum of the framework that defines a given discipline and therefore lack the skill set needed to develop their own interest in a given topic (Lawless and Kulikowich, 2006; Renninger et al., 2015a). Even within a single lesson, student situational interest will rise and fall with different portions of the activity, but by triggering situational interest, students are more likely to be motivated to learn new content and continue to engage as long as interest continues to be triggered (Palmer, 2009). Palmer engaged students in simple inquiry activities, separate from their typical science classroom activities that were considered to be novel experiences. Due to the novelty of the process and content, students' interest was triggered, but not consistently. The portions within the inquiry activity that were most novel, included opportunities for social interactions, and allowed students to explore were more interesting for the students than those parts of inquiry that did not include the exploration or social components (Palmer, 2009). If these lessons continued, and students continually engaged in novel experiences, had opportunities to explore the content, and engage in social interactions, their triggered situational interest may develop into a more maintained situational interest (Hidi and Harackiewicz, 2000). Maltese and Harsh (2015) looked at interest development across a continuum of ages starting in middle school and moving to undergraduate research experiences (UREs) for upper division majors, and they indicated that more closed inquiry experiences are better for triggering situational interest whereas more open-ended experiences like UREs are more appropriate for those with an individual interest.

Triggering situational interest is important for developing student's interest, but does not always support learning.

TABLE I: Breakdown of pedagogical interventions in developing interest along the Hidi and Renninger (2006) phases of interest.

Types of Interest	Pedagogical Interventions	Sources
Triggering situational Interest	Novel experiences and closed/controlled inquiry experiences	Palmer, 2009; Maltese and Harsh, 2015
	Reading about scientists' struggles (social and or scientific)	Hong and Lin-Siegler, 2012
	A series of interactive learning activities in a large introductory lecture course	Yuretich et al., 2001
Maintaining situational interest	Providing context for domain content (e.g., physics)	Häussler and Hoffman, 2000; Hoffman, 2002
	Repeated involvement (inquiry activities), novelty (discrepant events), and social interactions	Palmer, 2004
	Writing activities linking personal goals and values to class content	Hulleman and Harackiewicz, 2009
	Course-based undergraduate research experiences	Kortz and van der Hoeven Kraft, 2016
Supporting individual interest	Using interest as part of the self-regulatory process to find ways to make boring tasks interesting	Sansone and Smith, 2000; Sansone and Thoman, 2005
	Providing opportunities for choice, encouragement of interest	Maltese and Tai, 2010
	Immersive summer experiences in a cohort-style model with sustained mentor support	Miller et al., 2007
	Undergraduate research experiences and other mastery experiences (summer and or throughout the school year)	Baber et al., 2010; Maltese and Harsh, 2015

Harp and Mayer (1998) found that when students had extra images and information that was interesting, or as they dubbed, "seductive," in a science text, students had lower comprehension than those who did not have the interesting details. This is also the case in multimedia scientific presentations, the more interesting or seductive the content, the less students were able to deeply process it (Mayer et al., 2008). Translated into the classroom, this could mean that creating a fun classroom with videos, puzzles, and food may not be beneficial for developing interest beyond trigging situational interest, may be catering to curiosity rather than interest, or simply sugar-coating the content rather than providing a meaningful learning experience, and, as a result, could be deleterious for learning beyond a surface level (Jonas, 2011; Renninger and Hidi, 2016). For example, when humor and bright colors were added to math problems in an effort to increase triggered interest, it actually decreased interest with those students who already had an individual interest in math (Durik et al., 2015). However, when targeted context is added to scientific text (in which the details support a deeper understanding of the content), student interest and comprehension increase. Hong and Lin-Siegler (2012) found that students who read about the struggles of scientists to achieve their goals in addition to the standard content were more likely to retain content, solve more complex problems, and were more interested in physics. Yuretich et al. (2001) argue that by making the class more interactive through a series of group activities and group-based exams in a large lecture oceanography class, students were more likely to show up, which then led them to enjoy learning the content more and led to an interest in science as a whole.

Maintaining Situational Interest

Other researchers have examined how to facilitate interest beyond triggering situational into a maintained interest (Table I). Hulleman and Harackiewicz (2009) asked middle-school students to write essays connecting their classroom science content to their own interests and values and others to write about the content alone. Those who made connections between content and their own values were more likely to develop a maintained interest in their science classes and were more willing to consider science as a possible future career path, which would indicate movement toward a greater self-concept in science, which can lead to individual interest (Krapp, 2002b), but if left unsupported, may fade away (Hidi and Renninger, 2006). Kortz and van der Hoeven Kraft (2016) describe a Course-Based Undergraduate Research Experience (CURE) for an introductory geology class where students were able to research a topic of their own choosing. Providing a choice tends to the need for autonomy (Krapp, 2002a) or for building knowledge from incoming interest, but without sustained exposure, may remain as situational interest (Hidi and Renninger, 2006).

Student interest has been successfully maintained through contextualization of content and leads to longer preservation of learning gains (Häussler and Hoffman, 2000). Hoffman (2002) developed curriculum around major concepts in physics (mechanics, speed, and force, etc.), but taught them through the appropriate contextual elements (e.g., how an artificial heart works, determining how a bike helmet works, respectively), which in turn led to sustained interest for both boys and girls in the classroom. This is particularly salient as girls tend to disassociate and lack individual interest in physics. By providing context for how physics was useful to them, Häussler and Hoffman (2000) found that girls developed a more sustained interest in the domain. Swarat et al. (2012) tested Häussler and Hoffman's model of what developed interest for students: domain content, context for that domain, or the application of the content in the classroom as an activity. They identified that domain and context were less important than how it was applied in the classroom through the activity, indicating that delivery is critical in any aspect of developing interest.

Palmer (2004) worked with primary-level, preservice teachers who entered the course with generally high levels of disinterest toward science (especially the physical science topics). He found that by implementing opportunities for students to be involved through repeated-inquiry lessons, where they experienced novel or discrepant events and were able to interact with their peers shifted their attitudes toward science to more positive ones (albeit global measures). Their interest in science was sustained which led to a greater motivation to learn more. As opposed to Palmer's research from 2009, which was only one inquiry lesson with middle school aged children, these were adults with continued exposure to content through inquiry. Both the age of the students and continued exposure in these examples may have played a role in the movement from triggered interest to a more maintained interest. Lastly, several summer programs for targeting students who are traditionally underrepresented in the geosciences directly targeted student interest (Miller et al., 2007; Baber et al., 2010). Miller et al. (2007) provided a cohort-model of Hispanic-American high school students who were supported by mentors and tracked in their geoscience pipeline provides evidence that entering with a situational interest that is supported through engaging content and emotionally supportive learning environment and peers can lead to sustained interest (Miller et al., 2007). Baber et al. (2010) examined two different programs, one for high school students and one for undergraduates in STEM (science, technology, engineering, and mathematics) with a focus in the geosciences. Students were fostered to build their self-efficacy through mastery experiences, such as undergraduate research, and when supported, their interest in the geosciences developed and or was maintained (Table I).

Supporting Individual Interest

Students who engage in self-regulation of learning (SRL) are able to set goals, and monitor their emotions, actions, and motivation as they engage in a task and learn from those experiences to build on that knowledge (Zimmerman, 2001). Those who successfully engage in self-regulation generally have a better understanding of content and are better performing students because they have a deeper set of strategies to employ in order to be successful (Zimmerman, 2001). If students are interested, they are more likely to engage in SRL. The further along the continuum of interest (Fig. 1), the better a student is at self-regulating (Sansone and Thoman, 2005; Hidi and Ainley 2008). Alexander et al. (1997) determined that as student interest increased, the use of deeper processing strategies increased. Harackiewicz et al. (2008) described evidence that different classroom environments may help or hinder students' interest based on the likelihood of students persisting from one class to the next. If students with a greater interest employ more productive learning strategies, and a classroom environment can influence this process, then there may be interventions that faculty can employ in the classroom to increase student success and interest. For example, a student may not be particularly interested in a given assignment, and as a result will engage in the task in order to achieve a noninterest related goal (e.g., grades). However, if the assignment has options for a student to choose how s/he completes the assignment, interest is more likely to be part of the driver of self-regulation (Sansone and Smith, 2000). Students who already have an individual interest will find ways to make boring tasks more interesting through an employment of alternative interest-enhancing strategies such as creating a game out of the task or even providing self-awarded rewards at the end of the task (Sansone and Smith, 2000; Sansone and Thoman, 2005). Students may also seek outside activities (e.g., Science Olympiad) in order to continue engaging in content one finds interesting, but is not provided in the classroom (Renninger et al., 2015b). In other words, there appears to be a reciprocal relationship between developing student interest and developing their learning strategies such that as students are more interested, they develop more meaningful and useful strategies for learning (Sansone and Smith, 2000; Sansone, 2009). A word of caution, because adolescents particularly struggle between long-term benefits from some interests and immediate fulfillment of other interests, this becomes particularly acute for students who lack strong self-regulatory skills (Husman and Lens, 1999; Hofer, 2010), so this reciprocal relationship may be more with adults rather than adolescents and younger students.

In general, there is no cure-all perfect lesson that will trigger and sustain learning. However, the most critical elements to consider are creating an environment where students feel comfortable and have the ability to explore their interests in the context of the given curriculum. Inquiry that moves from a more closed approach to a more open-ended curriculum may have the greatest potential for this (Maltese and Harsh, 2015; Ryker and McConnell, 2017).

CONCLUSIONS & GEOSCIENCE EDUCATION RESEARCH IMPLICATIONS

There is evidence that external influences can support or hinder an individual's interest, such as parental education background, peer influences, or even cultural experiences. However, the instructional practices of the instructor can have significant impact on the student development of interest (Bergin, 1999; Ainley and Ainley, 2011). In addition, while triggering situational interest is critical for initial levels of motivation, working to develop a student's individual interest, or at the very least a sustained situational interest should be the target toward which instructional practices should be aimed. Practices that are best for facilitating student learning (scientific inquiry, student collaborative work, problem-based learning, mastery experiences, positive affective environments, developing strong self-regulation skills, learning content in context; Table I) are also the factors that can support student interest provided the instructor has the skills to support student learning (Rotgans and Schmidt, 2011).

Although it is clear that interest is a biological part of how our brain operates (Hidi, 2016), it is important to note that correlation does not indicate causation. Interest is an incredibly complex response to many different stimuli in the environment and a result of the social interactions we have developed over time. There is still a long way to go in how much we can say with certainty on how it originates and develops. However, with that caveat, there is much we as a community can do to consider future directions of research.

The National Research Council (NRC, 2012) identified the areas of greatest need for the Discipline Based Education Research (DBER) community, and the call for this set of papers asked that the authors synthesize results and define the directions for the geoscience research (GER) community. As such, several key chapters in the DBER report (NRC, 2012) can help guide where the GER community can move forward with this research.

- DBER Chapter 4: Conceptual understanding of content
- DBER Chapter 5: Problem solving and spatial reasoning
- DBER Chapter 6: Instructional Strategies
- DBER Chapter 7: Emerging areas including the role of UREs, transfer of knowledge, metacognition (and self-regulation), and affective experiences

If we want to understand what instructional strategies are most effective for student learning, we need to better measure and determine student interest development over time. Students' ability to self-regulate and their very affective experiences are tightly interwoven with interest (van der Hoeven Kraft et al., 2011). Interest is most commonly sustained when it is developed early, before middle school (Ainley and Ainley, 2015); however, many of our students are only first exposed to the geosciences in their introductory college classes (Wilson, 2013), how does that impact our ability to recruit and retain majors and are there ways we can help to foster and facilitate growth of interest in a short period of time? How can we leverage the content we teach to optimize the interest continuum?

Early experiences in the outdoors and informal learning experiences and engaging instructors can be powerful in developing interest for students (Elkins and Elkins, 2007; LaDue and Pacheco, 2013). Field experiences do have important affective experiences for students that are critical in shaping their learning experiences (Stokes and Boyle, 2009). Where do these experiences fall in the interest continuum? How do day excursions differ from longer field experiences? Is this true for all students across a more diverse spectrum than our current population?

If field experiences are not strong interest triggers for a more diverse population, how can we support multiple ways to develop student interest? Is it possible that UREs may be a source of interest-developing activity? These are activities that have been identified as high-impact activities in other domains as well as in the geosciences (Jarrett and Burnley, 2003; Kuh, 2008; Baber et al., 2010), in addition to place-based learning (Semken, 2005; Semken and Butler-Freeman, 2008). How can these experiences equate on the interest continuum as compared with field experiences?

In other words, there are many possible directions a more consistent application of an interest framework can help to inform us with these challenges. As a community, if we apply the more nuanced framework of interest as that proposed by Hidi and Renninger (2006), geoscience educators can consider curricular and instructional design and the GER community can pose and test research questions examining how we can affect change in students' interest.

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