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3. CHILDREN EXPERIENCING THE OUTDOORS

A Natural Setting for Science Learning in the United States

INTRODUCTION

Outline of the Chapter

This chapter will demonstrate how outdoor education can answer the call for science education reform while benefiting the whole child. It begins by outlining research on how outdoor experiences can provide science engagement benefits that last a lifetime. We then outline the specific science reforms that have been presented in the United States and globally to encourage lifelong science achievement. The remainder of the chapter draws connections between how outdoor education can address reform goals and strengthen the likelihood that benefits provided from outdoor experiences will last a lifetime. First, we make the case for how fostering a connection to nature can complement and augment science instruction. We then outline different forms of outdoor education in formal, non-formal, and informal settings, highlighting place-based instruction and considerations for urban settings as special cases. We acknowledge challenges associated with using outdoor education as a science instruction methodology, paying special attention to issues of diversity around ethnicity, gender and culture. The chapter ends with a summary and an invitation for educators to consider outdoor education as a powerful tool in implementing science education reform.

Student-Centered Instruction

Hammerman and Hammerman (2013, pp. 48–49) presented a detailed overview of how instruction can be interpreted through both traditional and student-centered lenses. The latter is consistent with reform efforts described in this chapter. The traditional teacher focuses on test preparation, directs activities for students (e.g. "cookbook" activities and labs), and creates lessons focused on the "right" answers with minimal

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contextual relation to the real world. A teacher using student-centered instruction allows students to ask questions and design their own learning, facilitates student critical and creative thinking (rather than dictates), learns alongside students, and works to provide context so that students understand learning situated in real-world contexts. In response, students participating in student-centered classrooms gather and contextualize information through analyzing data and reflective questioning as opposed to memorization and parroting of facts as may occur in a traditional classroom. Student-centered work emphasizes investigations, data, and meaning-making, while traditional student work often focuses on notes and worksheets.

Outdoor education provides ample and varied opportunities to support student-centered approaches to teaching. Outdoor education offers a learning environment "where students can be free to investigate and explore and/or be inspired and create without the barriers to learning that are often found in the classroom" (ibid., p. 49).

The Nature of Outdoor Education

Outdoor education refers to using natural settings both as an environment for learning and as a teaching tool. Outdoor education can provide authentic learning experiences called for in recent science education reform goals. A large body of research demonstrates benefits not only for science achievement, but also for motivation to learn in science and other subjects, for connection to nature, as well as for social and cognitive development. Though outdoor education has numerous benefits for science teaching, these extend far beyond the science classroom. They include equipping students with the knowledge, skills, and dispositions needed for a lifetime of learning about, and engagement with, science and the environment.

Many science professionals have described an early interest in the natural world that persisted through stages of formal education as they moved toward life-long careers in science. Scientists who have recounted early experiences in outdoor settings include the naturalists Rachel Carson and Jane Goodall, who attributed their early experiences exploring nature as contributing to their strong relationship with the natural world (Atkins, 2000; Farber, 2000; Huxley, 2007). The physicist Richard Feynman (2005) identified explorations in nature with his father as providing context for learning about patterns and structure. The naturalist and biologist Edward O. Wilson (1994) credited his free explorations in natural settings with piquing his interest in entomology and nature's patterns, and the paleontologist Stephen J. Gould (1991; 2002) described his early revelations about the natural world and his connections with Darwin's explorations as the foundation of his life's work.

Early outdoor experiences as reported by science professionals have the potential to support both children who will choose careers in science as well as those who will connect with science in other ways during their lifetimes. Many adults identify their free explorations in natural settings when children as formative events or significant life experiences (SLEs) (Chawla & Cushing, 2007; Chawla, 2001; 2006; Palmer, Suggate, Robottom, & Heart, 1999; Sobel, 1990; 2002), impacting their world views.

Many adults associate the time spent in nature as children with adult choices related to occupation, academic interests, and hobbies (Corin, Jones, Andre, Childers, & Stevens, 2015) as well as environmental appreciation and stewardship (Chawla, 1999; 2009; Wells & Lekies, 2006). Since these stories suggest that early nature explorations may spark life-long interest in the environment and science, they should encourage science educators to focus on the value of providing young children with experiences in the natural world.

Positive impacts of outdoor experiences may also be realized before children reach adulthood. Research on outdoor learning (Dillon et al., 2006; Eaton, 2000; Malone, 2008; SEER, 2000) has found outdoor experiences to be effective for developing cognitive skills that enhance classroom-based learning. Further, following outdoor experiences, researchers have documented improved environmental attitudes (Cheng & Monroe, 2010, p. 45), and improved comfort levels in the outdoors (Carrier, 2009, p. 9). Cognitive and affective benefits of outdoor education have the potential to promote engagement in critical thinking (Hungerford & Volk, 1990), which is essential for developing science reasoning.

Concerns have arisen about children's decreased outdoor time and increased time indoors (Coyle, 2005; Malone, 2008) as outlined by American author Richard Louv (2008) who coined the term "nature-deficit disorder" in his book *Last Child in the Woods*. Louv's book assimilated and inspired a large body of research on the benefits of time in nature, including physical (Frumkin, 2001), psychological (ibid.; Taylor & Kuo, 2009), and cognitive well-being (Dillon et al., 2006; Frumkin, 2001; Malone, 2008; Rickinson et al., 2004; Taylor & Kuo, 2009; Wells & Evans, 2003). Other benefits include decreased instances of myopia (Rose et al., 2008, pp. 1280–1283), improved attention (Kuo & Faber Taylor, 2004, p. 1584; Taylor & Kuo, 2009, pp. 405–406), decreased stress (Wells & Evans, 2003, pp. 319–320), and connections to nature (Kahn & Kellert, 2002). Although Dickinson (2013) cautions about this movement's casting of time in nature as the key to most any individual or societal ill, the volume of empirical studies chronicling positive associations with time in nature suggests that outdoor education offers strong potential to provide tangible benefits.

Beyond the psychological, emotional, and physical benefits of time in nature, learning about the natural world in nature has the potential to enrich instruction by providing sensory and contextual information that anchor science lessons in the natural world (Ives & Obenchain, 2006; Malone, 2008; Rivkin, 1997). Using the outdoors as a setting and focus of instruction has been linked to improved science test scores, increased ability to apply science concepts to real-world situations, increased enthusiasm and interest in science, and enhanced emotional and cognitive development (Dillon et al., 2006; Lieberman & Hoody, 1998; Malone, 2008). Outdoor education experiences encourage children to ask and seek answers to questions (Renninger, 2000), thus potentially boosting overall science learning (Falk, 2001; 2005, p. 267). Given the varied benefits to children and potential to inspire life-long engagement with the natural world and science, outdoor education has enormous potential to contribute to reform efforts in science education.

REFORM EFFORTS

The launch of the Russian satellite Sputnik in 1957 initiated educational reforms in science in the United States and beyond, and over decades these reforms included a range of pivotal documents (e.g., AAAS, 1993; 2001; 2007). These documents laid out the content and practices necessary for students' paths toward science literacy including a heavy emphasis on scientific reasoning and critical thinking as well as authentic learning experiences. Relatedly, calls for providing students with authentic learning experiences (e.g., assessing the health of a river by documenting its macroinvertebrate populations) have been prompted by various reform efforts (e.g., AAAS, 1990; NRC, 2007a).

More recent reforms of science education as identified in *Framework for K–12 Science Education* (2012) encourage engagement in science practices to build students' appreciation of science and proficiency in science over multiple years (NRC, 2012, p. 26). This document guided development of the *Next Generation Science Standards* and defined science practices necessary for understanding how science helps humans confront challenges in society such as the development of clean energy and making personal decisions about health care (NGSS Lead States, 2013). Presented along with Cross Cutting Concepts that connect key features of learning about the world (e.g., patterns, cause and effect, energy and matter) and Disciplinary Core Ideas (e.g., life, physical, Earth/space science, engineering design), the framework defines the following scientific and engineering practices:

1. asking questions and defining problems;
2. developing and using models;
3. planning and conducting investigations;
4. analyzing and interpreting data;
5. using mathematics and computational thinking;
6. constructing explanations and designing solutions;
7. engaging in argumentation from evidence; and
8. obtaining, evaluating, and communicating information (NRC, 2012, p. 8).

Outdoor education can offer an important setting for contributing to these science education reform objectives. The term outdoor education has been used in many contexts, including adventure education (Hattie, Marsh, Neill, & Richards, 1997), informal nature exploration (Falk, 2005), and structured education held outdoors. In this chapter, we draw on the definition outlined by Priest (1986, p. 13): Outdoor education (a) is a method for learning, (b) is experiential, (c) takes place primarily in the outdoors, (d) requires use of all senses and domains, (e) is based upon interdisciplinary curriculum matter, and (f) is a matter of relationships involving people and natural resources. The following sections present research on outdoor education and young children learning science, outline several forms of outdoor education, and present observed barriers to outdoor education including among diverse audiences. The chapter ends with discussion of pathways for educators to consider outdoor education as a legitimate tool for addressing science reform efforts.

CONNECTION TO NATURE AND CHILDREN'S SCIENCE LEARNING

Research suggests that early science instruction may be pivotal in building life-long interest in science. Connecting children with the natural world may augment this process. Young children are more capable of engaging in scientific reasoning than previously thought, and these understandings support providing students with early opportunities for science learning (NRC, 2007b, pp. 251–260). Researchers suggest that very young learners can distinguish objects from symbols representing those objects (DeLoache, 2005, para. 9–11). By the age of three or four children can already determine the credibility of reports (Koenig, Clement, & Harris, 2004, p. 697). Further, children seem to retain an innate interest in science throughout elementary school (Osborne, 2007, p. 105). By providing children with learning opportunities that build on their inherent interests, we can impact children's lives at an early stage. One promising method for leveraging children's abilities and interests in order to promote science learning is to engage young children in experiential science activities connecting with the natural world (Loucks-Horsley et al., 1990, p. 48). Children have a strong interest in the natural world (Kirikkaya, 2011; Maltese & Tai, 2010; Osborne, Simon, & Collins, 2003) and their experiences in the natural world have been found to improve their interest in science (Lindemann-Matthies, 2005; Zoldosova & Prokop, 2006). Although connection to nature seems to wane as children approach adolescence (Kaplan & Kaplan, 2002; Osborne, 2007), profound or sustained experiences in nature have been found to lastingly affect views of nature on into adulthood (Chawla, 1999; Ewert, Place, & Sibthorp, 2005; Wells & Lekies, 2006). By building on children's connection to nature, science educators may be able to help foster a paralleled lasting effect with science interest.

Building Learning on Children's Prior Knowledge

Educators have an opportunity to boost interest in school science by integrating outdoor education into science instruction in ways that both leverage and build on children's connection to nature. Children's curiosity about the natural world develops through informal observations (Luce & Hsi, 2015; Spektor-Levy, Baruch, & Mevarech, 2013), and science educators can help children build scientifically accurate explanations for phenomena to begin to make sense of observed patterns in their world. Children may, for example, have noticed and wondered about dew on blades of grass, observed the movement of the sun across the sky, noticed that some trees lose their leaves in winter while others remain evergreen. Children often develop their own personal theories to explain phenomena such as seasonal or weather patterns, and educators can position learning opportunities in the context of children's experiences. Rennie (2007, pp. 128–130) identified characteristics of learning as personalized, contextual, and cumulative; therefore, providing such experiences for young children is critical to building a base for future learning. Educators can both examine children's prior experiences in nature to build on their current understandings as well as guide them through new experiences. Providing children with experiences in the natural world offers personal and contextual connections and can influence learning for years to come (Chawla, 1999; 2009).

Fostering a Connection to Nature

To achieve the connection with nature that may augment science learning, educators should prioritize direct experiences. Kellert (2002) distinguished between children's direct, indirect, and vicarious experiences in nature. According to Kellert, direct experiences involve physical contact with natural settings and non-human species in an unstructured format. Indirect experiences may involve physical contact, but that contact is managed or restricted by adults, as in a nature center or zoo. Vicarious experiences involve no physical contact, including videos, photographs, and textbook representations of the natural world. Kellert (2002) found that indirect and vicarious experiences, more typical of children's experiences in the context of school, are insufficient to significantly impact a child's affective, cognitive, and evaluative development in a way that contributes to his or her environmental relationship and connections with nature (pp. 118–120). In a study of the influence of natural elements in home environments, Wells (2000) found low-income urban children's relocations to greener residences had a distinct effect on children's cognitive function (pp. 790–791). In a related study of day-care settings in Sweden, Grahn, Mårtensson, Lindblad, Nilsson, and Ekman (1997) found that children whose day care included outdoor time had greater attentional capacity than children in day-care settings with less outdoor time.

A key aspect of direct experiences in nature is the less-structured or "free" aspect that Kellert (2002, pp. 118–190) described as central to identification with the natural world. Direct experiences in natural settings can provide opportunities for free-choice learning. Free-choice learning experiences are learning experiences that are self-motivated, voluntary, socially mediated, and guided by an individual's interests (Dierking, Falk, Rennie, Anderson, & Ellenbogen, 2003, p. 109). Free-choice learning experiences in natural settings have the potential to promote pro-environmental behaviors and attitudes in children (Ballantyne & Packer, 2005, p. 282) in addition to honing children's interests in natural science (Lindemann-Matthies, 2005; Renninger, 2007). When children are free to explore in natural settings, they often discover things of interest to them, make observations, and gather data without being part of a structured science learning experience (Eberbach & Crowley, 2009; Lindemann-Matthies, 2005). While opportunities for truly free choice learning in school settings are limited, opportunities do exist elsewhere.

Children's interest in the natural world seems to peak during elementary school, and researchers have found that an individual's relationship to nature is most positively impacted before age eleven (Kaplan & Kaplan, 1989; Sobel, 2002; Wells & Lekies, 2006). Ernst and Theimer (2011) reported an increase in connectedness with nature in programs serving children in grades three to six, with negligible increases in programs serving children at the high-school level (pp. 590–591). Similarly, Liefländer, Fröhlich, Bogner, and Schultz (2012) found that nine-to-ten-year-old children were more connected to nature than children age eleven to thirteen. Additionally, they report that although short-term connectedness to nature increased with participation in a four-day environmental education program at a local nature center, younger children retained their connectedness levels four weeks after participation, while older children did not (pp. 377–378).

This research on young children's connection to nature may also point to an opportunity to leverage early experiences in nature to sustained interest in science. Researchers have found that children have a strong interest in the natural world (Kirikkaya, 2011; Maltese & Tai, 2010; Osborne et al., 2003), and children's experiences in the natural world have been found to improve their interest in science (Lindemann-Matthies, 2005; Zoldosova & Prokop, 2006). By building on children's connection to nature, science educators may be able to help foster a paralleled lasting effect with science interest. On their own, children may not draw connections between their experiences in the natural world and the science they are learning in school, tending to view school science as a classroom-bounded enterprise (Carrier, Thomson, Tugurian, & Stevenson, 2014, p. 2211). Educators have an opportunity to strengthen children's connections with nature and simultaneously improve their interest in school science by explicitly integrating outdoor education into science instruction. The following section reviews examples and research demonstrating this notion.

INTEGRATING OUTDOOR EDUCATION INTO SCIENCE INSTRUCTION

Efforts to provide authentic learning contexts situated in the outdoors have grown over the last several decades. Examples of outdoor programs across countries include The Boston Schoolyard Initiative, which has focused on establishing outdoor classrooms in schoolyards that include professional development programs, and Science in the Schoolyard, for teachers in urban schools (Manzo, 2008, para. 18–21). In addition to programs in the United States, schoolyard greening efforts have occurred in Canada (Learning Grounds sponsored by the Evergreen Foundation), in England (Learning through Landscapes), and in Sweden (Skolans Uterum), among others (Dyment, 2005; Rivkin, 1997). These programs have the goal of promoting schoolyard experiences to supplement traditional classroom instruction. Outdoor experiences, whether in the schoolyard or elsewhere have the potential to intellectually and affectively connect children with the natural world and provide opportunities for interaction with nature's patterns and variation. A variety of designs and settings for learning both indoors and out follows.

Formal Education

Formal learning is generally defined as in-school learning that is highly structured and mediated by a teacher (Eshach, 2007, pp. 172–173). Although Kellert (2002) emphasized the need for free structured exploration of nature, research suggests that integrating outdoor education into structured settings fosters a connection to nature and boosts science learning. The main advantage of integrating ongoing outdoor education, such as in the schoolyard, into formal settings is the opportunity for sustained, supported learning as opposed to one-time experiences. Field trips are often isolated and lack continuity compared to schoolyard activities that offer students opportunities to explore weather patterns, seasonal changes, and life cycles on a regular basis. Researchers have consistently found that one-day interventions have less impact on children's connectedness to nature than do longer interventions (Cheng & Monroe, 2010; Ernst & Theimer, 2011; Liefländer et al., 2012).

Schoolyard activities offer ample opportunities to link outdoor education to many curriculum areas. For example, students engaged in building, cultivating, and observing a pollination garden on school property may learn about plant biology and plant-pollinator interactions (science), use various tools to measure changes in plants (technology), engage in problem solving to ensure the garden remains well-watered (engineering), and collect and analyze data on plant growth and pollinator visitation (mathematics). By using local and accessible schoolyard settings as a learning tool, students are provided with a context in which to situate multi-disciplinary knowledge and skills.

Although more research is needed on outdoor education in formal settings, it appears that schoolyard science offers cognitive, affective, social, and physical benefits (Carrier Martin, 2003, p. 57; Coyle, 2010). Several studies have found a link between increased experiences in nature and academic performance (Rickinson et al., 2004; SEER, 2000). Schoolyard science lessons have been found to improve students' environmental attitudes, behaviors, and outdoor comfort levels (Carrier, 2009, pp. 9–11; Skelly & Zajicek, 1998, pp. 581–582). Additional benefits were improved confidence, pride in community, stronger learning motivation, and an improved sense of responsibility (Rickinson et al., 2004).

Non-Formal Education

Non-formal education is, in a sense, situated between formal and informal education. It shares with formal education structured activities guided by the instructor, but the nature of instruction is highly adaptable and generally more student centered (Eshach, 2007, pp. 173–174). Field trips have been many teachers' choice to provide children with non-formal exploration experiences in nature (Anderson & Zhang, 2003; DeWitt & Storksdieck, 2008; Rickinson et al., 2004) and when presented well, non-formal experiences in informal settings have the potential to provide children with experiences that extend learning (Behrendt & Franklin, 2014, p. 242). For instance, a class may visit a nature center and go for a guided walk. The instructor has clearly defined goals and learning objectives, but he or she encourages student exploration and questions, and the learning activity adapts to those explorations. The main learning objectives of the walk may center on plant adaptations, but student questions about spiders can result in an impromptu lesson on arachnid life cycles.

One particularly effective form of non-formal education used by many teachers is published environmental education curricula. In the United States, examples of such curricula include Project WET, Project WILD, and Project Learning Tree. Each of these programs offer professional development introducing teachers to non-formal education techniques (e.g., close examination of patterns in nature, focus on form and function), as well as ideas of how to use natural settings as an integrating context for instruction in science. Further, such experiences provide opportunities across disciplines including social studies, language arts, and mathematics. Research suggests that this type of professional development and exposure to curriculum is effective for building practices that involve issue analysis and critical thinking among middle school students (Stevenson, Peterson, Bondell, Mertig, & Moore, 2013, pp. 4–5), as well as boosting content knowledge in science (Broussard, Jones, Nielson, & Flanagan, 2001, p. 40).

Informal Education

Informal education refers to spontaneous learning as occurs through personal reading, watching television, talking with family, and engaging in hobbies or any other unstructured learning opportunities (Eshach, 2007, pp. 173–174). In a science education context, informal learning is often associated with field trips to museums or nature centers, or inquiry-based learning in which students drive the learning process. Both informal learning environments (such as nature centers) and inquiry-based practices have been shown to improve scientific reasoning skills (Gerber, Cavallo, & Edmund, 2010, pp. 545–546).

Effective outdoor education offers learners opportunities to contextualize and create meaning from experiences. Experiential learning frameworks suggest four steps – experiencing, reflecting, conceptualizing, and applying (Kolb, Boyatzis, & Mainemelis, 2000). Informal learning occurs during the experiencing step, in which learners are encouraged to engage in self-guided explorations. The reflection step helps learners connect their observations to their prior knowledge, after which they can use their observations to conceptualize a new understanding about the world, and finally apply new understanding to future experiences (ibid., pp. 200–201). Although connections to nature suggest that student-centered explorations are critical to gaining maximum cognitive, affective, and social benefits from time spent in nature (Kellert, 2002, p. 139), guiding children to draw meaning from their explorations in formal, non-formal, and informal learning experiences is critical to leveraging the benefits of outdoor education into sustained science learning (Falk & Dierking, 2000, p. 86).

Place-Based Instruction

Children can establish meaningful relationships with specific places in nature (Devine-Wright & Clayton, 2010; Gruenewald & Smith, 2014; Moore, 1986; Sobel, 2002), and providing opportunities for connecting children to places in nature can support such relationship building. The combination of place meanings and place attachments, held by a person or a group, constitutes a functional definition of a "sense of place" (Brandenburg & Carroll, 1995). Place-based education focuses on using the local community as an integrating context for learning in an attempt at making learning relevant to the lives of students (Powers, 2004).

Place-based education does not necessarily occur outdoors, but many forms of it have an outdoor education component and have shown themselves to be highly effective in building connections to nature as well as to interest and achievement in science. Smith and Sobel (2010) outlined a large body of research that supports place-based education for building motivation for learning and higher academic achievement in science and other subjects such as mathematics and language arts as well as improvement in areas not measured by testing such as self-motivation, confidence, and civic engagement.

Urban Settings

Children have been found to enjoy exploring nature even in relatively urban settings (Karsten, 2005; Karsten & Vliet, 2006; Moore, 1986; 1997), as well as in more wild locations (Sobel, 2002). However, there may be a desirable level of "naturalness," to generate awe and wonder in children (Hadzigeorgiou, 2012). There may also be a point at which the remoteness of the setting challenges a child's comfort level in such a way as to negatively impact the child's feelings about the experience (Bixler, Carlisle, Hammitt, & Floyd, 1994; Kals & Ittner, 2003). The novelty of the setting of field experiences may also negatively impact children's feelings about nature, particularly if the setting is unfamiliar for the student (DeWitt & Storksdieck, 2008, p. 184). Children can establish meaningful relationships with specific places in nature that may contribute to their connections with it (Devine-Wright & Clayton, 2010; Gosling & Williams, 2010; Gruenewald & Smith, 2014; Moore, 1986; Smith, 2002; Sobel, 2004). Schoolyards (urban and otherwise) have been used effectively to promote environmental learning and comfort levels (Carrier Martin, 2003; Dillon et al., 2006; Lopez, Campbell, & Jennings, 2008; Malone & Tranter, 2003; Rickinson et al., 2004).

CHALLENGES TO OUTDOOR EDUCATION

Direct encounters with nature have a long history in the education of children (Cornell, 1989; Hammerman, Hammerman, & Hammerman, 2001; Rickinson et al., 2004; Sundberg & Öhman, 2008), but many educational programs around the world have abandoned nature studies in authentic settings, including the outdoors. Despite the long history of outdoor education, some reform efforts have served to discourage such practices as schools shifted focus toward accountability models of instruction and global competition structured curricula with direct links toward career preparation.

Research on the benefits and barriers of including outdoor instruction have a dedicated education base (Coyle, 2005; 2010; Malone, 2008), but outdoor experiences continue as peripheral education practices (Barker, Slingsby, & Tilling, 2002; Carrier, Tugurian, & Thomson, 2013). Despite the benefits of outdoor experiences, traditional elementary schools rarely include outdoor learning opportunities as regular components of curriculum (Burriss & Burriss, 2011; Sobel, 2004). Instead of designing activities that move beyond the indoor classroom to the outdoors, teachers tend to base instruction indoors (Dyment, 2005, pp. 35–37), often relying on print and web-based media to teach children about the natural environment. Perhaps as a result, children often fail to connect their experiences in science class to the outdoor world around them (Carrier et al., 2013, p. 2075).

One challenge to outdoor education may be related to low comfort levels among students. Younger generations have been documented to spend less unrestricted time in outdoor surroundings and spend more time indoors or in controlled outdoor settings than previous generations. Some reasons for more time spent inside include fear of the outdoors, a preference for indoor screen time, or urbanization (Hofferth & Sandberg, 2001; Louv, 2008; Malone, 2008). Fear of the outdoors may be both a cause of avoidance and a result of it, as the lack of experience with the outdoors may contribute to children's fear of it (Bixler et al., 1994, para. 9). These fears have been documented in several studies in terms of general comfort in nature (ibid.; Carrier Martin, 2003) and fears specific to wildlife (Van Velsor, 2004). Haras (2010, p. 25) pointed out that fears of or discomfort when outdoors may impact learning in such environments. Students who do not feel they "belong" in the outdoors have less inclination to connect with and care for the natural world. Encouragingly, comfort levels have been shown to improve with time in nature (Carrier Martin, 2003, p. 56), suggesting that teachers who help students spend time in nature in spite of their fears may be able to help overcome them.

Comfort levels of teachers, administrators, and parents may also present barriers to outdoor education. Teachers have expressed safety concerns about using natural settings for environmental education (Simmons, 1998, p. 26). These fears range from concerns about animals, including insects, and poisonous plants to fear of the unknown. Parent anxiety about outdoor hazards has further impacted the amount of time children spend in the outdoors in free play (Sutterby, 2009, pp. 290–291). Parents' fears are influenced by global media, resulting in parents limiting children's free explorations in outdoor settings (Gill, 2007; Valentine, 1997, pp. 74–75). Malone (2008) described a building cultural fear of public spaces that further influences classroom cultures.

In addition to safety and litigation concerns, elementary teachers face challenges as science educators that may reinforce their tendency toward teaching science indoors. These challenges include elementary teachers' low self-efficacy in science teaching

(Cobern & Loving, 2002; Sandholtz & Ringstaff, 2011), school policies that have resulted in the marginalization of science in formal school settings (CEP, 2007), and the resulting lack of time for rich science instruction (Cocke, Buckley, & Scott, 2011). Time constraints for science teaching have been documented for decades (Finson, Lisowski, Fitch, & Foster, 1996; Murphy & Beggs, 2003; Stevenson, Carrier, & Peterson, 2014), and limited time spent teaching science and social studies continues to be a challenge for teachers (Cocke et al., 2011; West, 2007). Assessments of the knowledge of science acquired by students have been identified as limiting their learning experiences and reducing motivation for learning in the United Kingdom as well as the United States (TLRP, 2006; CEP, 2007; Jones & Edmunds, 2006; NRC, 2011; Pringle & Carrier Martin, 2005), yet situating instruction in the outdoors has the potential to increase student interest.

These barriers likely help explain why schools rarely include outdoor learning experiences in natural settings (Burris & Burris, 2011), which may contribute to children's disconnection from school science (Calabrese Barton & Yang, 2000; Cobern, 2000). Providing more opportunities for experiences in the natural world in the context of schooling may remediate deficits in experience, improving comfort levels in the outdoors (Carrier Martin, 2003, p. 56). When children fail to connect with science, they are learning in school with the outdoor world around them (Carrier et al., 2013, p. 2075), addressing children's experiences in the context of school may support their connections. Children's elementary science experiences, when aligned with learning in the outdoors, may encourage their connections with elementary science as they move into upper grades (Calabrese Barton & Yang, 2000; Cobern, 2000), and these experiences can improve science learning for all.

OUTDOOR EDUCATION AND DIVERSE AUDIENCES

Ethnicity

Outdoor education is beneficial for all children, but ensuring access to nature experiences may be especially beneficial for minority populations. In a review of research related to inequity in children's exposure to natural environments, Strife and Downey (2009, pp. 112–113) found that children's access to and experience in nature varies by ethnicity and socio-economic status, with minority and poorer students having less access to nature. In the United States minority populations are disproportionally concentrated in urban centers, where there is less direct access to natural areas, and lack of transportation in these areas can make gaining access logistically difficult or impossible (Godbey, 2009, pp. 18–19). Further, minority populations may be culturally excluded from natural areas, as outdoor recreation tends to be dominated by Caucasian populations of middle to high socio-economic status (Finney, 2014; Jones, Jones, Hardin, Chapman, Yarbrough, & Davis, 1999; Shores, Scott, & Floyd, 2007).

Providing students with connections using outdoor learning opportunities may have promise for addressing achievement gaps associated with environmental and science literacy. African-American and Hispanic populations traditionally underperform their Caucasian counterparts in documented assessments of science, yet all students benefit from culturally responsive experiences that can build students' self-efficacy for learning science (Andersen & Ward, 2014, p. 10). Some research suggests that a key reason behind the achievement gap is rooted in language; therefore, encouraging experiences that provide opportunities for building language can narrow learning gaps. This reasoning is supported by Vygotsky's vision on the importance of language in learning. By using the environment as the common "language," populations that traditionally underperform in reading and language arts can have access to a different way to gather and interact with information. Because all children can directly observe nature, school-based outdoor education has the potential to provide a culturally relevant context for science learning that draws on experiences teachers can provide for all children. Research on environmental literacy has shown that outdoor education boosted environmental attitudes and behaviors among African-American and Hispanic students even more than among Caucasian students (Larson, Whiting, & Green, 2011; Stevenson et al., 2013), and similar trends may hold in a science learning context.

Gender

Research suggests that leveraging girls' higher levels of connection to nature through outdoor education may help support girls continuing in science in upper grades. Researchers have found significant gender differences with respect to children's experiences and attitudes toward the environment, with girls having more pro-environmental attitudes than boys (Coyle, 2005; Stevenson et al., 2013; Zelezny, Chua, & Aldrich, 2000). For example, Müller, Kals, and Pansa (2009, pp. 62–65) found that adolescent girls display significantly more emotional affinity to nature than boys. They also found girls spent more time in nature and were more willing to act in support of the environment than were boys. Girls have demonstrated particularly high interests in the biological sciences (Baram-Tsabari & Yarden, 2008, pp. 82–86), which educators may build on through outdoor exploration (Moore, 1986). However, outdoor education has the potential to build environmental attitudes and behaviors among fourth and fifth grade boys (Carrier, 2009, p. 7), suggesting that outdoor education may capitalize on existing attitudes and behaviors for girls and build them for boys. Pro-environmental attitudes and connection to nature may be an important tool for educators in encouraging and maintaining girls' interest in science. Maintaining interest as girls become older may be particularly important. Research suggests girls ages from five to six spend similar amounts of time outdoors as boys, but that older boys (ages 10–12 and 15–17) spend significantly more time outdoors than do girls, representing a thirty-one percent decrease in outdoor time over five years among girls (Cleland et al., 2010, pp. 403–404). Parental influence was a major factor in encouraging girls' outdoor time, however this parental influence was not found with boys.

Culture

Culture may play a role in determining a child's environmental identity (Clayton, 2003). Although adults across cultures displayed preference for natural settings and concern for the environment are commonly aligned, different cultures evaluate the importance of the environment differently (Kahn & Kellert, 2002; Kaplan & Kaplan, 1989; Schultz & Zelezny, 1998; Ulrich, 1993; Van den Berg, Hartig, & Staats, 2007). For example, Native American cultures traditionally honor interconnectedness with nature (Cajete, 1999). In a comparison of Americans living in Namibia and native Namibians, Chang and Opotow (2009) found Namibians assigned rights to non-human entities, while Americans were less likely to do so. The presence, absence, or condition of the environment accessible to certain cultures may also play a role in the way people in that culture relate to the environment. Müller and associates (2009, pp. 62–65) found adolescents in Lithuania have a higher affinity toward nature than German adolescents. They attributed this difference to Germany's more industrialized and urban character.

Although American schools include a great deal of content related to the natural world (NRC, 2012), they rarely connect to children's interests by relocating science instruction outdoors (Burriss & Burriss, 2011; Carrier et al., 2013; Coyle, 2009; Dyment, 2005). Studies have repeatedly documented that teachers feel they do not have time to integrate outdoor education or environmental topics in class, largely due to pressure from standardized testing (Ko & Lee, 2003; Stevenson et al., 2014; Tal & Argaman, 2005). Given the demonstrated link between outdoor education and academic achievement, educators should view this reality as a missed opportunity. Outdoor education could be seen as complementary rather than antithetical to reform goals, but lack of outdoor education in schools may explain why despite high interest in nature, children generally lose interest in school science as they move toward middle school (Osborne et al., 2003; Thomson & Fleming, 2004). Some authors have suggested that one possible reason for children's disengagement with school science is the inability of traditional school science to acknowledge children's way of thinking about nature (Calabrese Barton & Yang, 2000; Cobern, 2000).

DISCUSSION

Outdoor education offers a myriad of opportunities for impacting children's knowledge, attitudes, and behaviors that encourage personal interactions with nature and environmental stewardship. These opportunities can capitalize on children's natural curiosity about science and their world (Luce & Hsi, 2015; Spektor-Levy et al., 2013). Outdoor education has been shown to positively impact student interest, motivation, emotional development, and cognitive gains (Dillon et al., 2006; Malone, 2008, p. 15). Outdoor learning occurs in formal, non-formal, and informal education settings. The integration of outdoor contexts in formal education to connect with children's lives has the potential to fully integrate school subjects and offer rich opportunities for learning in: science, social studies, mathematics, language arts, physical education, and the arts. In addition to enhancing children's interests, shared class participation in outdoor activities gives teachers and students a chance to recognize, acknowledge, and affirm children's identities as learners.

In the outdoors, children can be active participants in learning, and outdoor experiences encourage exploration, critical thinking, and problem solving in authentic settings that connect directly with patterns in nature. Using the outdoors as a context for learning, children can investigate patterns, energy flow, form and function, consider living and non-living components of the natural world, and participate in practices of science. Whether educators are preparing children for careers in science or for public engagement in science (Feinstein, Allen, & Jenkins, 2013) the inclusion of outdoor experiences can provide children with a well-rounded education.

Despite the challenges of outdoor education, overcoming the barriers is possible. It may not be realistic to expect teachers to relocate some of their instruction outdoors. For example, the outdoors may be less accessible in urban settings, or teachers may feel they lack the skills necessary to teach in the outdoors. In such cases field trips to nature centers may be an option to provide children with the benefits of increased experience in natural settings. In addition, professional development opportunities can impact teachers' efficacy in connecting children with the outdoors, and the combination of professional development with established curricula developed for outdoor instruction can help expand teachers' efficacy and build opportunities for all students.

Given the decades of reform efforts to improve instruction, current strategies are emerging that build on new understandings of learning (NRC, 2005). It is important for educators to understand and incorporate strategies that attend to children's prior knowledge, begin to build a deep foundation of factual knowledge, and develop metacognition that allows learners to take charge of learning. Outdoor education should be viewed as a legitimate tool for addressing reform efforts offering potential to build young children's foundations for future learning and engagement.

REFERENCES

AAAS (American Association for the Advancement of Science). (1990). *Science for All Americans*. Washington, DC. Retrieved November 30, 2015, from http://www.project2061.org/publications/sfaa/online/sfaatoc.htm

AAAS (American Association for the Advancement of Science). (1993). *Benchmarks for Science Literacy*. Washington, DC. Retrieved November 30, 2015, from http://www.project2061.org/publications/bsl/online/index.php

AAAS (American Association for the Advancement of Science). (2001). *Atlas of Scientific Literacy*. Washington, DC. Retrieved November 30, 2015, from http://www.project2061.org/publications/atlas/

AAAS (American Association for the Advancement of Science). (2007). *Atlas of Scientific Literacy*. Washington, DC. Retrieved November 30, 2015, from http://www.project2061.org/publications/atlas/

Anderson, D., & Zhang, Z. (2003). Teacher perceptions of field-trip planning and implementation. *Visitor Studies Today*, *6*(3), 6–12.

Andersen, L., & Ward, T. J. (2014). Expectancy-value models for the STEM persistence plans of ninth-grade, high-ability students: A comparison between black, hispanic, and white students. *Science Education*, *98*(2), 216–242.

Atkins, J. (2000). *Girls Who Looked under Rocks: The lives of six pioneering naturalists*. Nevada City, CA: Dawn.

Ballantyne, R., & Packer, J. (2005). Promoting environmentally sustainable attitudes and behaviour through free-choice learning experiences: What is the state of the game? *Environmental Education Research*, *11*(3), 281–295.

Baram-Tsabari, A., & Yarden, A. (2008). Girls' biology, boys' physics: Evidence from free-choice science learning settings. *Research in Science & Technological Education*, *26*(1), 75–92.

Barker, S., Slingsby, D., & Tilling, S. (2002). Teaching biology outside the classroom: Is it heading for extinction? *FSC Occasional Publication*, *72*(May), 1–16.

Behrendt, M., & Franklin, T. (2014). A review of research on school field trips and their value in education. *International Journal of Environmental & Science Education*, *3*, 235–245.

Bixler, R. D., Carlisle, C. L., Hammltt, W. E., & Floyd, M. F. (1994). Observed fears and discomforts among urban students on field trips to wildland areas. *The Journal of Environmental Education*, *26*(1), 24–33.

Brandenburg, A. M., & Carroll, M. S. (1995). Your place or mine? The effect of place creation on environmental values and landscape meanings. *Society & Natural Resources*, *8*(5), 381–398.

Broussard, S. R., Jones, S. B., Nielson, L. A., & Flanagan, C. A. (2001). Forest stewardship education: Fostering positive attitudes in urban youth. *Journal of Forestry*, *99*(1), 37–42.

Burriss, K., & Burriss, L. (2011). Outdoor play and learning: Policy and practice. *International Journal of Education Policy and Leadership*, *6*(8), 1–12.

Cajete, G. (1999). *Igniting the Sparkle: An indigenous science education model*. Skyland, NC: Kivaki Press.

Calabrese Barton, A., & Yang, K. (2000). The culture of power and science education: Learning from Miguel. *Journal of Research in Science Teaching*, *37*(8), 871–889.

Carrier Martin, S. (2003). The influence of outdoor schoolyard experiences on students' environmental knowledge, attitudes, behaviors, and comfort levels. *Journal of Elementary Science Education*, *15*(2), 51–56.

Carrier, S. J. (2009). Environmental education in the schoolyard: Learning styles and gender. *The Journal of Environmental Education*, *40*(3), 2–12.

Carrier, S. J., Thomson, M. M., Tugurian, L. P., & Stevenson, K. T. (2014). Elementary science education in classrooms and outdoors: Stakeholder views, gender, ethnicity, and testing. *International Journal of Science Education*, *36*(13), 2195–2220.

Carrier, S. J., Tugurian, L. P., & Thomson, M. M. (2013). Elementary science indoors and out: Teachers, time, and testing. *Research in Science Education*, *43*(5), 2059–2083.

CEP. (2007). *Choices, Changes, and Challenges: Curriculum and instruction in NCLB era*. Washington, DC: Center on Education Policy.

Chang, V., & Opotow, S. (2009). Conservation values, environmental identity, and moral inclusion in the Kunene Region, Namibia: A comparative study. *Beliefs and Values: Understanding the Global Implications of Human Nature, 1*, 79–89.

Chawla, L. (1999). Life paths into effective environmental action. *The Journal of Environmental Education*, *31*(1), 15–26.

Chawla, L. (2001). Significant life experiences revisited once again: Response to Vol. 5(4) "Five critical commentaries on significant life experience research in environmental education." *Environmental Education Research*, *7*(4), 451–461.

Chawla, L. (2006). Research methods to investigate significant life experiences: Review and recommendations. *Environmental Education Research*, *12*(3–4), 359–374.

Chawla, L. (2009). Growing up green: Becoming an agent of care for the natural world. *The Journal of Developmental Processes*, *4*(1), 6–23.

Chawla, L., & Cushing, D. (2007). Education for strategic environmental behavior. *Environmental Education Research*, *13*(4), 437–452.

Cheng, J. C.-H., & Monroe, M. C. (2010). Connection to nature: Children's affective attitude toward nature. *Environment and Behavior*, *44*(1), 31–49.

Clayton, S. (2003). Environmental identity: Conceptual and operational definition. In S. Clayton & S. Opotow (Eds.), *Identity and the Natural Environment: The psychological significance of nature* (pp. 45–65). Cambridge, MA: MIT Press.

Cleland, V., Timperio, A., Salmon, J., Hume, C., Baur, L. A., & Crawford, D. (2010). Predictors of time spent outdoors among children: 5-year longitudinal findings. *Journal of Epidemiology and Community Health*, *64*(5), 400–406.

Cobern, W. W. (2000). *Everyday Thoughts about Nature: A worldview investigation of important concepts students use to make sense of nature with specific attention to science* (Contemporary Trends and Issues in Science Education, Vol. 9). Dordrecht, The Netherlands: Springer.

Cobern, W. W., & Loving, C. C. (2002). Investigation of preservice elementary teachers' thinking about science. *Journal of Research in Science Teaching*, *39*(10), 1016–1031.

Cocke, E. F., Buckley, J., & Scott, M. A. (2011, September). *Accountability and teacher practice: Investigating the impact of a new state test and the timing of state test adoption on teacher time use*. Paper presented at the SREE Conference, Washington, DC.

Corin, E. N., Jones, M. G., Andre, T., Childers, G. M., & Stevens, V. (2015). Science hobbyists: Active users of the science-learning ecosystem. *International Journal of Science Education, Part B*, *8455* (Dec. 2015), 1–20.

Cornell, J. (1989). *Sharing the Joy of Nature: Nature activities for all ages*. Nevada City, CA: Dawn.

Coyle, K. J. (2005). *Environmental Literacy in America*. Washington, DC: National Environmental Education & Training Foundation.

Coyle, K. (2009). *Time Out: Using the outdoors to enhance classroom performance. A school readiness guide for teachers and parents*. National Wild Life Federation. Retrieved April 9, 2016, from https://www.nwf.org/pdf/Be%20Out%20There/TimeOutwithBOTActivities.pdf

Coyle, K. J. (2010). *Back to School: Back outside! Create high performing students.* Reston, VA: National Wildlife Federation.

DeLoache, J. S. (2005). Mindful of symbols. *Scientific American*, *293*(2), 72–77.

Devine-Wright, P., & Clayton, S. (2010). Introduction to the special issue: Place, identity and environmental behaviour. *Journal of Environmental Psychology*, *30*(3), 267–270.

DeWitt, J., & Storksdieck, M. (2008). A short review of school field trips: Key findings from the past and implications for the future. *Visitor Studies*, *11*(2), 181–197.

Dickinson, E. (2013). The misdiagnosis: Rethinking "nature-deficit disorder." *Environmental Communication: A Journal of Nature and Culture*, *7*(3), 315–335.

Dierking, L. D., Falk, J. H., Rennie, L., Anderson, D., & Ellenbogen, K. (2003). Policy statement of the "Informal Science Education" Ad Hoc Committee. *Journal of Research in Science Teaching*, *40*(2), 108–111.

Dillon, J., Rickinson, M., Teamey, K., Morris, M., Choi, M. Y., Sanders, D., & Benefield, P. (2006). The value of outdoor learning: Evidence from research in the UK and elsewhere. *School Science Review*, *7*(320), 107–112.

Dyment, J. (2005). Green school grounds as sites for outdoor learning: Barriers and opportunities. *International Research in Geographical and Environmental Education*, *14*(1), 28–45.

Eaton, D. (2000). Cognitive and affective learning in outdoor education. *Dissertation Abstracts International – Section A: Humanities and Social Sciences*, *60*(10-A), 3595.

Eberbach, C., & Crowley, K. (2009). From everyday to scientific observation: How children learn to observe the biologist's world. *Review of Educational Research*, *79*(1), 39–68.

Ernst, J., & Theimer, S. (2011). Evaluating the effects of environmental education programming on connectedness to nature. *Environmental Education Research*, *17*(5), 577–598.

Eshach, H. (2007). Bridging in-school and out-of-school learning: Formal, non-formal, and informal education. *Journal of Science Education and Technology*, *16*(2), 171–190.

Ewert, A., Place, G., & Sibthorp, J. (2005). Early-life outdoor experiences and an individual's environmental attitudes. *Leisure Sciences*, *27*(Feb. 2015), 225–239.
Falk, J. H. (2001). *Free-Choice Science Education: How we learn science outside of school*. New York, NY: Teacher's College Press.
Falk, J. H. (2005). Free-choice environmental learning: Framing the discussion. *Environmental Education Research*, *11*(3), 265–280.
Falk, J. H., & Dierking, L. D. (2000). *Learning from Museums: Visitor experiences and the making of meaning*. Walnut Creek, CA: Altamira Press.
Farber, P. (2000). *Finding Order in Nature: The naturalist tradition from Linnaeus to EO Wilson*. Baltimore, MD: John Hopkins University Press.
Feinstein, N. W., Allen, S., & Jenkins, E. (2013). Outside the pipeline: Reimagining science education for nonscientists. *Science*, *340*(6130), 314–317.
Feynman, R. P. (2005). *The Pleasure of Finding Things Out: The best short works of Richard P. Feynman*. Cambridge, MA: Perseus.
Finney, C. (2014). *Black Faces, White Spaces: Reimagining the Relationship of African Americans to the Great Outdoors*. Chapel Hill, NC: UNC Press.
Finson, K. D., Lisowski, M., Fitch, T., & Foster, G. (1996). The status of science education in K–6 Illinois schools. *School Science and Mathematics*, *96*(3), 120–127.
Frumkin, H. (2001). Beyond toxicity: Human health and the natural environment. *American Journal of Prevent*, *20*(3), 234–240.
Gerber, B. L., Cavallo, A. M. L., & Edmund, A. (2010). Relationships among informal learning environments, teaching procedures and scientific reasoning ability. *International Journal of Science Education*, *23*(5), 535–549.
Gill, T. (2007). *No Fear: Growing up in a risk averse society*. London, UK: Calouste Gulbenkian Foundation.
Godbey, G. (2009). *Outdoor Recreation, Health, and Wellness: Understanding and enhancing the relationship*. Washington, DC: Resources for the Future.
Gosling, E., & Williams, K. J. (2010). Connectedness to nature, place attachment and conservation behaviour: Testing connectedness theory among farmers. *Journal of Environmental Psychology*, *30*(3), 298–304.
Gould, S. (1991). *Bully for Brontosaurus*. New York, NY: Norton.
Gould, S. (2002). *The Structure of Evolutionary Theory*. Cambridge, MA: Belnap Press of Harvard University Press.
Grahn, P., Mårtensson, F., Lindblad, B., Nilsson, P., & Ekman, A. (1997). Ute på dagis [Outdoors at daycare]. *Stad och land*, *145*, 20–27. (In Swedish)
Gruenewald, D. A., & Smith, G. A. (Eds.). (2014). *Place-Based Education in the Global Age: Local diversity*. New York, NY: Psychology Press.
Hammerman, D. R., Hammerman, W. M., & Hammerman, E. L. (2001). *Teaching in the Outdoors*. Danville, IL: Interstate.
Hammerman, E. L. & Hammerman, D. R. (2013). Extending teachers' work to outdoor learning environments: Applying high-quality instruction for meaningful learning. In E. Kimonen & R. Nevalainen (Eds.), *Transforming Teachers' Work Globally: In search of a better way for schools and their communities* (pp. 35–53). Rotterdam, The Netherlands: Sense.
Haras, K. (2010). Overcoming fear: Helping decision makers understand risk in outdoor education. *Pathways: The Ontario Journal of Outdoor Education*, *22*(2), 25–32.
Hattie, J., Marsh, H. W., Neill, J. T., & Richards, G. E. (1997). Adventure education and Outward Bound: Out-of-class experiences that make a lasting difference. *Review of Educational Research*, *67*(1), 43–87.
Hadzigeorgiou, Y. (2012). Fostering a sense of wonder in the science classroom. *Research in Science Education, 42*(5), 985–1005.
Hofferth, S. L., & Sandberg, J. F. (2001). How American children spend their time. *Journal of Marriage and Family*, *63*(2), 295–308.

Hungerford, H. R., & Volk, T. (1990). Changing learner behavior through environmental education. *The Journal of Environmental Education*, *21*(3), 8–21.

Huxley, R. (Ed.). (2007). *The Great Naturalists*. London, UK: Thames & Hudson.

Ives, B., & Obenchain, K. (2006). Experiential education in the classroom and academic outcomes: For those who want it all. *Journal of Experiential Education*, *29*(1), 61–77.

Jones, M. G., & Edmunds, J. (2006). Models of elementary science instruction: Roles of science specialist teachers. In K. Appleton (Ed.), *Elementary Science Teacher Education: International perspectives on contemporary issues and practice* (pp. 317–343). Mahwah, NJ: Lawrence Erlbaum & AETS.

Jones, M. G., Jones, B. D., Hardin, B., Chapman, L., Yarbrough, T., & Davis, M. (1999). The impact of high-stakes testing on teachers and students in North Carolina. *The Phi Delta Kappan*, *81*(3), 199–203.

Kahn, P. H., & Kellert, S. (2002). *Children in Nature: Psychological, sociocultural, and evolutionary investigations*. Cambridge, MA: MIT Press.

Kals, E., & Ittner, H. (2003). Children's environmental identity: Indicators and behavioral impacts. In S. Clayton & S. Opotow (Eds.), *Identity and the Natural Environment: Psychological significance of nature* (pp. 135–157). Cambridge, MA: MIT Press.

Kaplan, R., & Kaplan, S. (1989). *The Experience of Nature: A psychological perspective*. New York, NY: Cambridge University Press.

Kaplan, R., & Kaplan, S. (2002). Adolescents and the natural environment: A time out. In P. H. Kahn & S. R. Kellert (Eds.), *Children and Nature: Psychological, sociocultural, and evolutionary investigations* (pp. 227–258). Cambridge, MA: MIT Press.

Karsten, L. (2005). It all used to be better? Different generations on continuity and change in urban children's daily use of space. *Children's Geographies, 3*(3), 275–290.

Karsten, L., & Vliet, W. (2006). Children in the city: Reclaiming the street. *Children, Youth and Environments, 16*(1), 151–167.

Kellert, S. R. (2002). Experiencing nature: Affective, cognitive, and evaluative development in children. In P. H. Kahn & S. R. Kellert (Eds.), *Children and Nature: Psychological, sociocultural, and evolutionary investigations* (pp. 117–151). Cambridge, MA: MIT Press.

Kirikkaya, E. B. (2011). Grade 4 to 8 primary school students' attitudes towards science: Science enthusiasm. *Educational Research and Reviews*, *6*(4), 374–382.

Ko, A. C., & Lee, J. C. (2003). Teachers' perceptions of teaching environmental issues within the science curriculum: A Hong Kong perspective. *Journal Science Education and Technology*, *12*(3), 187–204.

Koenig, M. A., Clément, F., & Harris, P. L. (2004). Trust in testimony: Children's use of true and false statements. *Psychological Science*, *15*(10), 694–698.

Kolb, D. A., Boyatzis, R. E., & Mainemelis, C. (2000). Experiential learning theory: Previous research and new directions. In R. J. Sternberg & L. F. Zhang (Eds.), *Perspectives on Thinking, Learning, and Cognitive Styles* (pp. 227–247). Mahwah, NJ: Lawrence Erlbaum Associates.

Kuo, F. E., & Faber Taylor, A. (2004). A potential natural treatment for attention-deficit/hyperactivity disorder: Evidence from a national study. *American Journal of Public Health, 94*(9), 1580–1586.

Larson, L. R., Whiting, J. W., & Green, G. T. (2011). Exploring the influence of outdoor recreation participation on pro-environmental behaviour in a demographically diverse population. *Local Environment*, *16*(1), 67–86.

Lieberman, G. A., & Hoody, L. L. (1998). *Closing the Achievement Gap: Using the environment as an integrating context for learning. Results of a nationwide study.* Poway, CA: Science Wizards.

Liefländer, A. K., Fröhlich, G., Bogner, F. X., & Schultz, P. W. (2012). Promoting connectedness with nature through environmental education. *Environmental Education Research*, *19*(3), 370–384.

Lindemann-Matthies, P. (2005). "Loveable" mammals and "lifeless" plants: How children's interest in common local organisms can be enhanced through observation of nature. *International Journal of Science Education*, *27*(6), 655–677.

Lopez, R., Campbell, R., & Jennings, J. (2008). The Boston schoolyard initiative: A public-private partnership for rebuilding urban play spaces. *Journal of Health Politics, Policy and Law, 33*(3), 617–638.

Loucks-Horsley, S., Kapitan, R., Carlson, M. O., Kuerbis, P. J., Clark, R. C., Marge Melle, G., … Walton, E. (1990). *Elementary School Science for the '90s*. Washington, DC: Association for Supervision and Curriculum Development.

Louv, R. (2008). *Last Child in the Woods: Saving our children from nature-deficit disorder*. Chapel Hill, NC: Algonquin.

Luce, M. R., & Hsi, S. (2015). Science-relevant curiosity expression and interest in science: An exploratory study. *Science Education*, *99*(1), 70–97.

Malone, K. (2008). *Every Experience Matters: An evidence based research report on the role of learning outside the classroom for children's whole development from birth to eighteen.* Stoneleigh Park, Warks., UK: Farming and Coutryside Education.

Malone, K., & Tranter, P. (2003). Children's environmental learning and the use, design and management of school grounds. *Children, Youth and Environments, 13*(2). Retrieved April 9, 2016, from http://colorado.edu/journals/cye

Maltese, A. V., & Tai, R. H. (2010). Eyeballs in the fridge: Sources of early interest in science. *International Journal of Science Education*, *32*(5), 669–685.

Manzo, K. K. (2008). Schools adapting curriculum to the outdoors. *Education Week*, *28*(15), 3.

Moore, R. C. (1986). The power of nature orientations of girls and boys toward biotic and abiotic play settings on a reconstructed schoolyard. *Children's Environments Quarterly, 3*(3), 52–69.

Moore, R. C. (1997). The need for nature: A childhood right. *Social Justice, 24*(3), 203–220.

Müller, M. M., Kals, E., & Pansa, R. (2009). Adolescents' emotional affinity toward nature: A cross-societal study. *Journal of Developmental Processes*, *4*(1), 59–69.

Murphy, C., & Beggs, J. (2003). Children's perceptions of school science. *School Science Review*, *84*(308), 109–116.

NGSS Lead States. (2013). *Next Generation Science Standards: For states, by states. The standards – Arranged by disciplinary core ideas and by topics* (Vol. 1). Washington, DC: National Academies Press.

NRC (National Research Council). (2005). *How Students Learn: Science in the classroom.* Washington, DC: National Academies Press.

NRC (National Research Council). (2007a). *Rising Above the Gathering Storm: Energizing and employing America for a brighter economic future*. Washington, DC: National Academies Press.

NRC (National Research Council). (2007b). *Taking Science to School: Learning and teaching science in grades K–8*. Washington, DC: National Academies Press.

NRC (National Research Council). (2011). *Successful K–12 STEM Education: Identifying effective approaches in science, technology, engineering, and mathematics.* Washington, DC: National Academies Press.

NRC (National Research Council). (2012). *A Framework for K–12 Science Education: Practices, crosscutting concepts, an core ideas*. Washington, DC: National Academies Press.

Osborne, J. (2007). Engaging young people with science: Thoughts about future direction of science education. In C. Linder, L. Östman, & P.-O. Wickman (Eds.), *Promoting Scientific Literacy: Science education research in transaction. Proceedings of the Linnaeus Tercentenary Symposium held at Uppsala University, Uppsala, Sweden, May 28–29, 2007* (pp. 105–112). Retrieved April 9, 2016, from https://uu.diva-portal.org/smash/get/diva2:272594/FULLTEXT02.pdf

Osborne, J., Simon, S., & Collins, S. (2003). Attitudes towards science: A review of the literature and its implications. *International Journal of Science Education, 25*(9), 1049–1079.

Palmer, J. A., Suggate, J., Robottom, I., & Heart, P. (1999). Significant life experiences and formative influences on the development of adults' environmental awareness in the UK, Australia and Canada. *Environmental Education Research*, *5*(2), 181–200.

Powers, A. L. (2004). An evaluation of four place-based education programs. *The Journal of Environmental Education*, *35*(4), 17–32.

Priest, S. (1986). Redefining outdoor education: A matter of many relationships. *Journal of Environmental Education*, *17*(3), 13–15.

Pringle, R. M., & Carrier Martin, S. (2005). The potential of upcoming high-stakes testing on the teaching of science in elementary classrooms. *Research in Science Education, 35,* 347–361.

Rennie, L. J. (2007). Learning science outside of school. In S. K. Abell & N. G. Lederman (Eds.), *Handbook of Research on Science Education* (pp. 125–167). Mahwah, NJ: Lawrence Erlbaum Associates.

Renninger, K. A. (2000). Individual interest and its implications for understanding interinsic motivation. In C. Sansone & J. M. Harackiewicz (Eds.), *Intrinsic Motivation: Controversies and new directions* (pp. 373–404). San Diego, CA: Academic Press.

Renninger, K. A. (2007). Interest and motivation in informal science learning. *Learning*, 45. Retrieved April 9, 2016, from http://www.informalscience.com/researches/Renninger_Commissioned_Paper.pdf

Rickinson, M., Dillon, J., Teamey, K., Morris, M., Choi, M. Y., Sanders, D., & Benefield, P. (2004). *A Review of Research on Outdoor Learning*. Shrewsbury, UK: Field Studies Council.

Rivkin, M. (1997). The schoolyard habitat movement: What it is and why children need it. *Early Childhood Education*, *25*(1), 61–66.

Rose, K. A., Morgan, I. G., Ip, J., Kifley, A., Huynh, S., Smith, W., & Mitchell, P. (2008). Outdoor activity reduces the prevalence of myopia in children. *Ophthalmology*, *115*(8), 1279–1285.

Sandholtz, J. H., & Ringstaff, C. (2011). Reversing the downward spiral of science instruction in K–2 classrooms. *Journal of Science Teacher Education*, *22*(6), 513–533.

Schultz, P. W., & Zelezny, L. C. (1998). Values and proenvironmental behavior: A five-country survey. *Journal of Cross-Cultural Psychology*, *29*(4), 540–558.

SEER (State Education & Environment Roundtable). (2000). *The Effects of Environment-Based Education on Student Achievement*. San Diego, CA. Retrieved May 26, 2016, from http://www.seer.org/pages/research/CSAP2000.pdf

Shores, K. A., Scott, D., & Floyd, M. F. (2007). Constraints to outdoor recreation: A multiple hierarchy stratification perspective. *Leisure Sciences*, *29*(3), 227–246.

Simmons, D. (1998). Using natural settings for environmental education: Perceived benefits and barriers. *The Journal of Environmental Education*, *29*(3), 23–31.

Skelly, S. M., & Zajicek, J. M. (1998). The effect of an interdisciplinary garden program on the environmental attitudes of elementary school students. *HortTechnology*, *8*(4), 579–583.

Smith, G. A. (2002). Place-based education. *Phi Delta Kappan*, *83*(8), 584–594.

Smith, G. A., & Sobel, D. (2010). *Place- and Community-Based Education in Schools*. New York, NY: Routledge.

Sobel, D. (1990). A place in the world: Adults' memories of childhood's special places. *Children's Environments Quarterly*, *7*(4), 5–12.

Sobel, D. (2002). *Children's Special Places: Exploring the role of forts, dens, and bush houses in middle childhood*. Detroit, MI: Wayne State University Press.

Sobel, D. (2004). *Place-Based Education: Connecting classrooms & communities* (Nature Literacy Series, No. 4). Great Barrington, MA: The Orion Society.

Spektor-Levy, O., Baruch, Y. K., & Mevarech, Z. (2013). Science and scientific curiosity in pre-school – The teacher's point of view. *International Journal of Science Education*, *35*(13), 2226–2253.

Stevenson, K. T., Carrier, S. J., & Peterson, M. N. (2014). Evaluating strategies for inclusion of environmental literacy in the elementary school classroom. *Electronic Journal of Science Education*, *18*(8), 1–17.

Stevenson, K. T., Peterson, M. N., Bondell, H. D., Mertig, A. G., & Moore, S. E. (2013). Environmental, institutional, and demographic predictors of environmental literacy among middle school children. *PLoS ONE*, *8*(3). Retrieved April 10, 2016, from http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3606223/

Strife, S., & Downey, L. (2009). Childhood development and access to nature: A new direction for environmental inequality research. *Organization & Environment*, *22*(1), 99–122.

Sundberg, M., & Öhman, J. (2008). Hälsa och livskvalitet. In K. Sandell & S. Sörlin (Eds.), *Friluftshistoria: Från "härdande friluftslif" till ekoturism och miljöpedagogik. Teman i det svenska friluftslivets historia* (pp. 102–117). Stockholm, Sweden: Carlsson.

Sutterby, J. A. (2009). What kids don't get to do anymore and why. *Childhood Education*, *85*(5), 289–292.

Tal, R. T., & Argaman, S. (2005). Characteristics and difficulties of teachers who mentor environmental inquiry projects. *Research in Science Education*, *35*(4), 363–394.

Taylor, A. F., & Kuo, F. E. (2009). Children with attention deficits concentrate better after walk in the park. *Journal of Attention Disorders*, *12*(5), 402–409.

Thomson, S., & Fleming, N. (2004). *Examining the Evidence: Science achievement in Australian schools in TIMSS 2002* (TIMMS Australia Monograph, No. 7). Australian Council for Educational Research: Camberwell, Vic., Australia.

TLRP. (2006). *Science Education in Schools: Issues, evidence, and proposals*. London, UK: Teaching and Learning Research Programme, Institute of Education, University of London.

Ulrich, R. S. (1993). Biophilia, biophobia, and natural landscapes. In S. R. Kellert & E. O. Wilson (Eds.), *The Biophilia Hypothesis* (pp. 73–137). Washington, DC: Island Press.

Valentine, G. (1997). "Oh Yes I Can." "Oh no you can't.": Children and parents' understandings of kids' competence to negotiate public space safely. *Antipode*, *29*(1), 65–89.

Van den Berg, A. E., Hartig, T., & Staats, H. (2007). Preference for nature in urbanized societies: Stress, restoration, and the pursuit of sustainability. *Journal of Social Issues*, *63*(1), 79–96.

Van Velsor, S. W. (2004). *A Qualitative Investigation of the Urban Minority Adolescent Experience with Wildlife*. (Doctoral dissertation). University of Missouri, Columbia, MI.

Wells, N. M. (2000). At home with nature effects of "greenness" on children's cognitive functioning. *Environment and Behavior*, *32*(6), 775–795.

Wells, N. M., & Evans, G. W. (2003). Nearby nature: A buffer of life stress among rural children. *Environment and Behavior*, *35*, 311–330.

Wells, N. M., & Lekies, K. S. (2006). Nature and the life course: Pathways from childhood nature experiences. *Children, Youth and Environments*, *16*(1), 1–25.

West, M. (2007). Testing, learning, and teaching: The effects of test-based accountability on student achievement and instructional time in core academic subjects. In C. Finn, Jr. & D. Ravitch (Eds.), *Beyond the Basics: Achieving a liberal education for all children* (pp. 45–62). Washington, DC: Thomas B. Fordham Institute.

Wilson, E. O. (1994). *Naturalist*. Washington, DC: Island Press.

Wilson, R. (1995). Nature and young children: A natural connection. *Young Children*, *50*(6), 4–11.

Zelezny, L. C., Chua, P. P., & Aldrich, C. (2000). New ways of thinking about environmentalism: Elaborating on gender differences in environmentalism. *Journal of Social Issues*, *56*(3), 443–457.

Zoldosova, K., & Prokop, P. (2006). Education in the field influences children's ideas and interest toward science. *Journal of Science Education and Technology*, *15*(3–4), 304–313.