Nature Journaling: A Mediating Activity

for Scientific Practices in the Classroom

by

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ABSTRACT

Today's science education has been highly criticized in the United States despite reform efforts that attempt to promote more wholistic and integrated goals for teaching and learning science, which include both the understanding of key content and the acquisition of scientific skills. Outdoor education may be a means with which to better engage students in science, but educators often find this type of teaching difficult to adopt for a variety of reasons. Nature journaling may be a useful access point to outdoor education for teachers experiencing those barriers. This study examines a six-month implementation of nature journaling activities in a high school Ecology & Animal Behavior course. It was found that students completing nature journaling in this classroom utilized both scientific knowledge and scientific practices in their work, and that instances and depth of these demonstrations increased as a general trend over time, which may be considered successful learning according to situativity theory. Further, students communicated their understanding of what they were accomplishing through their journal work as highly beneficial, though their own perceptions of their competencies in scientific practices did not change. Though additional research needs to be conducted, this study points to a potentially positive relationship between modern science education and outdoor learning through nature journal activities.

Dedicated to Fabian Perez and Anna Morgan, my fellow outdoor enthusiasts.

May our children together and forever be in awe of this world.

ACKNOWLEDGMENTS

I would first like to thank the members of my supervisory committee: Dr. Nico Franz, for designing and enacting my first outdoor education experience; Dr. Michelle Jordan, for eliciting and nurturing my professional interests as a student in the Learning Sciences program; and Dr. Andrea Weinberg, my committee chair, for guiding and supporting me through my final semesters of graduate work. I appreciate all of the advice and kindness that each of you has shown me throughout my many years at ASU. I would also like to express my gratitude to the Helios Education Foundation for contributing in part to my tuition expenses, lifting a bit of weight from my shoulders, and to my students, who have graciously allowed me into their lives as both a teacher and a researcher. Finally, a special thank you to Star, who was there for me during this incredibly challenging year, and all the years before that. Thank you.

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Introduction

In this rapidly changing world, criticisms of American education are both varied and abundant (Kolodner, 1991) (e.g., Moore, 1990). Given that schools in the United States continue to operate under outdated models of teaching and learning in which large numbers of students passively receive information from a lecturing instructor (Banilower et al., 2013; Kolodner, 1991; Stein et al., 2016, pp. 211-213; Tyack & Tobin, 1994), students are often deprived of the opportunity to actively engage with academic material and develop key skills for living in the Digital Age. These *twenty-first century skills* are those that many believe to be necessary for success and prosperity in the modern day (Stein et al., 2016, p. 212). This lack of opportunity can be clearly seen in today's science classrooms (Banilower et al., 2013; National Research Council, 2012, p. 1) and is of particular concern given that American students consistently underperform in this subject area compared to students of other countries (see Bybee et al., 2008, pp. 101-104; Moore, 1990; Ripley, 2013, p. 3).

Despite reform efforts (see Bybee et al., 2008, pp. 50-64; National Research Council, 2012; Tyack & Tobin, 1994), science instruction still tends to focus on the memorization of content from seemingly discrete scientific disciplines (American Association for the Advancement of Science, 2001, pp. 3, 237; Moore, 1990). Students rarely get the chance to engage in any type of inquiry in their science classes and are even more rarely afforded space to freely explore and apply their knowledge of and between fields of study (American Association for the Advancement of Science, 2001, pp. 237; Banilower et al., 2013). Not only does this create a skewed vision of the sciences as professions, but it also tends to be incredibly dull, and therefore leads to a lack of long-term retention of content (American Association for the Advancement of Science, 2001, p. 4), despite the focus of accountability measures on that very thing. This lecture-dominated style of science instruction may be contributing to poor student performance (see Bybee et al., 2008, pp. 80-85, 101-104; Moore, 1990; Ripley, 2013, p. 3) and driving students away from a field of study that could – and should – be both fun and interesting at its best but should at the very least by useful (Maienschein, 1998; Moore, 1990). Fortunately, outdoor education has the potential to meet the demands of modern science instruction, and teachers who are interested in utilizing it may find a simple and accessible entry point in classroom nature journaling.

Literature Review

Historical Grounding

Science Education

Despite the commonplace nature of science courses in American schools today, the early days of science education in this country were marked by slow progress. It wasn't until religious teachings began to lose their foothold in education that more practical curricula were able to find their way into the system. By the mid-1800s, science education in the US was well established in the form of coursework in natural philosophy (i.e., physics and chemistry) and natural history (i.e., biology and earth science) (Bybee et al., 2008, p. 70-71), both of which emphasized the acquisition of knowledge through memorization (Underhill, 1941, in Bybee et al., 2008, p. 71) and the preparation of students for their civic duties as American citizens (Bybee et al., 2008, p. 70-71; Tyack, 2003, pp. 9-37).

Throughout the late 1800s and the early 1900s, science education underwent small modifications that reflected shifting attitudes across the nation (Bybee et al., 2008, pp. 71-72). Major change did not take place until the mid-1900s, when the United States found itself in direct competition with the Soviet Union over advancements in science and technology. After the launch of *Sputnik I* by the Soviets in 1957, science education came to be viewed more pointedly as a means to get ahead in an international race for dominance, which provided a commonly grounded goal for the American people. This much needed sense of purpose for science in schools translated quickly into substantial monetary support for science and engineering programs, robust curriculum redevelopment, and a national culture that encouraged youth to pursue careers in these critical fields (Bybee et al., 2008, pp. 73-78; Dell'Olio & Donk, 2007, pp. 345-346). This time period became known as the Golden Age of science education (Bybee et al., 2008, p. 73), and it is associated with learning through inquiry (Bybee et al., 2008, pp. 73-78; Dell'Olio & Donk, 2007, pp. 345-346) in the form of laboratory experiments and related field work (Bybee et al., 2008, pp. 73-78).

Unfortunately, the vigor surrounding science education in America did not last. As the years went on and tensions with the Soviet Union cooled, people became dissatisfied with the amount of class time required to utilize the programs developed during the Golden Age, and they were eventually dismantled (Dell'Olio & Donk, 2007, p. 346). This complacency resulted in part in the widespread call for reform that followed the publication of *A Nation at Risk* in the 1980s (see the National Commission on Excellence in Education, 1983). Subject areas of science and technology were identified as fields of vital concern given trends of decreasing enrollment in related courses, poor standardized test scores, and fewer graduates choosing those career paths, prompting a new era of educational reform (Bybee et al., 2008, pp. 50-64, 78-80).

These recent reforms focused on accountability measures (Tyack, 2003, pp. 123-126), and viewed K-12 schooling as a wholistic enterprise that should work from the ground up (Bybee et al., 2008, pp. 50-64, 78-80). They acknowledged that 'science' has generally been viewed as a body of knowledge rather than a set of practices (Bybee et al., 2008, p. 39), and that this knowledge has been presented to students in a very compartmentalized way that is not reflective of actual science (National Research Council, 2012, pp. 10-11). The new goal for science education then shifted to scientific literacy, which emphasizes not only scientific knowledge but also scientific practices, both of which are needed to cultivate people who informed and capable in adulthood (Bybee et al., 2008, pp. 86-92; Maienschein, 1998; National Research Council, 2012, p. 7-10). These efforts have continued into the twenty-first century, to the extent that it is otherwise known as the Era of Educational Reform (Bybee et al., 2008, p. 78).

Although some of the key values of the *Sputnik* era have reemerged through these modern-day reforms (Dell'Olio & Donk, 2007, p. 347), science education remains an area of concern even today. According to the National Assessment of Educational Progress (NAEP) Achievement Level Results of 2015, the majority of students performances in science are *at* or *below basic* levels: 64% in fourth and eighth grades, and 78% in twelfth grade, with none of these grade levels producing more than two percent of students who would be considered *advanced*. Results are even more dismal for most marginalized groups and students of color (National Assessment of Educational Progress, 2015), which highlights the achievement gap that persists among American youth (Bybee et al., 2008, pp. 82-83, 101-104). At the international level, students in the United States have been consistently outperformed by those of other countries in the Trends in International Mathematics and Science Study (TIMSS) (Bybee et al., 2008, pp. 101-102) and the Programme for International Student Assessment (PISA) (Bybee et al., 2008, pp. 102-104; Ripley, 2013, p. 3), among others. Further, there is a distinct pattern of student interest continually decreasing (Moore, 1990) and performance continually falling in these subject areas as children move from elementary to middle to high school levels of study (Bybee et al., 2008, pp. 80-81).[1]

Clearly, progress still needs to be made. Though educational leaders continue to encourage shifts towards more integrated approaches of science instruction that go beyond mere memorization of facts through frameworks such as the College Board Science Practices, the Next Generation Science Standards' Science and Engineering Practices, Habits of Mind, and the like (see Appendix A), it is not enough to simply indicate what the target skills are if specifications for how to mediate them are not also provided (Kolodner, 1991; Lee & Roth, 2003; National Research Council, 2012, pp. 19-20). There still exist many barriers to educational change (Banilower et al., 2013; McFadden, 2019; Tyack & Tobin, 1994; Wallace & Kang, 2004), and these frameworks have for the most part not been fully adopted in practice (Banilower et al., 2013). Truly facilitating these shifts is important because the memorization of scientific knowledge is insufficient for fostering scientific literacy (Maienschein, 1998), and scientific literacy is

[1]This information is presented given its status as currently acceptable means of determining student achievement. This is not meant to indicate that standardized tests are the only or the most appropriate method of measuring student performance. However, the task of evaluating forms of assessment is beyond the scope of this paper.

an appropriate goal for all students (not just the ones who intend to pursue careers in science) (National Research Council, 2012, pp. 1, 7-10). The skills associated with these disciplines, such as communicating ideas and relating knowledge from and across different domains (from College Board, 2021) are necessary not only for most modern careers but also for active civic engagement (Bybee et al., 2008, pp. 86-92; Lee & Roth, 2003; Maienschein, 1998; National Research Council, 2012, pp. 7-10) and general living in today's Digital Age (Maienschein, 1998; National Research Council, 2012, pp. 1, 7-10). Adopting instructional strategies that align with these larger goals is critical for successful reform (Bybee et al., 2008, pp. 83-84). Luckily, outdoor education may be a useful practice in this regard.

Outdoor Education

Outdoor education is a form of organized, experience-based learning that takes place outside of the typical classroom and is instead conducted in outdoor settings (Smith, 1987). This form of teaching rose to popularity around the Golden Age of science education (Donaldson, 1972; Smith, 1987) and began as the modest use of outdoor spaces to achieve curricular goals (Smith, 1987). The term has since been expanded to include a variety of different programs that take place in the out of doors (Adkins, 2002). Although there are many ways to engage in learning outside of the classroom (Adkins, 2002; Hawxwell et al., 2019), and 'outdoor education' today is a wildly general term, outdoor education programs have tended to fall into one of two main categories, both of which focus on learning *about* nature, but in different ways. There are programs that emphasize outdoor activities such as hiking, canoeing, camping, etc., termed herein as *adventure* *education*, and those with an emphasis on environmental literacy and conservation, termed herein as *environmental education*.

Though both are considered to be 'outdoor education', these two threads have very different goals. Adventure education seeks to teach students about nature, that they may overcome it if need be. In these types of programs, there is an emphasis on personal and social growth of participants, facilitated by structured opportunities to overcome physical challenges both individually and through teamwork. This contrasts with environmental education, which seeks to teach students about nature so that they can protect it for future generations. These types of programs place emphasis on environmental literacy and affect towards nature by increasing participants awareness of local and global environmental issues (Adkins, 2002; Smith, 1987). While these two forms of outdoor education can productively overlap, there are most often viewed as being separate from each other, existing perhaps on a spectrum, as depicted in Figure 1.

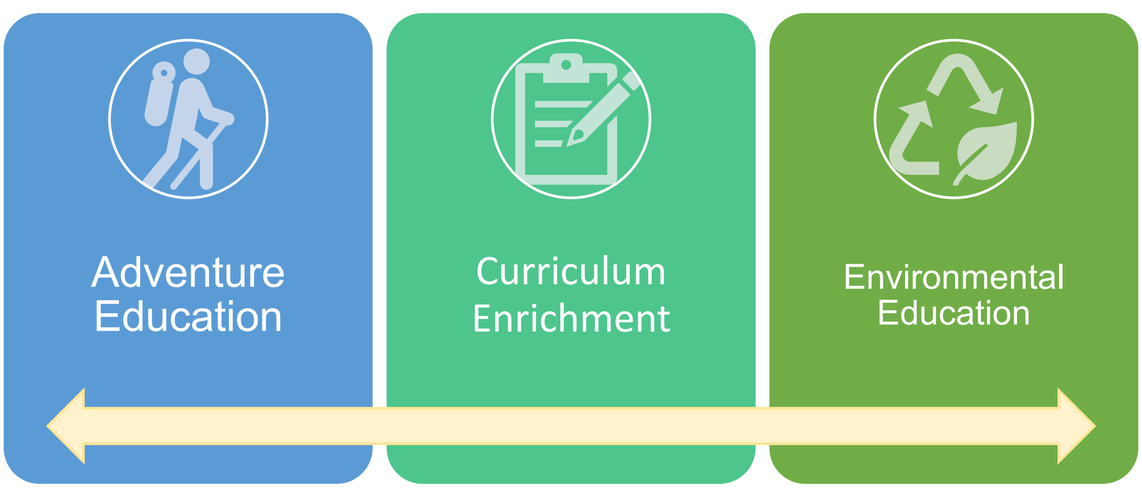


Figure 1. Spectrum of Outdoor Education Foci. Adapted from Hawxwell et al. (2019).

Lying between these two ends of the spectrum is *curricular enrichment*, the flexible middle ground that encompasses outdoor learning and a variety of possible academic goals. This perspective views outdoor spaces as contexts in which to learn but does not necessitate that the spaces themselves be the focus of content (Adkins, 2002). An alternative view to this spectrum (Figure 1) is a 'tree' of outdoor education, which branches off into different specialties that are rooted in several commonly shared characteristics (Figure 2).

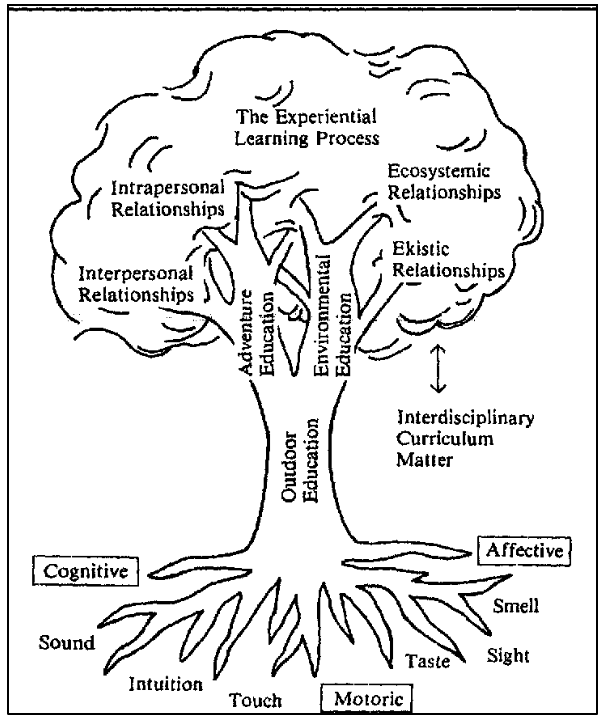


Figure 2. The Outdoor Education Tree. Taken from Priest (1986).

Although these divisions of outdoor education are still being interrogated (Adkins, 2002; Priest, 1986), the typical forms were well established by the 1970s, and academics were calling for research to elucidate their features. Donaldson (1972) identified critical needs for studies to include the theoretical bases for outdoor education, make suggestions for connecting outdoor programs to the traditional school curriculum, and inform professional development opportunities to prepare educators for teaching outside. Since that time, significant progress has been made in the research world in regard to the benefits afforded by outdoor education.

On the more affective and social end, outdoor education has been shown to improve students' interpersonal skills (American Institutes for Research, 2005) and increase student motivation (American Institutes for Research, 2005; Coyle, 2010; James & Williams, 2017). Implementation of outdoor programs can positively impact student attitudes towards other organisms (e.g., coyotes [Sponarski et al., 2016]) and conservation in general (Bogner & Wiseman, 1997; Dillon et al., 2006; Jeronen et al., 2017), and has also been shown to reduce undesirable student behaviors in the classroom (Dillon et al., 2006; SEER, 2000, in Coyle, 2010) such as absenteeism and disrespect towards teachers (SEER, 2000, in Coyle, 2010). Academically, outdoor education can provide engagement with higher levels of Bloom's taxonomy (Dillon et al., 2006; Waliczek et al., 2003) and improve student performance on standardized science tests (American Institutes for Research, 2005; Bartosh, 2003 & SEER, 2000, in Coyle, 2010).

Still, despite the increasing evidence supporting the use of outdoor education techniques, the ongoing trend among schools (with some notable exceptions, e.g., Keyes, 2017) has been to decrease, if not completely eliminate, their use (Coyle, 2010; James & Williams, 2017). This decrease in the prevalence of outdoor learning may be explained in part by the fact that most of the needs outlined in the 1970s (Donaldson, 1972) for this developing pedagogy remain at issue today. For example, published papers on outdoor education often fail to engage with educational theory. Further, present-day outdoor learning appears to favor interpersonal skills and student affect over curriculum-based content, thereby moving it away from goals of traditional schooling rather than connecting them (Hawxwell et al., 2019), and a lack of training in this area continues to inhibit many educators who would perhaps like to teach out of doors but are not familiar enough with outdoor education methods to get started on their own (Dillon et al., 2006; Scott et al., 2015). Perhaps the most consequential of issues plaguing outdoor education today is the imprecise use of related terminology among both educators and scholars. For instance, goals and approaches of teaching and learning outside may vary dramatically (e.g., adventure education and environmental education), though both continue to be referred to as 'outdoor education'. The lack of conceptual precision regarding what exactly outdoor education entails creates another potential barrier to its implementation.

Taken together, these lingering problems have muddied the waters of outdoor learning; the field lacks unity. Were more clarity provided for practicing educators, outdoor education would be better positioned to be adopted as a pedagogical strategy.

Theoretical Grounding

One of these issues that could be addressed over time is the lack of explicit theoretical foundations for outdoor education. In one estimate, about a third of existing articles on this topic fails to mention any theoretical grounding at all. It is imperative that future authors publishing in this area become conscientious of this lapse and include theoretical bases in their work, as it provides a common ground with which others can productively engage. Those that do include theory in their papers tend to focus on social constructivism and the experiential learning model (Hawxwell et al., 2019), both of which are natural fits for this educational practice because they marry the traditional philosophies of rationalism and sociohistoric theory (see Case, 1996, pp. 77-81).

Original rationalist philosophies translated over time into constructivist learning theory, which is most notably associated with Jean Piaget's theory of human development. This tradition views knowledge as something that is "constructed by the mind" (Case, 1996, p. 83), and learning as the process in which existing constructs must either be accepted or replaced to make sense of dissonant experiences. This differs from sociohistoric philosophies that have over time translated into cultural views on teaching and learning, such as Vygotsky's (Case, 1996, pp. 77-84) and Bandura's theories (Orey, 2010, pp. 55-59). From this perspective, knowledge is viewed as the creation of a social group, whereas learning is the initiation into that group such that one can participate in its interactions (Case, 1996, pp. 77-84). Social constructivism can be seen a middle ground between the two fundamental schools of thought.

Social constructivism posits that learning is a social process in which individuals construct their knowledge through interactions with external forces and artifacts (Orey, 2010, pp. 55-59). It acknowledges not only the individual component of learning (i.e., the internal processes) of rationalism, but also the broader context that plays a role in an individual's unique learning experience (i.e., the external influences) of sociohistoric theory. It is logical that outdoor education programs would typically adopt such a foundation. These programs tend to be place-based (see Sobel, 2004), meaning that they take into account local affordances and meaning (e.g., James & Williams, 2017); they emphasize student-led inquiry that allows young people to form their own understandings of natural phenomena (Dillion et al., 2006; James & Williams, 2017; Jeronen et al., 2017); and they promote collaboration between participants, thereby facilitating knowledge construction through social processes (American Institutes for Research, 2005; James & Williams, 2017; Jeronen et al., 2017; Smith, 1987).

Experiential learning is an instructional model that is founded in constructivism. It involves providing students with concrete experiences that they can reflect on, make sense of, and expand upon through further inquiry (Orey, 2010, pp. 259-266). Outdoor education programs are often created with this model in mind (e.g., Sponarski et al., 2016); students participate in designed or emergent learning experiences in the outdoors, which they are then able to discuss and make sense of together. Outdoor spaces are particularly suited for hosting these experiences, as they have the potential to capture and maintain students' attention through novelty, incongruity, emotion, and personal significance (four of the six criteria for filtering external stimuli [Franconeri & Sminos, 2003 and Hammel & Akyurek, 2009, in Bolin et al., 2012, p. 185]). This is especially true for those who have been unsuccessful in classroom-based endeavors in the past. The rich contexts of experience become ample material for retrieval cues in student memory, and the emphasis of outdoor education on conceptual understanding and local relevance should promote long-term retention of relevant content (Bolin et al., 2012, pp. 191-195). Afterwards, the reflection process and option for further inquiry can be facilitated by the instructor and may serve usefully as a connection between outdoor and classroom work.

Taking a step back, both social constructivism and experiential learning can be described as situative perspectives, meaning that they view learning at the systems level. This includes not only the individual minds engaged in the learning process, but also the unique context in which they are situated: the interactions and relationships between learners, the people around them, available tools,

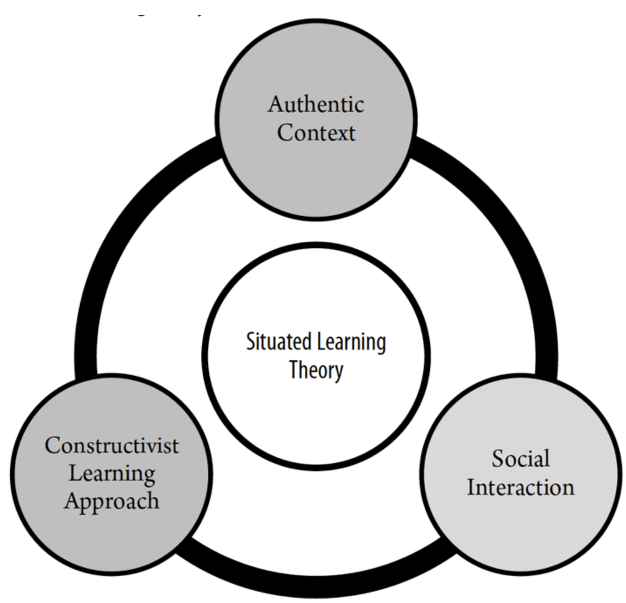


Figure 3. Key Tenets of Situated Learning Theory. Taken from Green et al., 2018).

existing culture, and so on (Greeno & Nokes-Malach, 2016, pp. 67-69; Packer & Maddox, 2016, p. 134). Learning is viewed as a process that takes place from within (the individual) but also as something that is externally facilitated (by society). It is no surprise that outdoor education, which emphasizes so heavily the importance of (natural) contexts, fits within this larger learning theory (Figure 3).

While there are many different ways one might measure learning according to constructivism or experiential learning, especially in a context as variable as outdoor education, situative learning theory can provide some direction. According to Greeno's view of this perspective (2011, pp. 41-47), learning can be observed as changes to an individual's participation in a community of practice (Figure 4) (Lave & Wenger, 1991). Grounding outdoor education research in such a perspective may provide some of the unity that could make this form of learning more accessible for educators.

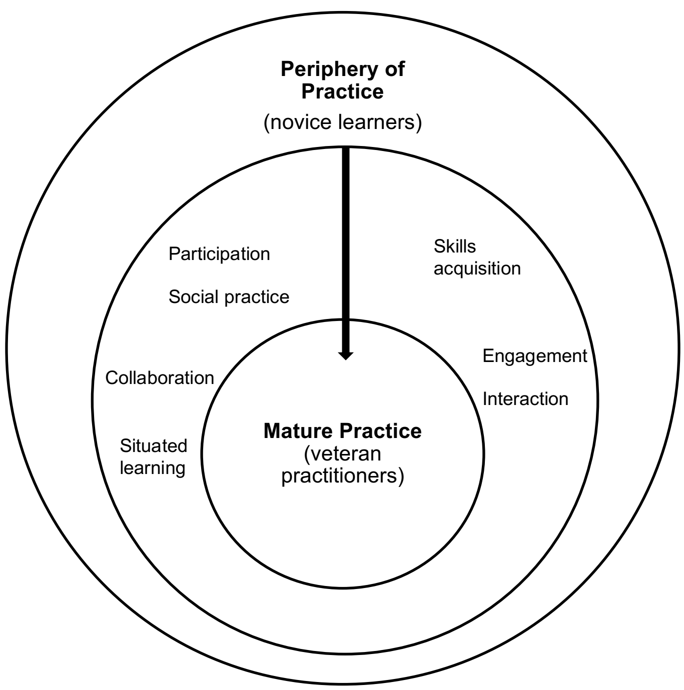


Figure 4. Learning Through Legitimate Peripheral Participation. Adapted from Lave & Wenger (1991).

Practical Grounding

While the different views of teaching and learning described above make sense at higher levels of abstraction, teachers on the ground often find that educational research lacks a practical perspective that would aid in its application (Ball, 2012; Gamoran, 2018; Nelson et al., 2009). One concrete teaching strategy that effectively joins these areas of science and outdoor education – *and* is the topic of quality available resources for educators (e.g., Laws & Lygren, 2020; Leslie & Roth, 2000; Peeters, 2020; Sustainable Forestry Initiative, 2019) – is nature journaling.

Nature journaling is the practice of making and recording observations of natural spaces. This might include local flora and fauna, environmental features, the weather, etc. (Colbert, 2020; Leslie & Roth, 2000, pp. 5-12; Peeters, 2020). In school settings, nature journaling activities typically involve a starting prompt followed by time for students to observe, write, and draw. The level of structure can be adapted to suit different age groups and subject areas, and the format of journal entries can be highly individualized to teachers' and students' liking (Colbert, 2020). The convenience and flexibility of this activity is further highlighted by the fact that few materials are needed to participate, and any number of outdoor spaces – not just the 'wilderness' – can be considered appropriate grounds for observation (Colbert, 2020; Leslie & Roth, 2000, pp. 5-12).

From a pedagogical standpoint, nature journaling can be a means with which to integrate multiple subject areas (e.g., science and art) (Leslie & Roth, 2000, pp. 197-201), or a way to provide opportunities for student-led inquiry in outdoor spaces (Hobart, 2005). It can be used to prompt students to engage in observation (Hobart, 2005; Laws & Lygren, 2020; Leslie & Roth, 2000, pp. 12-15), facilitate connections with nature, build positive classroom culture, and encourage curiosity in participants (Laws & Lygren, 2020; Leslie & Roth, 2000, pp. 12-15, 187-194). Existing resources with pre-made journaling prompts are often explicitly tied to the Next Generation Science Standards as well (see Laws & Lygren, 2020), putting this activity in a prime position to be utilized by teachers in order to further students' scientific literacy and advance science education reform efforts.

Still, nature journaling as an educational practice at the elementary and secondary school levels is nascent (Colbert, 2020). While naturalists (e.g., Rachel Carson, John Muir, David Henry Thoreau, and Charles Darwin) have engaged in record keeping via journals for quite some time (Sustainable Forestry Initiative, 2019), it has not until recently been translated into use within lower-level classrooms. Therefore, there exist few educational research efforts on its efficacy (Colbert, 2020).

Rationale

There are several problems associated with teaching science in today's day and age, and outdoor education may be usefully applied to address some of these issues due to its potential to simultaneously target the varied needs of twenty-first century students.

In terms of scientific practices (see Appendix A), outdoor education can provide rich engagement opportunities for participants that may not be possible in traditional classroom settings. Rather than being directed by teachers every step of the way, as is often the manner of operation for school-based lab work, outdoor experiences allow learners more independence to apply different skills (Dillon et al., 2006; James & Williams, 2017; Jeronen et al., 2017) and work collaboratively towards their goals as they pursue lines of inquiry (American Institutes for Research, 2005; James & Williams, 2017;

Jeronen et al., 2017; Smith, 1987). Some sciences, such as geography (Smith, 1987), plant biology, agricultural science (Waliczek et al., 2003), and ecology are particularly suited for outdoor learning given their compatibility with fieldwork. Additionally, outdoor education can easily incorporate content knowledge from within and across disciplines thanks to the naturally interconnected position of scientific study in the real world. For instance, in the outdoor education program studied by James & Williams (2017), students learned about water and its impacts on the Rocky Mountains environment through physical, earth, and life science lenses. To separate these sciences in context would be difficult even if it were desired. This intertwined nature of varying disciplinary domains should prompt students to make connections to their past learnings from different subject areas.

Given this potential of outdoor education to facilitate both content retention and skills acquisition, its integration into traditional schooling may be a viable step towards addressing the poor academic performance (see Bybee et al., 2008, pp. 101-104; Ripley, 2013, p. 3; Stein et al., 2016, p. 211) and general disinterest (see Moore, 1990) of American students in the sciences. However, the currently disjointed state of the field of outdoor education, as well as the lack of prescribed mediating activities for engaging students in scientific literacy practices (Lee & Roth, 2003), makes such an incorporation difficult in many ways. Teachers need concrete methods with which to start if they are to effectively adopt new perspectives on education in their classrooms.

Nature journaling is an existing outdoor education practice that may be a manageable first step for teachers who are interested in teaching outside of the classroom to better foster scientific literacy. Nature journaling is highly adaptable, requires few materials (Colbert, 2020; Leslie & Roth, 2000, pp. 12-15), and allows for the inquiry and exploration of various academic disciplines (Leslie & Roth, 2000, pp. 197-201). Given the need for additional research on this practice, this study will seek primarily to establish whether nature journaling is a viable means of engaging students in scientific skillsets.

As illustrated in Figure 4, it is posited that nature journaling activities will provide students with meaningful opportunities to engage with course content and scientific practices through the observation of their local environments, which will ultimately increase students' scientific competencies (*high-level conjecture*). The implementation (*embodiment*) of nature journaling in the classroom may be an effective mediating practice for fostering scientific literacy because it adheres to the learning theories described above (pp. 10-13); students will go through the experiential learning cycle in that they will be provided with real world experiences (*mediating processes*) that they can reflect upon and inquire further about in order to develop their understanding of course content (*outcomes*), and they will have the opportunity to collectively construct meaning of their observations during post-journaling discussions at the whole-class level (*mediating processes*). The consistent intervals of nature journaling work will also provide students with repeated opportunities to engage with scientific content and practices in different settings, encouraging automaticity (Bolin et al., 2012, p. 193) and the transfer of knowledge (Bolin et al., 2012, p. 229), both of which should lead to increased competency for students in these areas (*outcomes*). If students' patterns of participation do change in a positive way, it can be stated they have engaged in legitimate peripheral participation (Lave & Wenger, 1991) with the scientific community (*outcomes*), a potential measure of their learning as budding scientists.

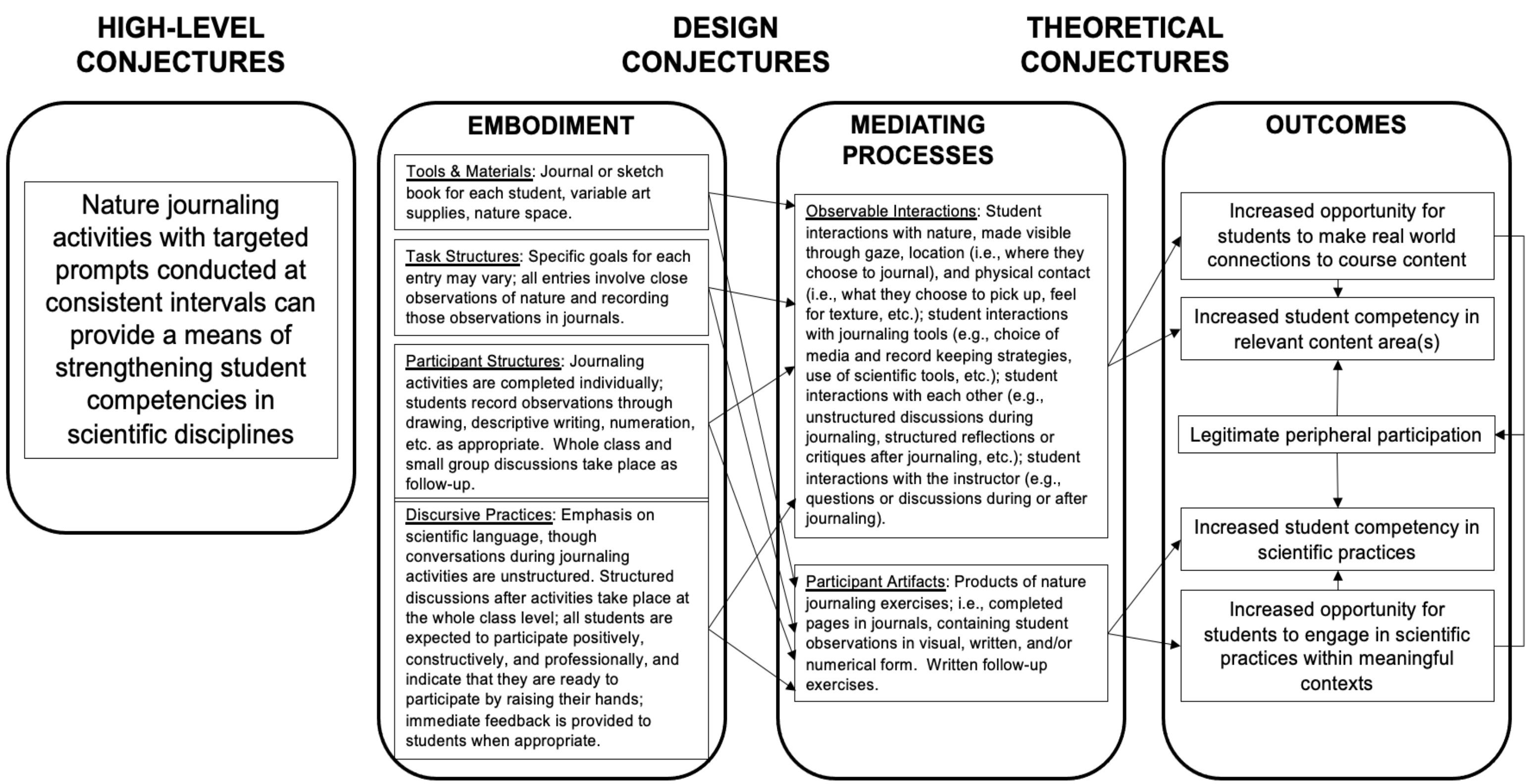


Figure 5. Conjecture Map. Learning Sciences tool (Sandoval, 2014) used to depict connections between theory, design, and outcomes of enactment.

Research Questions

This study seeks to answer the following two questions:

1. What elements of content knowledge and/or scientific practices are present in students' nature journals?
2. In what ways does nature journaling affect student competencies in content areas and/or scientific practices?

Methods

Design-Based Research

Scientific research is typically considered to be either basic or applied, with *basic research* constituting work that seeks to develop theory, and *applied research* constituting work that seeks to solve real-world problems. Design-based research (DBR), also known as educational design research (EDR), lies between these two forms of scientific inquiry, a position commonly depicted using Pasteur's Quadrant (Figure 6). DBR is a unique compilation of methods that simultaneously prioritizes theoretical and practical contributions to a context of interest. In other words, it is a means of *use-inspired basic research*. Whereas most studies would favor either knowledge for knowledge's sake or knowledge for utility's sake, educational design research rejects the notion that one cannot accomplish both (Barab, 2005, pp. 153-154; McKenney & Reeves, 2018, pp. 6-12). These types of studies tend to operate within real-world contexts, as opposed to removed laboratory settings; are conducted in collaboration with, as opposed to merely being conducted *on*, local stakeholders; and are both inherently interventionist and iterative (Barab, 2005, pp. 153-155; Barab & Squire, 2004, pp. 1-7; McKenney & Reeves, 2018, pp. 6-7). These qualities allow DBR to address relevant problems in the field of education with solutions that have been responsively investigated, developed, tested, and refined in-context with the help of local partners (McKenney & Reeves, 2018, pp. 12-15). At the same time, empirical findings from these collaborations are being constantly abstracted in order to further develop educational theory that might explain them, and to generalize interventions such that they might be applied to other contexts (McKenney & Reeves, 2018, pp. 18-19).

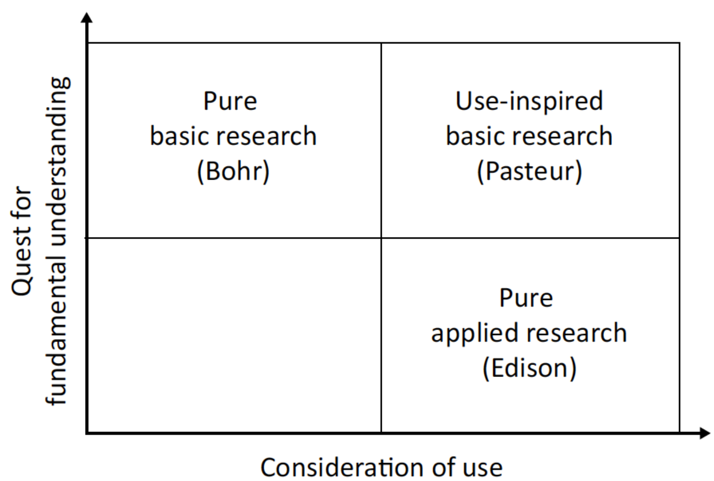


Figure 6. Pasteur's Quadrant. Matrix depicting the different underlying goals of scientific research. From Stokes (1977).

The collaborative aspect of this type of research makes it situative in nature. Therefore, researchers must adjust to the needs of the spaces in which they are working. For this reason, it is important to note that despite their commonalities, the precise methodologies utilized for these types of studies can be quire variable (Barab & Squire, 2004; McKenney, 2016, pp. 156-158; Sandoval, 2014). Though such flexibility can be highly advantageous for conducting this type of research, as it allows for greater ecological validity (Barab, 2005, p. 154; McKenney & Reeves, 2018, p. 7), DBR has also been heavily criticized for what some consider to be experimental design flaws. Efforts to alleviate such issues of credibility have focused on better articulating as well as strengthening the methodological approach(es) to design-based research (Barab, 2005) (e.g., Sandoval, 2014). One of the most extensive of these efforts comes from McKenney and Reeves (2018), who have recently produced a generic model of educational design research (Figure 7) which eloquently depicts the overarching processes that take place during this type of study.

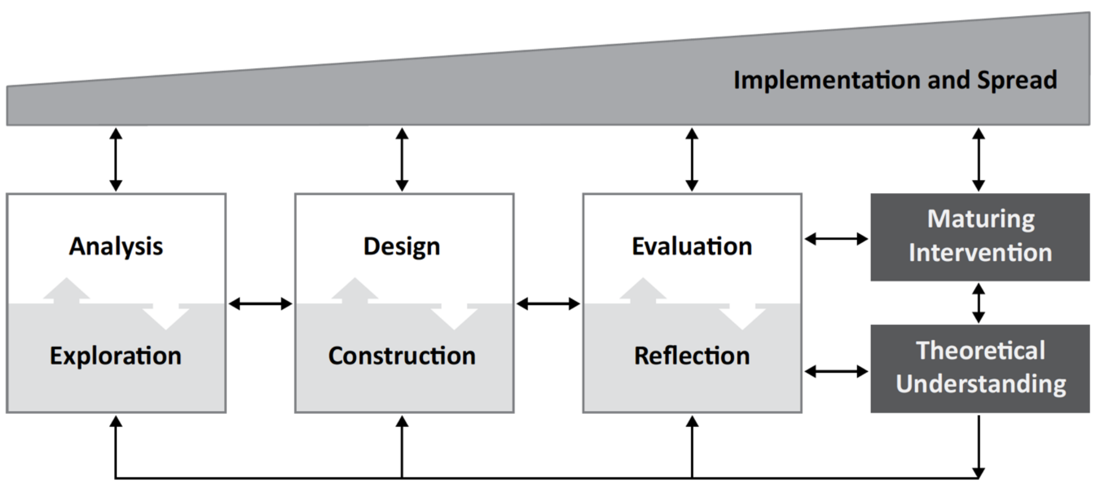


Figure 7. Generic Model of Design-Based Research. From McKenney & Reeves (2018).

The McKenney & Reeves (2018) model consists of three flexible phases, each of which focuses on key processes: analysis and exploration, design and construction, and evaluation and reflection. The analysis and exploration phase typically takes place first and involves familiarizing oneself with the problem at hand. Analyses might entail seeking initial insights from stakeholders via surveys or interviews and conducting a review of existing literature that provides information about similar issues (and solutions, if available) from the past. The design and construction phase involves the development of a potential solution (or solutions) to the problem of interest. Designing is analogous to outlining or planning in this context, whereas construction takes place when one produces a deliverable prototype of the proposed solution. Constructed prototypes may then be tested (evaluated) in the third phase. Information gathered from testing can be used for reflecting and gaining theoretical insights. As depicted in the diagram (Figure 7) each of these phases are connected to the overarching processes of implementation and spread. Therefore, one should have these goals in mind for their educational innovation throughout each of the three phases. In other words, work throughout the DBR process should begin as and continue to be use-inspired. Additionally, all phases are depicted as flexible and iterative (not hindered by a strictly sequential or linear format), as well as reflective of the dual foci of EDR through its integrated research and design processes that will contribute to theoretical and practical insights, respectively (McKenney & Reeves, 2018, pp. 82-87).

Educational design research was selected as the primary approach for conducting this study based on its dual foci. As an educator, I was interested in making a positive change in my classroom by implementing nature journal activities (applied research) while also furthering outdoor education theory in a generalizable way (basic research). The responsive nature of design-based research had an added appeal; changes could be made throughout the study to improve educational practice within my classroom, and better serve my students in real time.

Study Context

This study took place at a local charter school within the greater Phoenix area of Arizona. It was facilitated by an Ecology & Animal Behavior elective course, which served a diverse group of nineteen coed students (nine male and ten female) in both eighth and ninth grade. The course ran during the 2020/2021 school year.

To mitigate risks associated with the COVID-19 pandemic during that time, the charter operated according to the ongoing recommendations of the Arizona Department of Health Services (2021), and therefore experienced fluctuations in modes of instruction for all courses, including Ecology & Animal Behavior. The school operated entirely online from August to mid-October, implemented a hybrid model based on family choice from mid-October until Thanksgiving, and returned to online instruction until the end of February before reimplementing the hybrid model for the remainder of the school year. Students who elected to remain at home were permitted to do so during times when the school was open for hybrid learning. The Ecology & Animal Behavior course accommodated 1-3 in-person students during those periods, while the rest of students continued remained online.

The study ran continuously during the school year despite these fluctuations. Throughout the study, student participants were asked to complete their Ecology & Animal Behavior coursework, which included nature journaling for approximately thirty minutes each week. Time for this work was allotted during class when possible but was otherwise completed as homework, in the students' own outdoor spaces. Students who opted for in-person learning were able to utilize the outdoor spaces surrounding the school building when journaling was done in class, whereas those who chose distance learning completed all entries in their own neighborhoods.

This continual nature journaling activity required students to observe natural spaces, record their observations, and make connections to the content and skills targeted throughout the course. Assigned entries often contained specific prompts intended to focus students' attention to relevant coursework, though students were offered opportunities to complete freeform entries as well (see example on Figure 8). At the end of each established interval, all students submitted their journal entries by scanning and uploading them through the school's designated online learning platform. After each submission, follow-up activities (e.g., whole-class discussions) were conducted, in which students could share their observations, discuss connections to academic content, critique journaling strategies politely and constructively, and so on. The full schedule of implementation can be seen below in Table 1.

Nature Notebook Entries (1)

Academic and Lab Skills

Due October 28, 2020 9:00 PM

Points
10 points possible

Instructions

At consistent intervals, dedicate time (either 30min per week or 1hr twice monthly) to make an entry in your Nature Notebook. Nature Notebooks entries may be open-ended or has specific foci. In either case, the purpose of the entries is to spend time making detailed observations about the natural world, and making connections to information discussed in class.

For the first entry, complete the following:

- Choose and draw a desert organism from your local area (5 pts.). Be sure to include information about the date/time and location of your observations (1 pt.). **Keep in mind that you are observing and drawing a live organism, NOT just recreating the pictures from our Community Walkabout slideshow.**
- Write down observations regarding the organisms' physical characteristics (2 pts.)
- Make connections to our discussion on the desert biome and natural selection by writing down how you think any/all of those physical characteristics are adaptive to the environment (2 pts.)

Figure 8. Sample Journal Prompts from First Round of Entries.

Table 1. Study Implementation Schedule.

Interval of Activity		Dates	Activities	Status	Deliverables
Practice (Pre-) Entries	**Round 0**	9.15.20 – 9.30.20	• Nature Notebook Introduction during class • Practice entry on prokaryotic cell structure • Practice entry on systems thinking • Attitudes Survey	Online	• Nature journal practice entries • Attitudes Survey responses
Iteration 1	**Round 1**	10.1.20 – 11.3.20	• Nature journal open entries and an entry with a focus on Tinbergen's Four Questions • Whole class discussion and critique	Online & Hybrid (one student in person)	• Nature journal entries • Contributions to class discussion
	Round 2	11.4.20 – 12.10.20	• Nature journal open entries and an entry focused on biodiversity • Whole class discussion and critique	Hybrid & Online (two students in person)	• Nature journal entries • Contributions to class discussion
	Round 3	12.11.20 – 12.18.20	• Nature journal open entries	Online	• Nature journal entries
Student Evaluation & Reflection			• Reflective writing • Nature journal workshops (various)	Online	• Written responses • Nature journal entries
Iteration 2	**Round 4**	1.28.21 – 2.3.21	• Nature journal workshops on asking questions taking perspective • Nature journal entries focused on questions and new perspectives • FlipGrid share out of interesting questions	Online	• Nature journal entries • Contributions to FlipGrid activity
	Round 5	2.4.21 – 3.4.21	• Nature journal open entries • Whole class discussion and critique	Online & Hybrid (two students in person)	• Nature journal entries • Contributions to class discussion
	Round 6	3.5.21 – 3.26.21	• Nature journal workshop on data collection and models vs. diagrams • Nature journal entries focused on data and diagrams • Whole class discussion and critique	Hybrid (three students in person)	• Nature journal entries • Contributions to class discussion

Because this study utilized a design-based research approach (McKenney & Reeves, 2018), cycles of analysis and exploration, design and construction, and evaluation and reflection were integrated into the research process, while the goals of implementation and spread were considered consistently throughout.

Analysis and Exploration

Initial exploration of the problem in-context stemmed from personal experiences as an educator at the research site. The charter school in question boasts a rigorous curriculum, but rarely affords its younger students (grades 5-8) opportunities for exploration. As a result, students tend to focus on memorization at the lower grade levels, and struggle as they are required to transition to higher levels of thinking in their upper school classes. An investigation into how this lack of opportunity might be remedied led to the overall picture provided in the Literature Review (pp. 2-15), and the beginnings of a solution in nature journaling. As the study progressed, analyses and explorations of the problem at hand continued, and adjustments were made accordingly as new insights became available.

Design and Construction

The same is true for the design and construction of nature journal activities, which included but were not limited to journal entry prompts, grading criteria for entries, conservation starters for follow-up activities, etc. Nature journaling is an activity that I, as an educator and researcher, had not engaged with prior to this study. Therefore, there was a learning curve in regard to its implementation in the classroom. Participating in the activity individually and with students provided in-the-moment insights that allowed for minute adjustments to rounds of journaling, which fostered better facilitation of assignment objectives, alignment with unit topics, understanding of student struggles, and so on. Though there were only two major iterations during this school year, each consisting of three rounds (Table 1), design and construction took place continuously through formative design revisions.

Evaluation and Reflection

Evaluation and reflection took place at intentional points throughout the research process. After each round of nature journaling, reflective notes were compiled regarding students' performances. This allowed for informal record keeping in terms of patterns of trends in activity implementations, common elements between student works, robustness of class discussions, and the like (i.e., field notes [Rossman & Rallis, 2011, p. 193]). Additionally, formal evaluation and reflection on the part of the students was prompted in January upon their return from Winter Break; students were tasked with considering what aspects of the nature journal assignments had been useful or successful thus far (evaluation) as well as to think on which scientific practices they believed they were engaging in through their nature journals (reflection). This instance of evaluation and reflection prompted the shift from what have been labeled the first and second iterations (Table 1) as major changes were made in light of students' responses. Of course, further activity of this phase took place after data collection concluded.

Data Collection

After IRB (Figure B1, Appendix B) and research site approval (Figure B2, Appendix B) were obtained, students were recruited for participation in this study during class time via a recruitment script, and parents were notified of the study via the school's online communication platform (Figure B3, Appendix B). Both parents and students were made aware that participation in the study was completely voluntary, and that students could cease their participation at any time. They were also informed that the activities related to the study would be part of the Ecology & Animal Behavior coursework regardless of their choice to participate (or not), and that their (non)participation was unrelated to any grades in the class. Students who wanted to participate were asked to complete an assent form (Figure B4, Appendix B) and parents who consented to their child's participation were asked to complete a consent form (Figure B5, Appendix B). Of the nineteen total students in the class, thirteen (68%) agreed to participate and had parental permission. The remaining six students either were unable to obtain parental permission or failed to return both the assent and consent forms. Each of the students represented in the data displayed in this paper is one of the thirteen who agreed to participate and had parental consent; no students or parents chose to remove themselves (or their child) from the study while it was ongoing.

After the assent and consent process was complete, the study took place according to the schedule outlined in Table 1. All sources of data in the form of student work were initially submitted through and stored in the school's designated online learning platform. This included student responses to the Attitudes Survey (Table C1, Appendix C), nature journal entries, and reflective writing. Online lessons were automatically saved via this platform as well. Materials were only moved and stored in a secure secondary location (Google Drive) as needed, and students' identities were kept confidential through the use of pseudonyms, which have been utilized below.

Data Analysis

Attitudes Survey

Student perceptions of their own competencies were assessed through the Attitudes Survey (Figure D1, Appendix D) that they completed prior to the implementation of nature journaling in the classroom and again after the final round of entries collected for this study (Table 1). The survey contained several constructs to be analyzed, including students' *Science Identity*, through a Likert Scale.[2] To allow for statistical analysis, student responses were recorded in a spreadsheet (Table C1, Appendix C) and converted into numerical values based on their place in the scale. Responses of *Strongly Agree* were valued at 5, *Agree* at 4, *Neutral* at 3, *Disagree* at 2, and *Strongly Disagree* at 1. Students' individual responses were then averaged to provide an overall value for each construct for each student, and the responses pre- and post-implementation were compared using a two-tailed t-test.

Nature Journals

Students' nature journal entries were the primary source of data for this study, and they were examined using document analysis (McKenney & Reeves, 2018, pp.178-179). Prior to analysis, a set of codes ("labels for assigning units of meaning" to data [Miles & Huberman, 1994, p. 56, in DeCuir-Gunby, 2011]) were produced in accordance with which scientific practices students were expected to demonstrate based on in-class emphases and assignment guidelines. These codes for practices and their descriptions were adapted in part from the College Board Science Practices (College Board, 2021) and the Next Generation Science Standards Science and Engineering Practices (NGSS Lead States, 2013) (see Appendix A).

Coding is the process of assigning codes to raw data in order to identify elements of interest. Initial journal entries were open coded according to these pre-established structural codes (DeCuir-Gunby, 2011), during which time the codes themselves were revisited and revised multiple times to ensure clarity of constructs. Finalized versions of

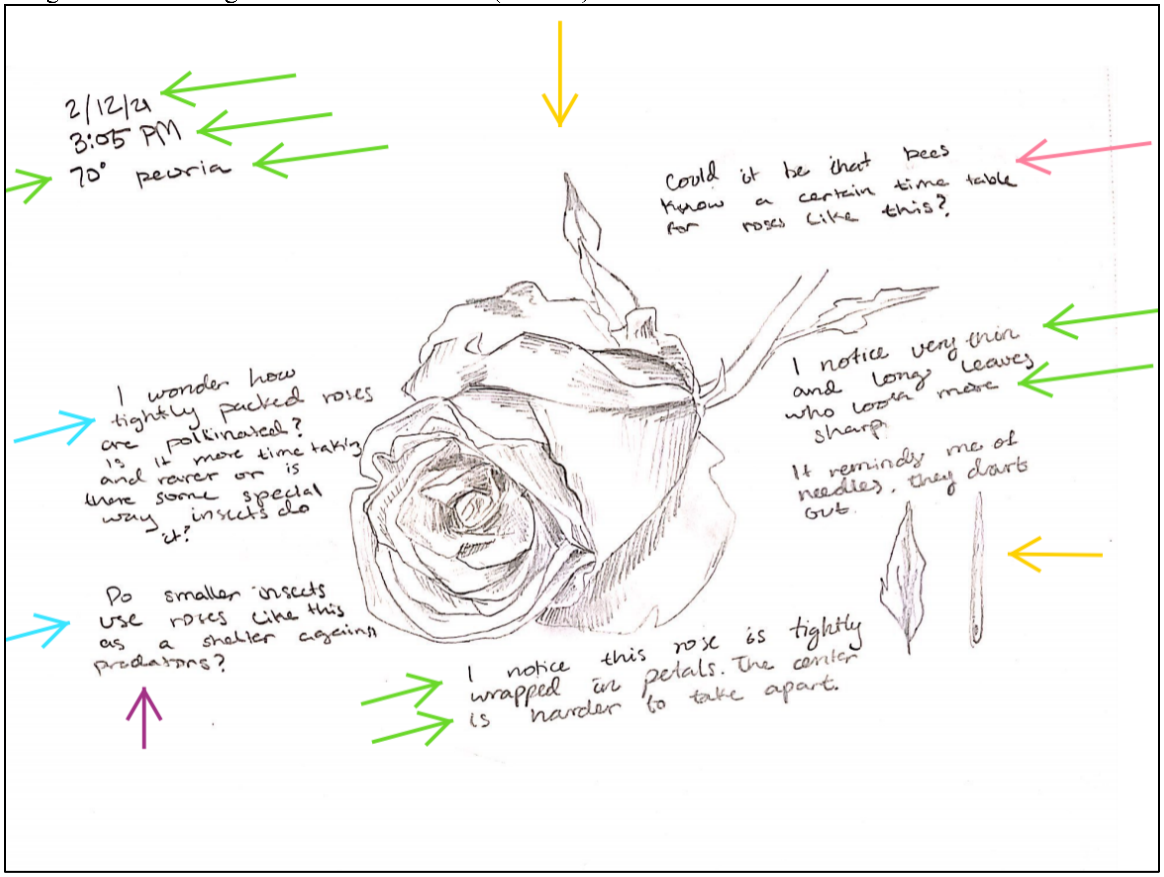
[2] Multiple constructs were included in this survey in order to leave room for potential explorations that might arise during the data collection process. As no emergent tangents formed, the Science Identity construct was the focus of analysis in regard to this survey (Figure D1, Appendix D).

these codes can be seen in Table 2 (all colored rows). Additional data-driven codes (DeCuir-Gunby, 2011) were added to the codebook to account for instances of student engagement in scientific practices that were *not* expected based on the skills that were explicitly targeted during class. Codes for these incidental demonstrations are included in Table 2 as well (gray rows). After open coding all of the journal entries by hand and revising the codebook along the way, entries were revisited and recoded several times for reliability. An example of a coded journal entry can be seen in Figure 9.

Table 2. Codebook of Scientific Practices. Includes codes for practices that were expected from students based on their Ecology & Animal Behavior coursework as well as codes for practices that were not yet targeted during class but were still demonstrated in student work (indicated by the asterisk).

Code	Description	Example
Making Observations	Student describes natural phenomena (anything that can be observed to occur or exist)	"White fuzz spreads around the center of the weed."
Asking Questions	Student asks questions that stem from the observation or discussion of natural phenomena	"Why would a snake need to be colorful?"
Creating Representations	Student uses visual models, diagrams and/or drawings to represent their observations	See drawings in journal entries (Figure 9)
Constructing Explanations	Student uses scientific ideas and/or principles to provide an explanation for natural phenomena	"Long roots [are] maybe to cover more surface area for efficient water collection."
Transferring Knowledge	Student relates observations of natural phenomena to knowledge from within and between content domain(s) through the use of scientific vocabulary	"The top side and bottom side of the snake are very different... maybe for *camouflage*."
Obtaining Information*	Student provides background information on natural phenomena obtained from external resources	"Scientific name: *Platycladus orientalis*"
Collecting Samples*	Student collects and attempts to preserve observed samples or specimens	See specimen samples in journal entries (Figure 11)
Conducting Investigations*	Student plans and carries out an investigation aimed at answering a specific question about the relationship between two variables	"I wanted to see the different behaviors of hummingbirds around my backyard and feeders [at different times of day]."

Figure 9. Sample Coded Journal Entry. Arrow colors indicate how each element of the entry has been categorized according to the codebook above (Table 2).



The number of times that each code appeared in a round of journal entries for each student was recorded in a spreadsheet for further analysis (Table C2, Appendix C). This data on frequency in regard to each scientific practice was then used to guide further understanding of students' use and competencies of those practices.

Results

Elements of Content Knowledge and Scientific Practices

To answer the first research question (*What elements of content knowledge and/or scientific practices are present in students' nature journals?*), coded journal entries were considered first in terms of Knowledge Transfer (Table 2), the skill of usefully applying information from one context to another, and then were considered in terms of which scientific practices students utilized in their work. Student perspectives of their own work was taken into account as well via the evaluation and reflection writing that was completed in January (Table 1).

Nature Journals

Students utilized an assortment of content knowledge when describing and labeling components in their nature journals throughout the several rounds of journaling. The most commonly referred to concepts were those of predator-prey relationships and adaptations, which appeared a total of 38 and 25 times in their journal entries, respectively. Following were pieces of information related to biomes, camouflage, evolution, and plant structure, which all appeared over ten times; then biodiversity, photosynthesis, and natural selection, which all appeared more than five times. The remaining concepts were brought up fewer than five times (Table 3).

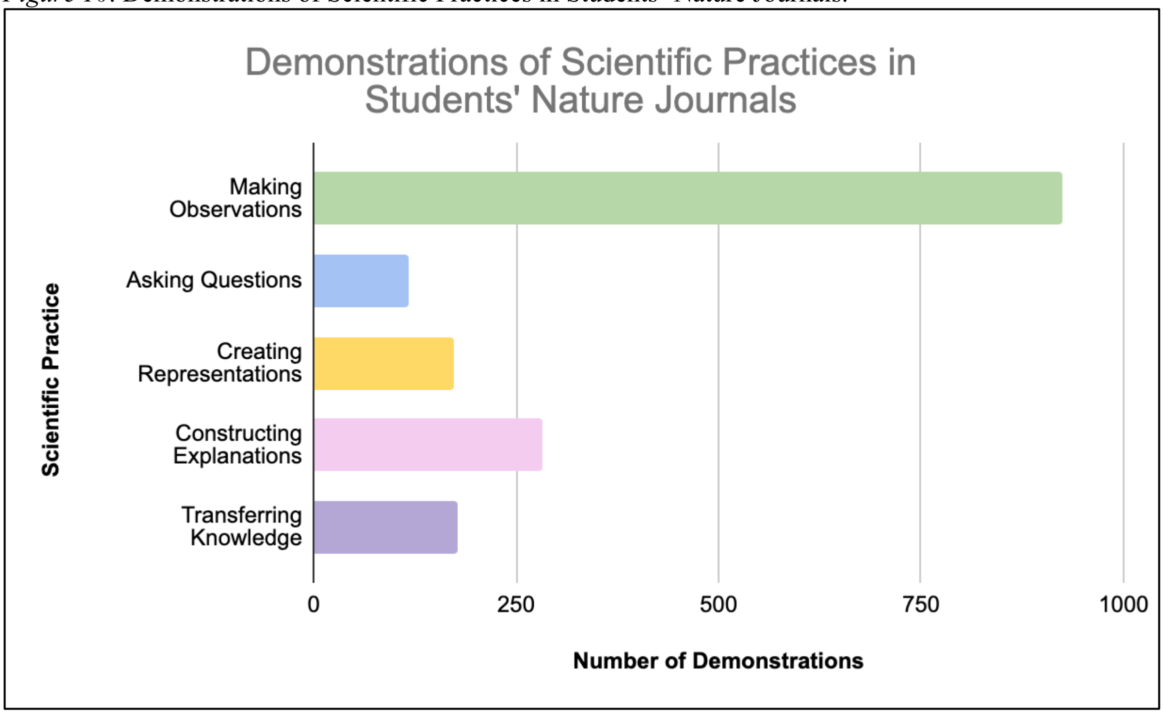
The pieces of knowledge that were utilized most frequently were all covered in class. In some instances, students were explicitly instructed to consider them during their journaling activities (Table 1). Others, highlighted in green, were used ‘spontaneously’, or without direct prompting from the instructor. Knowledge of plant anatomy, for example, was transferred to nature journaling contexts in equal frequency to knowledge of evolution (Table 3), despite the fact that this topic wasn’t covered in a biology class for these students for at least one year.

Table 3. Instances of Knowledge Transferred During Nature Journal Activities. Breakdown of topic area of all codes for Knowledge Transfer in nature journals, ordered from most frequent to least frequent occurrences. Highlighting indicates that content not covered in the Ecology & Animal Behavior course.

Vocabulary Utilized	Total Number of Times Utilized
(Apex) predator; prey; apex; scavengers; decomposers; food chain	38
Adapt(ed); adaptation(s)	25
Desert (biome); semi-arid; Sonoran; Rainforest (biome)	18
Camouflage; camouflaged	16
Flower/plant structural features (various)	12
Evolved; evolutionary; common ancestor; evolution; coevolution	12
Biodiversity	8
Photosynthesis; chlorophyll; stomata	8
Natural Selection; survival of the fittest; modification	8
Defense mechanism; defense	4
Mimicry; aposematism	3
Prokaryote structural features (various)	3
(Taxonomy) elapid; colubrid; arachnid	3
Competitors; competition	2
Biotic and abiotic factors	2
Mutualism	2
Crepuscular	2
Anatomy directionality (various)	2
Metabolism	2
Invasive (species)	1
Qualitative (data)	1
Limiting factor	1
Insect structural features (various)	1
Bird anatomy (various)	1
Recessive gene	1
Gene transfer	1
Stimuli	1

In addition, each of the targeted scientific practices (Table 2) was demonstrated by the class over the course of their nature journaling work. Of the skills specifically emphasized during class, students made observations the most often, for a total of 925 times. Together, they constructed 283 explanations for natural phenomena, transferred knowledge to the context of their nature spaces 178 times, created 174 representations of their nature, and asked 117 questions about their observations (Figure 10).

Figure 10. Demonstrations of Scientific Practices in Students' Nature Journals.



Further, students engaged in scientific practices not explicitly targeted during class time as well. These practices were Obtaining Information, Collecting Samples, and Conducting Investigations (Table 2). Across the rounds of journal entries, students sought out additional information about their observations eight times, collected four samples, and conducted two simple investigations.

Student Perceptions

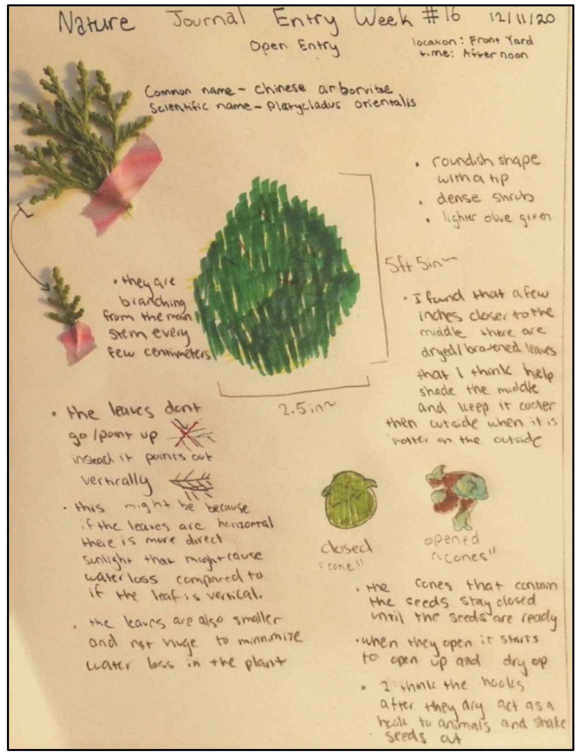


Figure 11. Journal Entry Illustrating the Practice of Collecting Samples.

During the midway evaluation and reflection in January (Table 1), students identified many successes of the nature journaling activities as they had occurred so far, as well as common suggestions for improvement. In terms of successes, students described many things that they view to be advantageous about participating in nature journaling. For example, students wrote that this activity prompts them to "look more closely [at] the organisms around [them]" and make connections "to the ecosystem as a whole rather than a small portion of it". One student even indicated that she appreciates the journal as a place "just to put thoughts" and that even though she hasn't yet, she "might try an experiment in the future and record it in the notebook, should a question... arise". Another student specifically mentioned the usefulness of follow-up activities:

> I think these nature notebook entries allow me to understand topics that I might not have understood before. Before I never completely understood Biodiversity and then when we took examples of other students I got to understand what I am supposed to be doing.

Taken together, the class articulated the benefits of "hands on" work in which they could "practice identifying [vocabulary] words" and "[apply] them to a real nature system". As one student wrote:

> These activities have definitely been beneficial because here in the notebook we can apply concepts we learned in class so then we understand that topic much better. For example when I drew a Cactus in my first prompt, I connected it back to evolution and adaptations which helped me understand adaptations better like how they conserve water and their thorns. It strengthens previous topics and really does benefit us.

These thoughts are further underscored by students' identifications of their own engagements with scientific practices, as 80% of the students who completed this evaluation and reflection activity indicated that they are able to Construct Explanations in their nature journals, thereby engaging with scientific content.[3] In terms of other scientific practices, 91% of participants indicated that they Ask Questions during journaling activities, whereas the others are less unanimous; 45% of students wrote that they Obtain Information and 36% that they Create Representations.

Alongside these successes, students' primary suggestions for improvements were focused on additional instruction. Over half of the participants indicated that they would like to see more structure in the journaling activities (fewer open-ended prompts), while some also mentioned that they would benefit from direct instruction on techniques for drawing. This feedback was instrumental in making the changes that moved the study from Iteration 1 to Iteration 2 (Table 1).

Effects of Nature Journaling on Student Competencies

To answer the second research question (*Does nature journaling facilitate an increase in student competencies in content areas and/or scientific practices?*), students' nature journal entries were considered in terms of the frequency of demonstrations of practices over the course of the school year, and then in terms of individual student

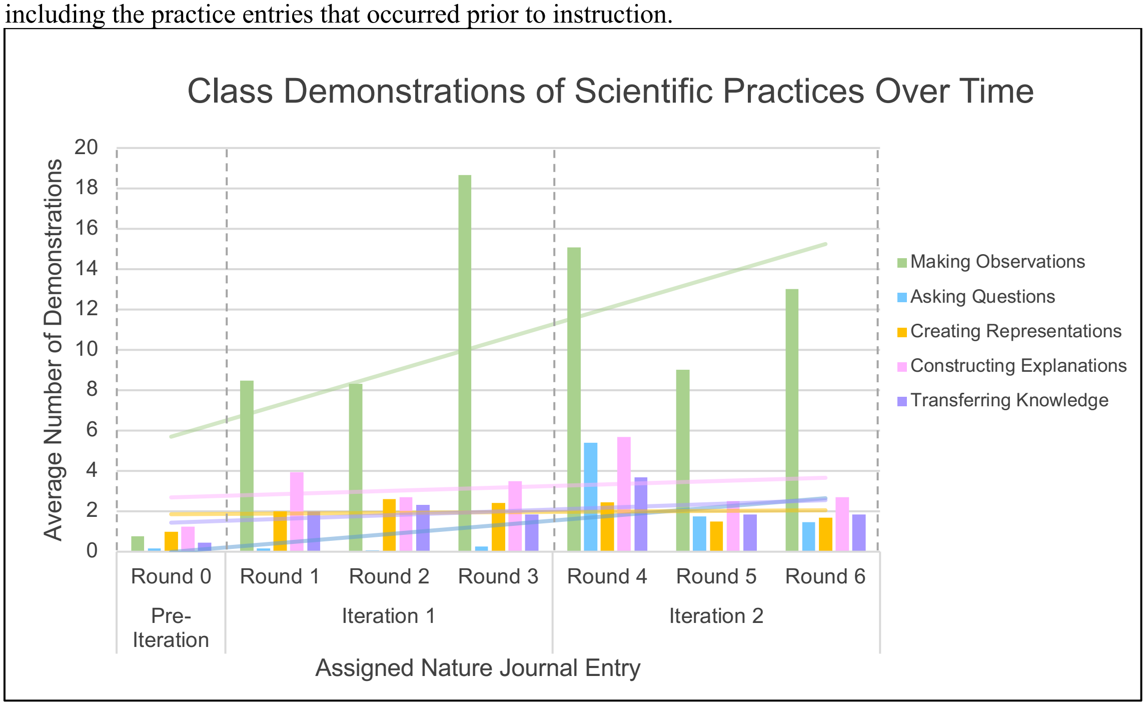
[3] Two of the thirteen students who participated in the study did not complete this activity with the class. Totals presents here then are out of eleven rather than thirteen.

improvement. Student perspectives of their own work were taken into account as well via the Attitudes Survey (Figure D1, Appendix D), which contains a construct intended to measure student confidence in science.

Nature Journals

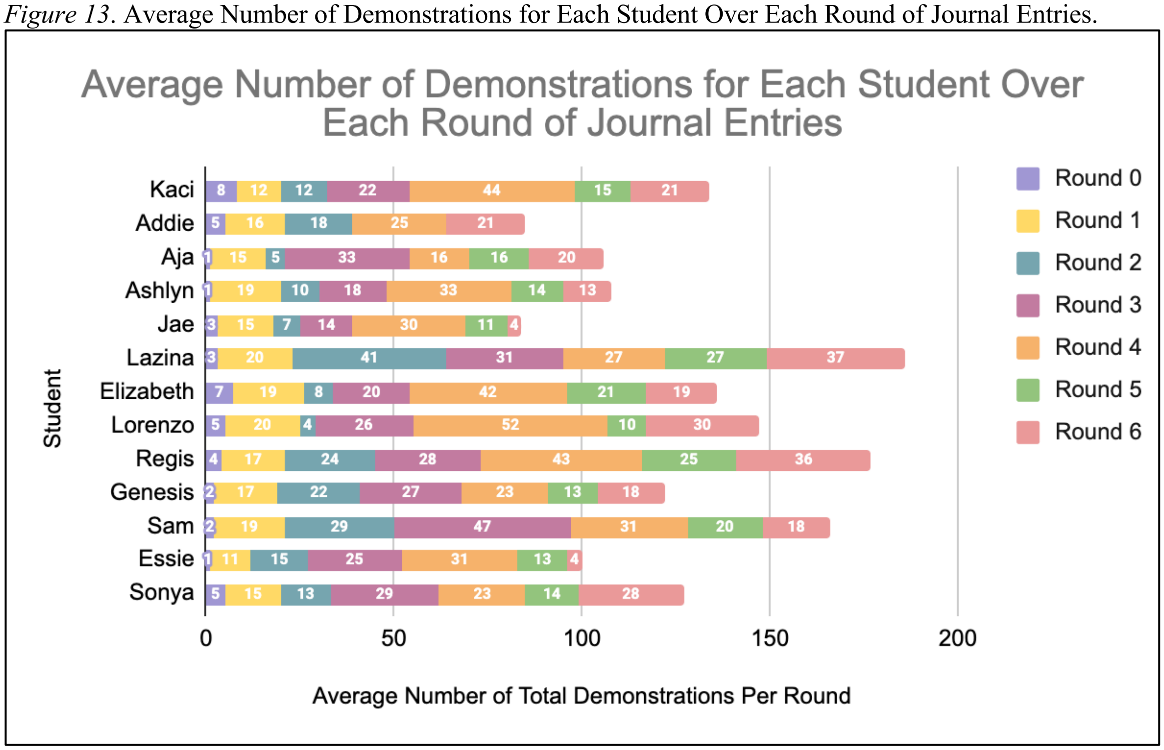
Generally speaking, instances of scientific practices increased over time in students' nature journals (Figure 12). The largest increase compared to the Round 0 practice entry (Table 1) was in Making Observations, though Asking Questions and Transferring Knowledge were improved upon as well. There were small gains in terms of the frequency of students Creating Representations and Constructing Explanations, though they remained somewhat steady overall. Still, in comparing the practice entries to the final entries, there is a statistically significant difference in the number of scientific practice demonstrations (t-value = 6.3201, p-value = 0.000038) (Table C2, Appendix C).

Figure 12. Class Demonstrations of Scientific Practices Throughout Journal Entries. Graph depicting the class's average number of demonstrations of scientific practices for each round of nature journal entries, including the practice entries that occurred prior to instruction.



Similarly, individual student performances saw increases in frequency over time. All students made impressive gains in the number of demonstrations of scientific practices across their journal entries (Figure 13), though some rounds of journaling clearly resonated more than others. For instance, Round 4 appears to have been the most fruitful in terms of student demonstrations, not Round 6, as one would expect in a strictly linear relationship. There were also noticeable individual differences in this area; some students maintained high performances throughout (e.g., Lazina), whereas others seem to have experienced bursts of productive engagement (e.g., Jae and Lorenzo).

Figure 13. Average Number of Demonstrations for Each Student Over Each Round of Journal Entries.



Another way one might characterize individual progress is in terms of changes in complexity or depth of performance, which was also seen in students' journal entries over time. Using Creating Representations as an example: students in the early stages of implementation tended to focus on plants, which might be considered easier to observe due to their incredibly slow movement. As time went on, it appears as though students became increasingly comfortable with including more difficult subject matter -- faster moving animals -- in their work as well. They also began to include depictions of organisms' surroundings and/or how the organisms fit into a larger system, as opposed to only representing them in an isolated manner. Further, students included increasingly complex structural features in their journal entries by including new strategies for visually illuminating information about their observations -- oftentimes strategies that were highlighted during previous round table discussions and critiques of other students' entries. Consider the progression depicted below in Figure 14. Already in the first round of journaling, this student utilizes a variety of format features in her representations, such as labels, multiple perspectives of the same subject, and 'zoom-ins'. After the first whole-class discussion, during which students discussed at length the benefits of including color in their diagrams, this student incorporated and maintained that feature in Round 2, as well as in all of her subsequent entries. Similar instances of students appropriating each other's methods of presentation take place throughout the study. This student was one of the first to utilize the 'zoom in' method, which was praised in whole-class discussions. The use of this strategy was then included in other students' subsequent work (Figure 15). Finally, in Round 3, she includes yet another feature, this time by including samples that she collected in the field (Figure 14). The instances of increased complexity, or at the very least students' exploration of different means of representing their observations, suggests an increased proficiency in this particular scientific skill.

Figure 14. Progression of One Student's Nature Journal Features Through Iteration 1.

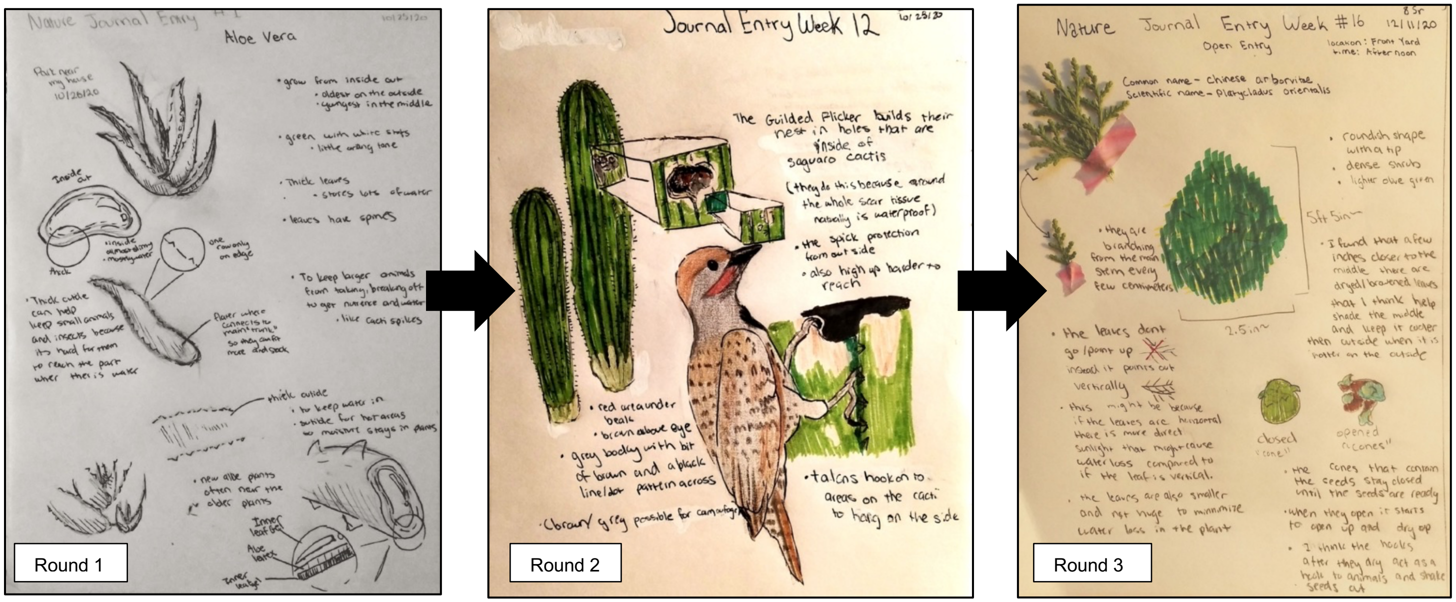
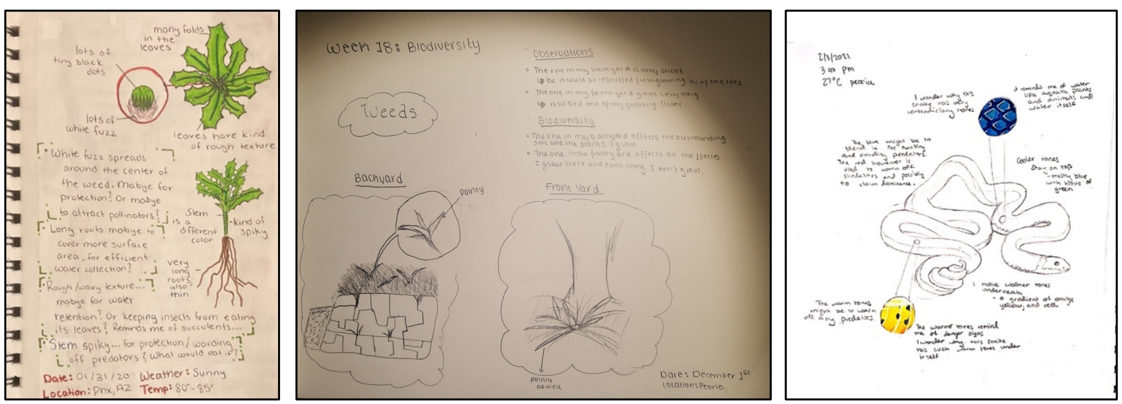


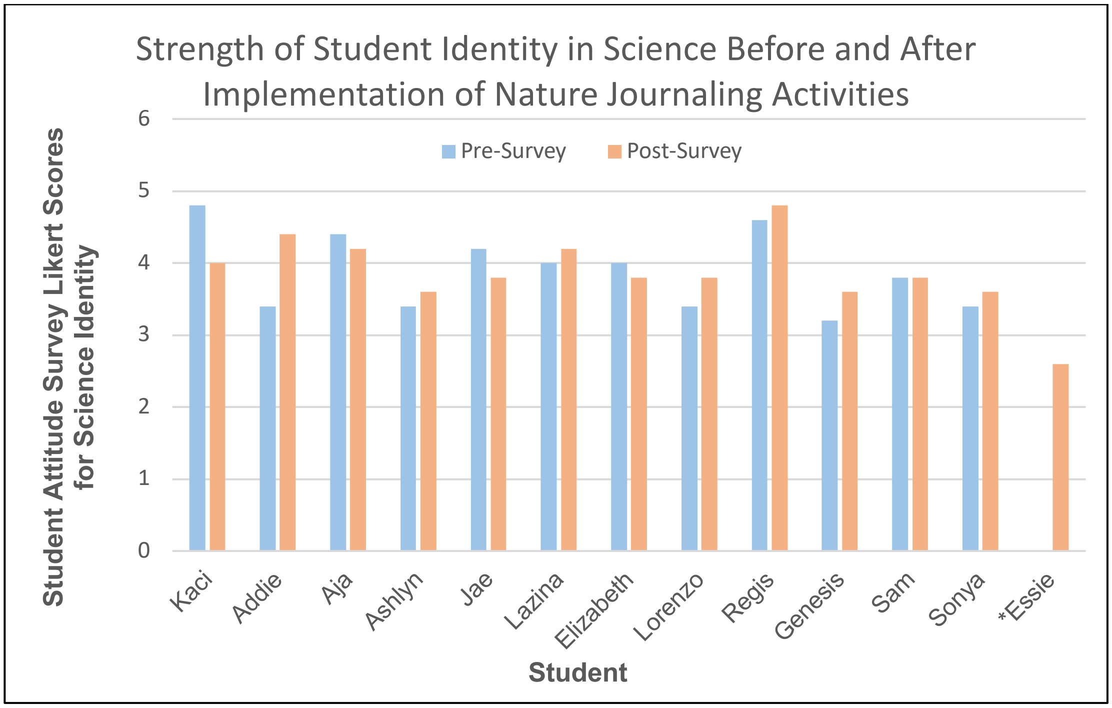
Figure 15. Instances of Student Appropriation of a Representation Strategy. Features the work of three different students after a whole-class discussion during which the 'zoom in' method was a key topic of interest.



Student Perceptions

Though there were small variations in student perceptions of their own skills in science (Figure 16) according to their responses on the Attitudes Survey (Figure D1, Appendix D) from before and after the implementation of nature journaling, these changes were not statistically significant (Table C1, Appendix C).

Figure 16. Strength of Student Identity in Science Before and After Implementation of Nature Journaling Activities.



In sum, the data indicate that students utilize knowledge from within and between classes (Table 3), engage in targeted scientific practices (Figure 10) as well as others (Table 2), and have increased the frequency (Figures 12 and 13) and depth of their practices (Figures 14 and 15). Data from student responses to surveys and in writing reveal that students believe their nature journaling activities to be beneficial for their learning, particularly in terms of Constructing Explanations, but that students' perceptions of their own competencies in science has not changed (Figure 16).

Discussion & Conclusions

Returning to the research questions (p. 19), substantial elements of both content knowledge and scientific practices were present in students' nature journals, and students were aware of how Constructing Explanations (Table 2) can act as a bridge between the two. Of particular interest were the incidental occurrences that took place in their entries. Students included components that were requested of them, but also went beyond the requirements, applying knowledge from coursework outside of Ecology & Animal Behavior (Table 3) and engaging in practices that had not yet been discussed during class (Table 2). In addition to the first research question, these 'spontaneous' forms of participation speak to the second question as well. The fact that students went beyond what was expected of them indicates that nature journaling can indeed act as a mediating activity for the target areas of content knowledge and scientific practices in the classroom. This, in combination with the increased frequency (Figures 12 and 13) and depth (Figures 14 and 15) of student work, points to a positive relationship between nature journaling and science education.

Limitations

While these results are promising on many fronts, this study was limited in several ways. First and foremost, the means of instruction for the 2020/2021 school year were not typical. The majority of students remained at home for distance learning (Table 1) in accordance with the Arizona Department of Health Services (2021) recommendations. As such, students did not have the (potential) benefit of collaboratively journaling alongside their instructor and their peers, and there were very few times and very few students that were able to be directly observed engaging with their nature journaling activities. Further, the facilitation of class discussions and follow-up activities were somewhat limited in the online setting because students were not required to have their cameras on during virtual meetings, per the policy of the school research site. Therefore, aspects of communication that would be afforded in person (gestures, direction of gaze, nodding, etc.), were removed from these interactions.

Additional constraints include the relatively small sample size (thirteen students), the short length (six months, Table 1), and the experimental nature of the implementation. Due to the timeframe, not all targeted scientific practices from the Ecology & Animal Behavior course were addressed here, which leaves some gaps in insight into the nature journals' potential for facilitating those practices. This was exacerbated by the fact that nature journaling was an activity that was new to me (as a participant, an instructor, and a researcher) at the beginning of the implementation; I was learning with the students as the course progressed. This likely resulted in instances of 'clumsy' teaching practices, which could have influenced the efficacy of this mediating activity.

Finally, participants in this study were not asked to complete any tasks beyond the required coursework. For that reason, data collection methods such as interviews (Rossman & Rallis, 2011), were not conducted. However, such direct conversations with students may have provided useful insights (Colbert, 2020), particularly during this time of social distancing.

Implications

For Researchers

Examining these results through a situative lens (Greeno, 2011, pp. 41-47), it appears as though nature journaling does facilitate student learning of content and scientific skills. As learners, students can be considered to be on the periphery of the scientific community. Nature journaling prompts students to engage in the practices of that community, and to become more familiar with the body of knowledge with which it operates. Opportunities such as this should increase competencies of individuals on the periphery, thereby bringing them closer to the 'inner fold' as they develop their expertise. Through this development, the *way* that students participate in a given community literally changes over time (Figure 4; Lave & Wenger, 1991), and this transition from novice to expert constitutes learning (Greeno, 2011, pp. 41-47). As demonstrated in this study, students' engagement with the content knowledge and practices of the scientific community changed in less than one school year; students utilized scientific skills more frequently, including Knowledge Transfer (Figures 12 and 13), and in some instances altered their approach to these utilizations (e.g., Creating Representations, Figures 14 and 15). This was accomplished through their own efforts as well as through collaboration, as students had the opportunity to see, discuss, and critique each other's work (Table 1), which often led to individuals making adjustments to their practice (Figure 15).

Grounding outdoor education not only in social constructivism (Orey, 2010, pp. 55-59) and the experiential learning model (Orey, 2010, pp. 259-266) but also in the larger view of situativity theory would provide clearer goals for this form of teaching -- namely, to change how students participate in a given community of practice. It may be worthwhile to investigate whether outdoor programs already conform to this idea in practice if not in explicitly articulated theoretical underpinnings. Other areas that might be further investigated based on these results include how the changes to students' participation hold up over time, which features of nature journaling activities foster students' sense of systemic affordances and conceptual agency (Greeno, 2011, p. 47), and how these activities might be enacted differently in a typical classroom setting. Additionally, further insight into students' perceptions of their own identities as scientists may be a worthy pursuit of further research; though students recognized that they were reinforcing information and engaging in scientific practices through their nature journals, their perceptions of their identities in science did not significantly change. While this could be attributed to the fact that many students scored highly on the survey initially (Table C1, Appendix C), thereby leaving little room for upward change, there may be something else at play. Of course, these many suggestions for future research would be beneficial not only for bolstering learning theory but also for the practical application of developing pedagogy for practitioners.

For Practitioners

Science educators today often find themselves in a quandary in which they are expected to foster scientific literacy in students, but are met with significant barriers (Banilower et al., 2013; McFadden, 2019; Wallace & Kang, 2004) that make it difficult to stray from traditional methods of instruction. Shifts towards more practical and integrated goals for science education (e.g., College Board, 2021; NGSS Lead States, 2013) are important for developing adults who can effectively function in the modern day, but (especially in light of existing barriers [Banilower et al., 2013; McFadden, 2019;

Wallace & Kang, 2004]), the end goal of scientific literacy (Bybee et al., 2008, pp. 78-79) with no mediating pathway is not enough for achieving said goal (Bybee et al., 2008, pp.83-84; Lee & Roth, 2003).

Outdoor education with nature journaling as an entry point may provide such a mediating pathway, as it allows students to apply content knowledge (Table 3) while also engaging in scientific practices (Figure 10). Importantly, this activity may be able to bypass many barriers to outdoor education due to its flexible constitution. Nature journals can be adapted to a variety of outdoor spaces, available materials, and classroom needs (Colbert, 2020; Leslie & Roth, 2000, pp. 12-15). The successful implementation of nature journaling in this Ecology & Animal Behavior class demonstrates these affordances; students completed their nature journal entries all in different locations due to the need for distance learning, and utilized resources available to them in their homes, as opposed to a collection of art materials that could be distributed in a typical classroom setting. Additionally, nature journal prompts were constructed in time with content units as they were covered and were often adjusted based on in-the-moment conversations and points of student interest.

To provide even more positive potential for this activity, the legitimate peripheral participation framework (Figure 4; Lave & Wenger, 1991) can provide direction for instructional goals. Suppose that a teacher chose to conduct nature journal activities with her class in order to engage students with scientific practices over the course of the school year. They are tasked with observing nature spaces and recording their observations, and therefore practice basic skills. How do they continue to advance towards scientific literacy? The framework (Figure 4; Lave & Wenger, 1991) provides illumination here: if the goal is moving students towards more expertise within the scientific community, then it naturally follows that students will at some point need to change their means of participation in order to engage more fully with that community. This provides guidance for how to advance students' developing expertise. The pairing of nature journaling with some other, more direct form of participation, such as citizen science (see US General Services Administration, 2021), could be a logical next step for fostering student competencies in target areas while also maintaining the foundational activity with which students are familiar.

Of course, how students engage with each other is also important (alongside how they engage with the scientific community). One cannot overemphasize the fact that students themselves recognized the benefits of the nature journaling activities, indicating that student buy-in was common in this class and may also be in others.

Additionally, though these points were not directly investigated in this study, nature journaling has an inherent potential for academic differentiation and may also facilitate interdisciplinary work. Differentiation is possible given that students work in their own notebooks and are afforded the freedom, when appropriate, to explore features of nature spaces that may not correspond with others. This provides a level of discretion that other activities may not be able to attain due to differentiated grouping and the close quarters of indoor classrooms. Nature journaling may also provide a means of integrating science work with other content areas or examining multiple sciences in an interdisciplinary way, a possibility that is suggested by students' knowledge transfer between courses (Table 3) as well as previous research (Colbert, 2020; James & Williams, 2017).

Concluding Thoughts

Given the current emphasis on scientific literacy (Bybee et al., 2008, pp. 78-79; Maienschein, 1998) and preparing students for adulthood in the twenty-first century (Stein et al., 2016, p. 212), it is critical that reform efforts provide not only end goals for science education, but also practical mediating strategies that teachers on the ground can use to facilitate them (Lee & Roth, 2003). Though additional research on the use of nature journals in the classroom is still needed to develop a full picture of this outdoor education practice (Colbert, 2020), the study presented here provides a glimpse into the positive influence that nature journaling may have on students' competencies in both scientific knowledge and skills. This, in combination with the accessibility and adaptability of this classroom activity, indicates that nature journaling may be a useful mediating activity for engaging students in science.

References

Adkins, C. (2002). *Outdoor, experiential, and environmental education: Converging or diverging approaches?*. ERIC Clearinghouse on Rural Education and Small Schools, AEL.

American Association for the Advancement of Science. (2001). *Designs for science literacy*. Oxford University Press.

American Institutes for Research. (2005). Effects of Outdoor Education Programs for Children in California [PDF file]. Retrieved from: https://www.air.org/sites/default/files/downloads/report/Outdoorschoolreport_0.pdf

Arizona Department of Health Services (2021). *Coronavirus Disease 2019: Schools (K-12) and Childcare*. Arizona Department of Health Services: Health and Wellness for All Arizonans. https://www.azdhs.gov/preparedness/epidemiology-disease-control/infectious-disease-epidemiology/index.php#novel-coronavirus-schools

Ball, A. F. (2012). To know is not enough: Knowledge, power, and the zone of generativity. *Educational Researcher*, *41*(8), 283-293.

Banilower, E. R., Smith, P. S., Weiss, I. R., Malzahn, K. A., Campbell, K. M., & Weis, A. M. (2013). Report of the 2012 national survey of science and mathematics education. *Horizon Research, Inc. (NJ1)*.

Barab, S. (2005). Design-based research: A methodological toolkit for the learning scientist. In R.K. Sawyer (Ed.), *The Cambridge handbook of the learning sciences*, (275-297). New York, NY: Cambridge University Press.

Barab, S., & Squire, K. (2004). Design-based research: Putting a stake in the ground. *The journal of the learning sciences*, *13*(1), 1-14.

Bogner, F. X., & Wiseman, M. (1997). Association tests and outdoor ecology education. *European journal of psychology of education*, *12*(1), 89.

Bolin, L., Durwin, C. C., & Reese-Weber, M. (2016). *EdPsych modules*. Sage Publications.

Bybee, R. W., Carlson-Carlson-Powell, J., & Trowbridge, L. W. (2008). *Teaching secondary school science: Strategies for developing scientific literacy*. Pearson Education.

Case, R. (1996). Changing views of knowledge and their impact on educational research and practice. In Olson, D. R., & Torrance, N. (Eds.). *The handbook of education and human development: New models of learning, teaching and schooling*. Wiley-Blackwell.

Colbert, J. (2020). *Exploring sustainability literacy through nature journaling in school gardens*. [Master's thesis, Arizona State University]. ASU Repository.

College Board (2021). *Science Practices*. AP Central. https://apcentral.collegeboard.org/courses/resources/science-practices.

Costa, A. L., & Kallick, B. (Eds.). (2008). *Learning and leading with habits of mind: 16 essential characteristics for success*. ASCD.

Coyle, K.J. (2010). Back to School: Back Outside! How Outdoor Education and Outdoor School Time Create High Performance Students [PDF file]. Retrieved from: https://www.nwf.org/~/media/PDFs/Be%20Out%20There/Back%20to%20School%20full%20report.ashx

DeCuir-Gunby, J. T., Marshall, P. L., & McCulloch, A. W. (2011). Developing and using a codebook for the analysis of interview data: An example from a professional development research project. *Field methods*, *23*(2), 136-155.

Dell'Olio, J. M., & Donk, T. (2007). *Models of teaching: Connecting student learning with standards*. Sage Publications.

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*, *87*(320), 107.

Donaldson, G. W. (1972). Research in outdoor education. *The Journal of Environmental Education*, *3*(4), 9-10.

Gamoran, A. (2018). Evidence-based policy in the real world: A cautionary view. *The Annals of the American Academy of Political and Social Science*, *678*(1), 180-191.

Green, C., Eady, M. J., & Andersen, P. J. (2018). Preparing quality teachers: Bridging the gap between tertiary experiences and classroom realities.

Greeno, J. G. (2011). A situative perspective on cognition and learning in interaction. In T. Koschmann (Ed.), *Theories of Learning and Studies of Instructional Practice*. New York, NY: Springer.

Greeno, J. G., & Nokes-Malach, T. J. (2016). Some early contributions to the situative perspective on learning and cognition. *Reflections on the learning sciences*, 59-75.

Hawxwell, L., O'Shaughnessy, M., Russell, C., & Shortt, D. (2019). 'Do you need a kayak to learn outside?': a literature review into learning outside the classroom. *Education 3-13*, *47*(3), 322-332.

Hobart, A. (2005). Sketching in nature. *The Science Teacher*, *72*(1), 30.

James, J. K., & Williams, T. (2017). School-based experiential outdoor education: A neglected necessity. *Journal of Experiential Education*, *40*(1), 58-71.

Jeronen, E., Palmberg, I., & Yli-Panula, E. (2017). Teaching methods in biology education and sustainability education including outdoor education for promoting sustainability—A literature review. *Education Sciences*, *7*(1), 1.

Keyes, D. (2017). Outdoor School in Oregon [PDF file]. Retrieved from: https://grayff.org/wp-content/uploads/2018/07/ODS-final-report.pdf.

Kolodner, J. L. (1991). The journal of the learning sciences: Effecting changes in education. *The Journal of the Learning Sciences*, *1*(1), 1-6.

Lave, J., &Wenger, E. (1991). Situated learning: Legitimate peripheral participation. Cambridge: Cambridge University Press.

Laws, J. M. & Lygren, E. (2020). *How to teach nature journaling*. Heyday Books.

Lee, S., & Roth, W. M. (2003). Science and the "good citizen": Community-based scientific literacy. *Science, Technology, & Human Values*, *28*(3), 403-424.

Leslie, C.W., & Roth, C.E. (2000). *Keeping a nature journal: Discover a whole new way of seeing the world around you*. Storey Publishing.

Maienschein, J. (1998). Scientific literacy. *Science*, *281*(5379), 917.

McFadden, J. (2019). Transitions in the perpetual Beta of the NGSS: One science teacher's beliefs and attempts for instructional change. *Journal of Science Teacher Education*, *30*(3), 229-258.

McKenney, S. (2016). Researcher-Practitioner Collaboration in Educational Design Research: Processes, Roles, Values, and Expectations. In M.A. Evans, M.J. Packer, & R.K. Sawyer (Eds.), *Reflections on the Learning Sciences*. New York, NY: Cambridge University Press.

McKenney, S., & Reeves, T. C. (2018). *Conducting educational design research*. Routledge.

Moore, R. (1990). What's wrong with science education & how do we fix it?. *The American Biology Teacher*, *52*(6), 330-337.

National Assessment of Educational Progress (2015). *Science Assessment Overall Achievement Levels*. [Data set]. The Nation's Report Card. https://www.nationsreportcard.gov/science_2015/#acl?grade=4

National Commission on Excellence in Education. (1983). A nation at risk: The imperative for educational reform. *The Elementary School Journal*, *84*(2), 113-130.

National Research Council. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. National Academies Press.

Nelson, S.R., Leffler, J.C., & Hansen, B.A. (2009). *Toward a research agenda for understanding and improving the use of research evidence*. Portland, OR: Northwest Regional Educational Laboratory.

NGSS Lead States. (2013). *Next Generation Science Standards: For States, By States*. Washington, DC: The National Academies Press.

Orey, M. (2010). *Emerging perspectives on learning, teaching and technology*. North Charleston: CreateSpace.

Packer, M. J., & Maddox, C. (2016). Mapping the territory of the learning sciences. *Reflections on the learning sciences*, 126-154.

Peeters, P. (2020). *Nature journaling*. Paperbark Writer. https://www.paperbarkwriter.com/nature-journaling/.

Priest, S. (1986). Redefining outdoor education: A matter of many relationships. *The Journal of environmental education*, *17*(3), 13-15.

Ripley, A. (2013). *The smartest kids in the world: And how they got that way*. Simon and Schuster.

Rossman, G. B., & Rallis, S. F. (2011). *Learning in the field: An introduction to qualitative research*. Sage.

Sandoval, W. (2014). Conjecture mapping: An approach to systematic educational design research. *Journal of the learning sciences*, *23*(1), 18-36.

Scott, G. W., Boyd, M., Scott, L., & Colquhoun, D. (2015). Barriers to biological fieldwork: What really prevents teaching out of doors?. *Journal of Biological Education*, *49*(2), 165-178.

Sobel, D. (2004). *Place-based education: Connecting classrooms & communities* (p. 105). Orion Society.

Smith, P. R. (1987). Outdoor education and its educational objectives. *Geography*, 209-216.

Sponarski, C. C., Vaske, J. J., Bath, A. J., & Loeffler, T. A. (2016). Changing attitudes and emotions toward coyotes with experiential education. *The Journal of Environmental Education*, *47*(4), 296-306.

Stein, M.K., Crowley, K., & Resnick, L. (2016). Educational policy and the learning sciences. In M.A. Evans, M.J., Packer, & R.K. Sawyer (Eds.), Reflections on the Learning Sciences (210-233).

Stokes, D. E. (1997). Stating the problem. *Pasteur's Quadrant: Basic Science and Technological Innovation.*

Sustainable Forestry Initiative (2019). *Nature journaling ideas*. Project Learning Tree. https://www.plt.org/educator-tips/nature-journaling-ideas/.

Tyack, D. (2003). *Seeking common ground: Public schools in a diverse society*. Harvard University Press.

Tyack, D., & Tobin, W. (1994). The "grammar" of schooling: Why has it been so hard to change?. *American educational research journal*, *31*(3), 453-479.

US General Services Administration (2021). About citizenscience.gov. *CitizenScience.gov*. https://www.citizenscience.gov/about/#.

Waliczek, T. M., Logan, P., & Zajicek, J. M. (2003). Exploring the impact of outdoor environmental activities on children using a qualitative text data analysis system. *HortTechnology*, *13*(4), 684-688.

Wallace, C. S., & Kang, N. H. (2004). An investigation of experienced secondary science teachers' beliefs about inquiry: An examination of competing belief sets. *Journal of research in science teaching*, *41*(9), 936-960.

APPENDIX A

SCIENTIFIC PRACTICE FRAMEWORKS

Figure A1. College Board's Scientific Practices.

Science Practices

AP Central / AP Courses & Exams / Science Practices

AP science revisions focus on seven overarching practices that capture important aspects of the work of scientists. Science practices describe the knowledge and skills that students should learn and demonstrate to reach a goal or complete a learning activity.

Science Practice 1

The student can use representations and models to communicate scientific phenomena and solve scientific problems.

Science Practice 2

The student can use mathematics appropriately.

Science Practice 3

The student can engage in scientific questioning to extend thinking or to guide investigations within the context of the AP course.

Science Practice 4

The student can plan and implement data collection strategies in relation to a particular scientific question. (Note: Data can be collected from many different sources, e.g., investigations, scientific observations, the findings of others, historic reconstruction and/or archived data.)

Science Practice 5

The student can perform data analysis and evaluation of evidence.

Science Practice 6

The student can work with scientific explanations and theories.

Science Practice 7

The student is able to connect and relate knowledge across various scales, concepts and representations in and across domains.

Figure A2. Habits of Mind for Twenty-First Century Success (Costa & Kallick, 2008).

Habits of Mind

 1.Persisting Stick to it! Persevering in task through to completion; remaining focused. Looking for ways to reach your goal when stuck. Not giving up.	 2.Managing impulsivity Take your Time! Thinking before acting; remaining calm, thoughtful and deliberative.
 3.Listening with understanding and empathy Understand Others! Devoting mental energy to another person's thoughts and ideas. Make an effort to perceive another's point of view and emotions.	 4.Thinking flexibly Look at it Another Way! Being able to change perspectives, generate alternatives, consider options.
 5.Thinking about your thinking (Metacognition) Know your knowing! Being aware of your own thoughts, strategies, feelings and actions and their effects on others.	 6.Striving for accuracy Check it again! Always doing your best. Setting high standards. Checking and finding ways to improve constantly.
 7.Questioning and problem posing How do you know? Having a questioning attitude; knowing what data are needed and developing questioning strategies to produce those data. Finding problems to solve.	 8.Applying past knowledge to new situations Use what you Learn! Accessing prior knowledge; transferring knowledge beyond the situation in which it was learned.
 9.Thinking and communicating with clarity and precision Be clear! Striving for accurate communication in both written and oral form; avoiding over generalizations, distortions, deletions and exaggerations.	 10.Gather data through all senses: Use your natural pathways! Pay attention to the world around you Gather data through all the senses; taste, touch, smell, hearing and sight.
 11.Creating, imagining, and innovating Try a different way! Generating new and novel ideas, fluency, originality	 12.Responding with wonderment and awe Have fun figuring it out! Finding the world awesome, mysterious and being intrigued with phenomena and beauty.
 13.Taking responsible risks Venture out! Being adventuresome; living on the edge of one's competence. Try new things constantly.	 14.Finding humor Laugh a little! Finding the whimsical, incongruous and unexpected. Being able to laugh at oneself.
 15.Thinking interdependently Work together! Being able to work in and learn from others in reciprocal situations. Team work.	 16. Remaining open to continuous learning I have so much more to learn! Having humility and pride when admitting we don't know; resisting complacency.

This and other resources available at www.habitsofmind.org

Figure A3. Next Generation Science Standards' Science and Engineering Practices (2013).

Asking Questions and Defining Problems
A practice of science is to ask and refine questions that lead to descriptions and explanations of how the natural and designed world works and which can be empirically tested.

Developing and Using Models
A practice of both science and engineering is to use and construct models as helpful tools for representing ideas and explanations. These tools include diagrams, drawings, physical replicas, mathematical representations, analogies, and computer simulations.

Planning and Carrying Out Investigations
Scientists and engineers plan and carry out investigations in the field or laboratory, working collaboratively as well as individually. Their investigations are systematic and require clarifying what counts as data and identifying variables or parameters.

Analyzing and Interpreting Data
Scientific investigations produce data that must be analyzed in order to derive meaning. Because data patterns and trends are not always obvious, scientists use a range of tools—including tabulation, graphical interpretation, visualization, and statistical analysis—to identify the significant features and patterns in the data. Scientists identify sources of error in the investigations and calculate the degree of certainty in the results. Modern technology makes the collection of large data sets much easier, providing secondary sources for analysis.

Using Mathematics and Computational Thinking
In both science and engineering, mathematics and computation are fundamental tools for representing physical variables and their relationships. They are used for a range of tasks such as constructing simulations; statistically analyzing data; and recognizing, expressing, and applying quantitative relationships.

Constructing Explanations and Designing Solutions
The products of science are explanations and the products of engineering are solutions.

Engaging in Argument from Evidence
Argumentation is the process by which explanations and solutions are reached.

Obtaining, Evaluating, and Communicating Information
Scientists and engineers must be able to communicate clearly and persuasively the ideas and methods they generate. Critiquing and communicating ideas individually and in groups is a critical professional activity.

APPENDIX B

RESEARCH APPROVAL DOCUMENTS

Figure B1. Approved Protocol Form. Research protocol form as approved prior to study, with redacted potentially identifying information regarding the school in question.

ASU Knowledge Enterprise Development
ARIZONA STATE UNIVERSITY

	Page: 1 of 7	
	PREPARED BY: Sarah Suloff	**APPROVED BY**:
DOCUMENT TITLE: LSE599: A Social Behavioral Protocol	**DEPARTMENT:** Office of Research Integrity and Assurance (ORIA)	**EFFECTIVE DATE**:

INSTRUCTIONS
Complete each section of the application. Based on the nature of the research being proposed some sections may not apply. Those sections can be marked as N/A. Remember that the IRB is concerned with risks and benefits to the research participant and your responses should clearly reflect these issues. You (the PI) need to retain the most recent protocol document for future revisions. Questions can be addressed to research.integrity@asu.edu. **PIs are strongly encouraged to complete this application with words and terms used to describe the protocol geared towards someone not specialized in the PI's area of expertise.**

IRB: 1. Protocol Title: Nature Journals and Scientific Practices

IRB: 2. Background and Objectives

2.1 List the specific aims or research questions in 300 words or less.
2.2 Refer to findings relevant to the risks and benefits to participants in the proposed research.
2.3 Identify any past studies by ID number that are related to this study. If the work was done elsewhere, indicate the location.

TIPS for streamlining the review time:

- ✓ Two paragraphs or less is recommended.
- ✓ Do not submit sections of funded grants or similar. The IRB will request additional information, if needed.

One of the major complaints surrounding the American public-school system is that schooling in the United States does not adequately provide students with the 21st Century skills needed to effectively work in the modern world. This is especially true for science education, which tends to focus on the memorization of content rather than the application of scientific principles and skills.

Though efforts have been made to emphasize the types of skills that students should be acquiring in their science classes (e.g. the Next Generation Science Standards' Science and Engineering Practices, Habits of Mind curricula, etc.), simply identifying those skills and communicating their importance to students is not enough to foster skills acquisition. Rather, educators must also focus on meaningful mediating activities through which students engage with the desired skill set.

Nature journaling is a potentially beneficial mediating activity for scientific practices. Though nature journaling can be variable in the details, it generally involves making use of observations, drawings, notes, etc. about outdoor spaces and their components. The activity engages participants in practices such as careful observation, model creation, data collection, the construction of scientific explanations, etc., and provides meaningful, anchoring experiences that are rooted in participants' sense of place. The purpose of this research is to describe what effects consistent nature journaling in the science classroom has on students' identity in science (i.e. confidence in scientific utilizing practices), motivation, and attitudes.

IRB: 3. Data Use - What are the intended uses of the data generated from this project?

Examples include: Dissertation, thesis, undergraduate project, publication/journal article, conferences/presentations, results released to agency, organization, employer, or school. If other, then describe.

Data will be used for thesis submissions, as well as potential publications and conferences/presentations.

IRB: 4. Inclusion and Exclusion Criteria

4.1 List criteria that define who will be included or excluded in your final sample.
Indicate if each of the following special (vulnerable/protected) populations is included or excluded:

- Minors (under 18)
- Adults who are unable to consent (impaired decision-making capacity)
- Prisoners
- Economically or educationally disadvantaged individuals

4.2 If not obvious, what is the rationale for the exclusion of special populations?
4.3 What procedures will be used to determine inclusion/exclusion of special populations?

TIPS for streamlining the review time.

✓ Research involving only data analyses should only describe variables included in the dataset that will be used.
✓ For any research which includes or may likely include children/minors or adults unable to consent, review content [here]
✓ For research targeting Native Americans or populations with a high Native American demographic, or on or near tribal lands, review content [here]
For research involving minors on campus, review content [here]

All students enrolled in Ecology and Animal Behavior (taught by the researcher, Sarah Suloff) at [redacted] (a 5-12 school in [redacted] Arizona) will be asked to participate. The students enrolled are in grades eight and nine. All student are minors (ages 13-16) and will therefore be required to obtain parental permission in order to participate.

IRB: 5. Number of Participants

Indicate the total number of individuals you expect to recruit and enroll. For secondary data analyses, the response should reflect the number of cases in the dataset.

There are currently nineteen students enrolled in Ecology and Animal Behavior. Accounting for any potential movement between electives, total participation should not exceed twenty students.

IRB: 6. Recruitment Methods

6.1 Identify who will be doing the recruitment and consenting of participants.
6.2 Identify when, where, and how potential participants will be identified, recruited, and consented.
6.3 Name materials that will be used (e.g., recruitment materials such as emails, flyers, advertisements, etc.) Please upload each recruitment material as a separate document, Name the document: recruitment_methods_email/flyer/advertisement_dd-mm-yyyy
6.4 Describe the procedures relevant to using materials (e.g., consent form).

The course instructor for Ecology and Animal Behavior [redacted] (Sarah Suloff) will recruit participants for this study by reading the Recruitment Script during class, which includes an overview of the research, what is required of participants, the voluntary nature of participation, and contact information for parents. Students will be asked to complete assent forms via Google Forms during class. Students' parents or guardians will be asked to grant permission for student participation as well on [redacted] (the communication platform for [redacted] families and teachers) and will have their own Google Form to complete.

The parent/legal guardian consent will not be sent more than two times; for a total of three counting the initial form sent. A non-response is viewed after repeated requests will be interpreted as a passive decline to participate.

Students will not be asked to provide assent in the absence of caregiver consent.

Failure to complete either Form will be taken to indicate non-consent and/or permission. Grades are not contingent on participation; forms results will remain unviewed for the duration of the data collection process.

IRB: **7. Study Procedures**

7.1 List research procedure step by step (e.g., interventions, surveys, focus groups, observations, lab procedures, secondary data collection, accessing student or other records for research purposes, and follow-ups). Upload one attachment, dated, with all the materials relevant to this section. Name the document: supporting documents dd-mm-yyyy

7.2 For each procedure listed, describe **who** will be conducting it, **where** it will be performed, **how long** is participation in each procedure, and **how/what data** will be collected in each procedure.

7.3 Report the total period and span of time for the procedures (if applicable the timeline for follow ups).

7.4 For secondary data analyses, identify if it is a public dataset (please include a weblink where the data will be accessed from, if applicable). If not, describe the contents of the dataset, how it will be accessed, and attach data use agreement(s) if relevant.

TIPS for streamlining the review time.

✓ Ensure that research materials and procedures are explicitly connected to the articulated aims or research questions (from section 2 above).

✓ In some cases, a table enumerating the name of the measures, corresponding citation (if any), number of items, sources of data, time/wave if a repeated measures design can help the IRB streamline the review time.

Students will participate in the Ecology and Animal Behavior course. All students will complete nature journals as part of those course; no additional research procedures or data instruments will be added to students' work. At the end of the grading period, students' classwork will be downloaded for analysis.

IRB: 8. Compensation

8.1 Report the amount and timing of any compensation or credit to participants.
8.2 Identify the source of the funds to compensate participants.
8.3 Justify that the compensation to participants to indicate it is reasonable and/or how the compensation amount was determined.
8.4 Describe the procedures for distributing the compensation or assigning the credit to participants.

TIPS for streamlining the review time.

- ✓ If partial compensation or credit will be given or if completion of all elements is required, explain the rationale or a plan to avoid coercion
- ✓ For extra or course credit guidance, see "Research on educational programs or in classrooms" on the following page: https://researchintegrity.asu.edu/human-subjects/special-considerations.
- ✓ For compensation over $100.00, review "Research Subject Compensation" at: https://researchintegrity.asu.edu/human-subjects/special-considerations for more information.

Students will not receive any direct or indirect compensation or credit for their participation. There is no penalty for choosing not to participate, nor any reward to choosing to participate.

IRB: 9. Risk to Participants

List the reasonably foreseeable risks, discomforts, or inconveniences related to participation in the research.

TIPS for streamlining the review time.

- ✓ Consider the broad definition of "minimal risk" as the probability and magnitude of harm or discomfort anticipated in the research that are not greater in and of themselves than those ordinarily encountered in daily life or during the performance of routine physical or psychological examinations or tests.
- ✓ Consider physical, psychological, social, legal, and economic risks.
- ✓ If there are risks, clearly describe the plan for mitigating the identified risks.

Because students' handwriting is included in their nature journals, there is a minimal risk that students' handwriting will be recognizable. To mitigate this risk, identifiable information, such as student names, references to specific locations, etc., will be redacted from their scanned entries. Additionally, students will be asked to write on science topics, as opposed to personally identifying experiences.

Sample prompt:
Choose one plant in your physical area. Draw your chosen plant and label its parts with anatomical names you remember from last year. Then, think on its prominent characteristics. How might these characteristics make this plant particularly suited to its environment (i.e. what adaptations do you see)?

IRB: 10. Potential Direct Benefits to Participants

List the potential direct benefits to research participants. If there are risks noted in 9 (above), articulated benefits should outweigh such risks. These benefits are not to society or others not considered participants in the proposed research. Indicate if there is no direct benefit. A direct benefit comes as a direct result of the subject's participation in the research. An indirect benefit may be incidental to the subject's participation. Do not include compensation as a benefit.

There are no direct benefits associated with students' participation.

IRB: **11. Privacy and Confidentiality**
Indicate the steps that will be taken to protect the participant's privacy.

11.1 Identify who will have **access to the data**.
11.2 Identify where, how, and how long data will be **stored** (e.g. ASU secure server, ASU cloud storage, filing cabinets).
11.3 Describe the procedures for **sharing, managing and destroying data**.
11.4 Describe any special measures to **protect** any extremely sensitive data (e.g. password protection, encryption, certificates of confidentiality, separation of identifiers and data, secured storage, etc.).
11.5 Describe how any **audio or video recordings** will be managed, secured, and/or de-identified.
11.6 Describe how will any signed consent, assent, and/or parental permission forms be secured and how long they will be maintained. These forms should separate from the rest of the study data.
11.7 Describe how any data will be **de-identified**, linked or tracked (e.g. master-list, contact list, reproducible participant ID, randomized ID, etc.). Outline the specific procedures and processes that will be followed.
11.8 Describe any and all identifying or contact information that will be collected for any reason during the course of the study and how it will be secured or protected. This includes contact information collected for follow-up, compensation, linking data, or recruitment.
11.9 For studies accessing existing data sets, clearly describe whether or not the data requires a Data Use Agreement or any other contracts/agreements to access it for research purposes.
11.10 For any data that may be covered under FERPA (student grades, etc.) additional information and requirements is available at https://researchintegrity.asu.edu/human-subjects/special-considerations.

The researcher (Sarah Suloff) will have access to raw data with identifiable information, and the rest of the study team will have access to reviewed and deidentified data. Data will be stored on an ASU cloud storage (i.e., Google Drive) and will be permanently deleted after three years.

Students will scan their nature journals into the Learning Management System [redacted] for grading purposes. Names and any other identifying information will be removed from the journal entries when data is transferred from the LMS to Google Drive. No contact information will be collected.

IRB: 12. Consent
Describe the procedures that will be used to obtain consent or assent (and/or parental permission).

12.1 Who will be responsible for consenting participants?
12.2 Where will the consent process take place?
12.3 How will the consent be obtained (e.g., verbal, digital signature)?

TIPS for streamlining the review time.
- ✓ If participants who do not speak English will be enrolled, describe the process to ensure that the oral and/or written information provided to those participants will be in their preferred language. Indicate the language that will be used by those obtaining consent. For translation requirements, see Translating documents and materials under https://researchintegrity.asu.edu/human-subjects/protocol-submission
- ✓ Translated consent forms should be submitted after the English is version of all relevant materials are approved. Alternatively, submit translation certification letter.
- ✓ **If a waiver for the informed consent process is requested, justify the waiver in terms of each of the following: (a) The research involves no more than minimal risk to the subjects; (b) The waiver or alteration will not adversely affect the rights and welfare of the subjects; (c) The research could not practicably be carried out without the waiver or alteration; and (d) Whenever appropriate, the subjects will be provided with additional pertinent information after participation.** Studies involving confidential, one time, or anonymous data need not justify a waiver. A verbal consent or implied consent after reading a cover letter is sufficient.
- ✓ ASU consent templates are [here].
- ✓ Consents and related materials need to be congruent with the content of the application.

The consent process will take place during normally scheduled hours for Ecology and Animal Behavior. Students will be read the Recruitment Script, which includes an overview of the research, what is required of participants, the voluntary nature of participation, and contact information for parents. Students will be asked to complete assent forms via Google Forms before leaving class. Students' parents or guardians will be asked to grant permission for student participation as well on [redacted] and will have their own Google Form to complete. Failure to complete either Form will be taken to indicate non-consent and/or permission.

IRB: 13. Site(s) or locations where research will be conducted.
List the sites or locations where interactions with participants will occur-

- Identify where research procedures will be performed.
- For research conducted outside of the ASU describe:
  - Site-specific regulations or customs affecting the research.
  - Local scientific and ethical review structures in place.
- For research conducted outside of the United States/United States Territories describe:
  - Safeguards to ensure participants are protected.
- For information on international research, review the content [here].

For research conducted with secondary data (archived data):

- List what data will be collected and from where.
- Describe whether or not the data requires a Data Use Agreement or any other contracts/agreements to access it for research purposes.
- For any data that may be covered under FERPA (student grades, etc.) additional information and requirements is available [here].
- For any data that may be covered under FERPA (student grades, homework assignments, student ID numbers etc.), additional information and requirements is available [here].

[redacted]

IRB: **14. Human Subjects Certification from Training.**

Provide the names of the members of the research team.

ASU affiliated individuals do not need attach Certificates. Non-ASU investigators and research team members anticipated to manage data and/or interact with participants, need to provide the most recent CITI training for human participants available at www.citiprogram.org. Certificates are valid for 4 years.

TIPS for streamlining the review time.

✓ If any of the study team members have not completed training through ASU's CITI training (i.e. they completed training at another university), copies of their completion reports will need to be uploaded when you submit.

✓ For any team members who are affiliated with another institution, please see "Collaborating with other institutions" [here]

✓ The IRB will verify that team members have completed IRB training. Details on how to complete IRB CITI training through ASU are [here]

Research Team:

- Sarah Suloff (ID: 8310019) completed on August 17th, 2019
- Andrea Weinberg (ID: 32558425) completed on August 6th, 2019

Figure B2. Research Site Permission Letter. Obtained prior to study from respective administration personnel. Potentially identifying information regarding the school in question has been redacted.

[redacted]

Research Site Permission Letter

09.25.20

Office of Research Integrity and Assurance,

Based on my review of the proposed research by Sarah Suloff under Andrea Weinberg, we give permission for her to conduct the study on the use of nature journals to mediate scientific practices at [redacted] As part of this study, we authorize the researcher to collect data through students' classwork in Ecology and Animal Behavior and/or Biology courses. Individuals' participation will be voluntary and at their own discretion, as well as their parents' or guardians'.

We understand that the research will include typical classroom instruction in a hybrid setting, surveys, pre-tests and post-tests, etc. This authorization covers the 2020/2021 school year. We reserve the right to withdraw from the study at any time if need be, and confirm that we are authorized to approve research in this setting.

Furthermore, we understand that any identifiable information within the data collected will remain entirely confidential and may not be provided to anyone outside of the research team without permission from the Arizona State University IRB.

Sincerely,

[redacted]

, Head of School

[redacted]

, Head of Operations

Figure B3. Recruitment Materials. Recruitment script (read during class to students) and recruitment email (sent to parents for review), with potentially identifying information about the school in question redacted.

Recruitment Script

I am a current graduate student under Professor Andrea Weinberg at Arizona State University's Mary Lou Fulton Teachers College. I am conducting a research study for my thesis to describe the effect of using nature journals in science classrooms. I am recruiting individuals from class to participate in my project this school year. Your participation would not involve anything in addition to the work you already do in class, but it would allow me to use your classwork as data for my research. Your participation in this study is completely voluntary, and you can end your participation at any time. I will not know until the end of my study who has chosen to participate and who has not, so your grade will not be affected in any way by your choice to or not to participate. Please complete the following Google Form [to be linked in the chat] to indicate whether or not you would like to participate. Thank you!

Parent Recruitment Email [redacted]

Hello, [redacted] families!

I hope that the school year has been going well for you so far. As you may remember from my introduction at the start of school, I am currently enrolled at Arizona State University's Learning Sciences program. Towards the completion of my degree program, I am conducting thesis research over the course of this semester and the next. I would like to invite your child(ren) in my Ecology and Animal Behavior class to participate in that research.

The purpose of my study is to describe the potential benefits of using nature journals in science classrooms. Nature journaling is an activity that all Ecology and Animal Behavior students will be required to complete as part of the course regardless of their choice to participate (or not participate) in this study. Therefore, students will not be asked to do any additional work by participating in the research; rather, consent to participate will allow me to use students' classwork from the 2020/2021 school year in the data collection process.

Participation in the study is completely voluntary, and you or your child can choose to stop participating at any time. I will not know until the end of my study whether individual students have chosen to participate or not, so students' grades will not be affected in any way by their choice. There are no known risks to participation in this project. Likewise, there is no compensation for participation. If your child does participate, his/her identifying information will remain confidential. Your child's name, face, or other identifying information will either not be included or will be redacted from any data used in thesis submissions, publications, and/or conference proceedings. There is minimal risk that your child's handwriting will be identifiable in his/her nature journal entries.

If you have any questions about this research, please contact me at sarah.suloff@[redacted]. When you have made a decision, please complete the following Google Form to indicate whether or not you have chosen to grant permission for your child's participation [insert link].

Thank you so much for your time and consideration!

Sarah Suloff

Figure B4. Participant Assent Form. Form completed by students to indicate their willingness to participate in the study.

Nature Journals and Scientific Practices

PARTICIPANT ASSENT FORM

I have been informed that my parent(s) have given permission for me to participate in a study surrounding the use of nature journals in science classes.

I will be asked to continue on with my schoolwork for the duration of the school year and am aware that my work may be used as data for this research.

My participation in this project is voluntary and I have been told that I may stop my participation in this study at any time. If I choose not to participate, I will continue on with my studies, but my work will no longer be used as data. Because my teacher will not know who has chosen to participate and who hasn't until the study is concluding, choosing not to participate or ending my participation will not affect my grade in any way.

______________________ Signature

______________________ Printed Name

__________ Date

Figure B5. Parent Consent Form. Form completed by parents or guardians of students to indicate their consent or non-consent to have their children participate in this study. Potentially identifying information about the school that the children attend has been redacted.

Nature Journals and Scientific Practices

PARENTAL LETTER OF PERMISSION

Note: Will be completed via Google Forms

Dear parent or guardian:

My name is Sarah Suloff and I am your child's Ecology & Animal Behavior and/or Biology teacher this year. I am also a student at Arizona State University's Mary Lou Fulton Teachers College and am currently completing my master's degree in Learning Sciences. To that end, I am conducting a research study to determine the potential uses of nature journals in science classes as a mediator for important scientific practices.

I am inviting student participation, which will involve the use of classwork from this school year as a source of data. Your child will not be required to complete any tasks that he/she would not already be completing as a student in my class. Your child's participation in this study is voluntary and there are no penalties for non-participation. I will not know who has chosen to participate until the end of the study, when grades have already been finalized for the grading period. If you choose not to have your child participate, or to withdraw your child from the study at any time, there will be no penalty. Likewise, if your child chooses not to participate or to withdraw at any time, there will be no penalty. Your child will continue his/her studies, but his/her work will not be included in the research process.

There is minimal risk that your child's handwriting from his/her nature journal will be identifiable. The results of the study may be used in reports, presentations, or publications, but identifying factors, including your child's name, will not be used. Measures to protect your child's confidentiality include, but are not limited to:

- The use of pseudonyms when referring to individual students
- The use of aggregate data when examining quantifiable findings
- The redaction of potentially identifying information from student writing, such as references to [redacted], names of teachers and/or other students, specific locations, and so on.

Please see the signature form on the following page. If you have any questions concerning the study or your child's participation in this study, please contact me directly at sarah.suloff@basised.com. You may also contact my advisor, Andrea Weinberg, at Andrea.Weinberg@asu.edu.

Thank you for your consideration. I am looking forward to continuing to work with your child this school year!

Sincerely,
Sarah Suloff

SSULOFF_IRB Materials   Parental Letter of Permission

____
Student Name

___ *I agree to allow my child's classwork to be used*
___ *I do NOT wish for my child's classwork to be used*

____________________ ____________________ __________
Signature Printed Name Date

If you have any questions about you or your child's rights as a subject/participant in this research, or if you feel you or your child have been placed at risk, you can contact the Chair of the Human Subjects Institutional Review Board, through the Office of Research Integrity and Assurance, at 480-965-6788.

APPENDIX C

COLLECTED DATA

Table C1. Attitudes Survey Responses. Student responses from the Attitudes Survey (Figure D1, Appendix D) were converted to numerical values based on the Likert Scale: Strongly Agree (5), Agree (4), Neutral (3), Disagree (2), and Strongly Disagree (1).

Subject Area Motivation	Student Pre-Test Responses														Student Post-Test Responses												
Statement	**Kaci**	**Addie**	**Aja**	**Ashlyn**	**Jae**	**Lazina**	**Elizabeth**	**Lorenzo**	**Regis**	**Genesis**	**Sam**	**Essie**	**Sonya**		**Kaci**	**Addie**	**Aja**	**Ashlyn**	**Jae**	**Lazina**	**Elizabeth**	**Lorenzo**	**Regis**	**Genesis**	**Sam**	**Essie**	**Sonya**
I enjoy learning about ecology and animal behavior.	5	4	2	5	3	4	4	4	5	4	4	4	-		5	5	5	5	3	5	4	4	5	4	5	4	5
Ecology and animal behavior are relevant to my daily life.	4	5	1	3	2	4	4	4	3	4	3	3	-		4	5	3	4	4	4	4	5	4	4	4	3	4
Being good at ecology and animal behavior is important to me.	5	5	5	4	5	3	4	4	5	4	4	5	-		4	5	5	5	2	4	4	4	5	4	4	4	5
I put enough effort into learning about ecology and animal behavior.	4	4	5	5	5	4	4	3	5	3	4	4	-		5	3	5	5	4	4	4	4	5	3	4	4	4
I believe I can master the knowledge and skills of these subjects.	5	5	5	5	5	4	4	3	5	4	5	4	-		5	5	5	5	4	4	4	4	5	4	5	3	4
Average	4.6	4.6	3.6	4.4	4	3.8	4	3.6	4.6	3.8	4	4	-		4.6	4.6	4.6	4.8	3.4	4.2	4	4.2	4.8	3.8	4.4	3.6	4.4
t-value	1.3320																										
p-value	0.2098035254																										
Interpretation	p-value > 0.05; Not significant (less than 95% confidence)																										

Science Identity	Student Pre-Test Responses														Student Post-Test Responses												
Statement	Kaci	Addie	Aja	Ashlyn	Jae	Lazina	Elizabeth	Lorenzo	Regis	Genesis	Sam	Essie	Sonya		Kaci	Addie	Aja	Ashlyn	Jae	Lazina	Elizabeth	Lorenzo	Regis	Genesis	Sam	Essie	Sonya
I frequently ask questions about the world around me.	5	3	4	3	5	4	4	1	4	3	2	4	-		4	5	5	4	4	4	4	4	4	4	3	3	3
I am comfortable with using models to represent ideas.	5	5	5	5	4	4	4	4	5	4	4	3	-		4	5	4	5	3	5	4	3	5	4	4	4	3
I can effectively conduct a scientific investigation.	5	4	5	3	4	4	4	4	5	3	4	3	-		4	3	4	3	4	4	3	4	5	3	4	4	3
I am confident in my ability to interpret data.	5	2	4	3	4	4	4	4	5	3	5	4	-		5	4	4	4	4	4	4	4	5	4	4	4	2
I can effectively construct explanations for natural phenomena.	4	3	4	3	4	4	4	4	4	3	4	3	-		3	5	4	2	4	4	4	4	5	3	4	3	2
Average	4.8	3.4	4.4	3.4	4.2	4	4	3.4	4.6	3.2	3.8	3.4	-		4	4.4	4.2	3.6	3.8	4.2	3.8	3.8	4.8	3.6	3.8	3.6	2.6
t-value	0.6345																										
p-value	0.5387043372																										
Interpretation	p-value > 0.05; Not significant (less than 95% confidence)																										

Environmental Attitudes	**Student Pre-Test Responses**														**Student Post-Test Responses**												
Statement	**Kaci**	**Addie**	**Aja**	**Ashlyn**	**Jae**	**Lazina**	**Elizabeth**	**Lorenzo**	**Regis**	**Genesis**	**Sam**	**Essie**	**Sonya**		**Kaci**	**Addie**	**Aja**	**Ashlyn**	**Jae**	**Lazina**	**Elizabeth**	**Lorenzo**	**Regis**	**Genesis**	**Sam**	**Essie**	**Sonya**
Today's environmental problems are significant.	5	5	5	5	5	5	4	4	5	4	5	5	-		5	5	5	5	5	5	4	5	4	4	4	5	5
Everyone can make a contribution to solving environmental problems.	5	5	5	5	5	5	4	5	5	4	4	5	-		5	5	5	5	3	4	4	1	5	4	4	4	2
I would be interested in participating in an environmentalist group.	5	5	5	5	5	4	3	4	3	4	3	3	-		4	5	3	5	3	4	3	3	3	4	3	4	2
I would be willing to stop using certain products if it would help other organisms.	5	5	4	5	5	5	4	4	4	4	4	5	-		5	5	3	5	4	4	3	5	4	4	3	4	3
Humans are no more important than any other type of organism.	5	5	5	5	5	4	4	5	4	4	3	5	-		4	5	3	5	4	4	4	2	4	4	3	5	4
Average	5	5	4.8	5	5	4.6	3.8	4.4	4.2	4	3.8	4.6	-		4.6	5	3.8	5	3.8	4.2	3.6	3.2	4	4	3.4	4.4	3.2
t-value	3.3364																										
p-value	0.006635256902																										
Interpretation	p-value < 0.05; Very significant (more than 95% confidence)																										

Perceptions of Nature	Student Pre-Test Responses														Student Post-Test Responses												
Statement	**Kaci**	**Addie**	**Aja**	**Ashlyn**	**Jae**	**Lazina**	**Elizabeth**	**Lorenzo**	**Regis**	**Genesis**	**Sam**	**Essie**	**Sonya**		**Kaci**	**Addie**	**Aja**	**Ashlyn**	**Jae**	**Lazina**	**Elizabeth**	**Lorenzo**	**Regis**	**Genesis**	**Sam**	**Essie**	**Sonya**
I enjoy being in natural outdoor spaces.	5	4	5	5	5	4	3	4	4	3	4	3	-		4	5	3	5	4	5	4	4	5	3	4	3	4
Cities are part of the natural world.	4	5	1	3	4	2	2	1	5	3	2	3	-		5	5	1	2	3	4	3	1	4	3	2	3	2
I can explore nature without leaving home.	5	5	1	4	4	4	3	4	5	4	4	4	-		4	5	4	4	2	5	3	1	5	4	4	4	2
I am curious about the local environment around me.	5	4	4	4	3	4	4	4	4	4	3	4	-		4	5	4	3	1	4	4	4	4	4	3	3	3
I feel a strong connection to the place I live along with the organisms within it.	4	3	5	3	2	3	3	4	4	4	2	2	-		4	5	3	5	2	4	4	2	4	4	4	2	2
Average	4.6	4.2	3.2	3.8	3.6	3.4	3	3.4	4.4	3.6	3	3.2	-		4.2	5	3	3.8	2.4	4.4	3.6	2.4	4.4	3.6	3.4	3	2.6
t-value	0.0871																										
p-value	0.9321815793																										
Interpretation	p-value > 0.05; Not significant (less than 95% confidence)																										

Table C2. Number of Demonstrations Per Student for Each Scientific Practice. This table depicts the total number of coded scientific practices (Table 2) for each student for each round of nature journaling across the practice entries and both iterations of implementation. Sums (total numbers of demonstrations combined) for each student, as well as rounded averages for each practice are included per round, and further statistics are included between sections for Iteration 1 and 2 and at the bottom.

		Round 0 (Practice Entry 1)													
		Kaci	**Addie**	**Aja**	**Ashlyn**	**Jae**	**Lazina**	**Elizabeth**	**Lorenzo**	**Regis**	**Genesis**	**Sam**	**Essie**	**Sonya**	**Rounded Average**
Code	**Making Observations**	3	1	0	0	1	0	1	0	0	0	0	0	4	0.769
	Asking Questions	1	0	0	0	0	0	0	1	0	0	0	0	0	0.154
	Creating Representations	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Constructing Explanations	2	2	0	0	1	1	5	2	3	0	0	0	0	1.231
	Transferring Knowledge	1	1	0	0	0	1	0	1	0	1	1	0	0	0.462
	Sum	8	5	1	1	3	3	7	5	4	2	2	1	5	3.62
		Round 1 (Iteration 1)													
		Kaci	**Addie**	**Aja**	**Ashlyn**	**Jae**	**Lazina**	**Elizabeth**	**Lorenzo**	**Regis**	**Genesis**	**Sam**	**Essie**	**Sonya**	**Rounded Average**
Code	**Making Observations**	6	7	8	7	10	8	10	9	8	8	12	7	10	8.462
	Asking Questions	0	0	0	0	0	2	0	0	0	0	0	0	0	0.154
	Creating Representations	1	1	3	5	1	5	2	1	1	1	1	1	3	2
	Constructing Explanations	4	4	2	3	3	4	6	6	6	4	4	3	2	3.923
	Transferring Knowledge	1	4	2	4	1	1	1	4	2	4	2	0	0	2
	Sum	12	16	15	19	15	20	19	20	17	17	19	11	15	16.538
		Round 2 (Iteration 1)													
		Kaci	**Addie**	**Aja**	**Ashlyn**	**Jae**	**Lazina**	**Elizabeth**	**Lorenzo**	**Regis**	**Genesis**	**Sam**	**Essie**	**Sonya**	**Rounded Average**
Code	**Making Observations**	5	12	0	4	5	23	2	1	9	17	11	10	9	108
	Asking Questions	0	1	0	0	0	0	0	0	0	0	0	0	0	0.077
	Creating Representations	3	3	2	1	1	8	2	1	2	5	3	1	2	34
	Constructing Explanations	3	1	0	2	0	7	0	0	11	0	6	4	1	35
	Transferring Knowledge	1	1	3	3	1	3	4	2	2	0	9	0	1	30
	Sum	12	18	5	10	7	41	8	4	24	22	29	15	13	16

		Round 3 (Iteration 1)													
		Kaci	Addie	Aja	Ashlyn	Jae	Lazina	Elizabeth	Lorenzo	Regis	Genesis	Sam	Essie	Sonya	Rounded Average
Code	Making Observations	13	-	28	12	9	22	12	17	18	19	25	23	26	224
	Asking Questions	0	-	0	1	0	0	0	1	0	0	1	0	0	0.25
	Creating Representations	4	-	3	2	1	4	2	1	3	5	3	0	1	29
	Constructing Explanations	3	-	1	2	1	5	6	4	5	3	10	1	1	42
	Transferring Knowledge	2	-	1	1	3	0	0	3	2	0	8	1	1	22
	Sum	22	-	33	18	14	31	20	26	28	27	47	25	29	26.667

		Iteration 1 Averages													
		Kaci	Addie	Aja	Ashlyn	Jae	Lazina	Elizabeth	Lorenzo	Regis	Genesis	Sam	Essie	Sonya	
	Rounded Average Sum	15	17	18	16	12	31	16	17	23	22	32	17	19	Rounded Average
Code														Making Observations	147.333
														Asking Questions	0.16
														Creating Representations	29.667
														Constructing Explanations	42.667
														Transferring Knowledge	26

		Round 4 (Iteration 2)													
		Kaci	Addie	Aja	Ashlyn	Jae	Lazina	Elizabeth	Lorenzo	Regis	Genesis	Sam	Essie	Sonya	Rounded Average
Code	Making Observations	23	13	9	12	10	15	19	20	16	14	11	21	13	196
	Asking Questions	2	8	1	11	8	4	4	13	9	1	5	2	2	70
	Creating Representations	4	1	2	2	3	4	3	2	2	2	2	2	3	32
	Constructing Explanations	11	0	2	4	7	3	11	6	11	5	8	3	3	74
	Transferring Knowledge	4	3	2	4	2	1	5	11	5	1	5	3	2	48
	Sum	44	25	16	33	30	27	42	52	43	23	31	31	23	32.308

		Round 5 (Iteration 2)													
		Kaci	Addie	Aja	Ashlyn	Jae	Lazina	Elizabeth	Lorenzo	Regis	Genesis	Sam	Essie	Sonya	Rounded Average
Code	Making Observations	3	1	0	0	1	0	1	0	0	0	0	0	4	0.769
	Asking Questions	1	0	0	0	0	0	0	1	0	0	0	0	0	0.154
	Creating Representations	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Constructing Explanations	2	2	0	0	1	1	5	2	3	0	0	0	0	1.231
	Transferring Knowledge	1	1	0	0	0	1	0	1	0	1	1	0	0	0.462
	Sum	8	5	1	1	3	3	7	5	4	2	2	1	5	3.62

		Round 6 (Iteration 2)													
		Kaci	Addie	Aja	Ashlyn	Jae	Lazina	Elizabeth	Lorenzo	Regis	Genesis	Sam	Essie	Sonya	Rounded Average
Code	Making Observations	23	13	9	12	10	15	19	20	16	14	11	21	13	196
	Asking Questions	2	8	1	11	8	4	4	13	9	1	5	2	2	70
	Creating Representations	4	1	2	2	3	4	3	2	2	2	2	2	3	32
	Constructing Explanations	11	0	2	4	7	3	11	6	11	5	8	3	3	74
	Transferring Knowledge	4	3	2	4	2	1	5	11	5	1	5	3	2	48
	Sum	44	25	16	33	30	27	42	52	43	23	31	31	23	32.308

		Iteration 2 Averages													
		Kaci	Addie	Aja	Ashlyn	Jae	Lazina	Elizabeth	Lorenzo	Regis	Genesis	Sam	Essie	Sonya	
	Sum	27	23	17	20	15	30	27	31	35	18	23	16	22	Rounded Average
Code	Making Observations														157.667
	Asking Questions														36.333
	Creating Representations														24
	Constructing Explanations														46.333
	Transferring Knowledge														31.333

Pre- vs. Post- (Practice Entry vs. Last Entry) Comparison	
t-value	6.3201
p-value	0.00003831014452
Interpretation	p-value < 0.05; Extremely significant (more than 99% confidence)

APPENDIX D

IMPLEMENTATION MATERIAL

Figure D1. Attitudes Survey. Administered to students prior to the innovation implementation and after their final round of entries included as part of this study (see Table 1).

E&AB Questionnaire

Complete the following survey. Choose how much you agree with each statement according to the scale provided (strongly disagree, disagree, neutral, agree, strongly agree).

Subject Area					
Statement	**Strongly Disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**
I enjoy learning about ecology and animal behavior.					
Ecology and animal behavior are relevant to my daily life.					
Being good at ecology and animal behavior is important to me.					
I put enough effort into learning about ecology and animal behavior.					
I believe I can master the knowledge and skills of these subjects.					
Science Practices					
Statement	**Strongly Disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**
I frequently ask questions about the world around me.					
I am comfortable with using models to represent ideas.					
I can effectively conduct a scientific investigation.					
I am confident in my ability to interpret data.					
I can effectively construct explanations for natural phenomena.					
The Environment					
Statement	**Strongly Disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**
Today's environmental problems are significant.					
Everyone can make a contribution to solving environmental problems.					
I would be interested in participating in an environmentalist group.					
I would be willing to stop using certain products if it would help other organisms.					
Humans are no more important than any other type of organism.					
Nature					
Statement	**Strongly Disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**
I enjoy being in natural outdoor spaces.					
Cities are part of the natural world.					
I can explore nature without leaving home.					
I am curious about the local environment around me.					
I feel a strong connection to the place I live along with the organisms within it.					