INTERNATIONAL JOURNAL OF SCIENCE EDUCATION, 2016
http://dx.doi.org/10.1080/09500693.2016.1251631

Routledge
Taylor & Francis Group

The dimensions and impact of informal science learning experiences on middle schoolers' attitudes and abilities in science

Pei-Yi Lin[a] and Christian D. Schunn[b]

[a]Department of Education, National Chengchi University, Taipei City, Taiwan; [b]Learning Research and Development Center, University of Pittsburgh, Pittsburgh, PA, USA

ABSTRACT
Learners encounter science in a wide variety of contexts beyond the science classroom which collectively could be quite influential on student attitudes and abilities. But relatively little is known about the relative influence of different forms of informal science experiences, especially for the kinds of experiences that students typically access. We conduct factor and regression analyses on data collected from a large number of diverse public-school attending 6th and 8th graders drawn from two regions in the USA. Students completed a science reasoning measure and surveys of attitudes, previously completed informal science learning experiences, and demographic factors. Factor analyses identify four dimensions of informal science learning participation (in home, semiformal, nature, and museums). Regression analyses find a relative specificity of effects, with particular outcomes associated with a subset of the forms of informal science participation, highlighting the importance of controlling for correlated factors. There were also a few differences by grade level, with different experiences influencing the development of competency beliefs in science in early vs. late middle schoolers.

ARTICLE HISTORY
Received 5 July 2016
Accepted 18 October 2016

KEYWORDS
Informal science learning; engagement; middle school

1. Introduction

Science learning is a cumulative process taking place both in and out of school (Duschl, Schweingruber, & Shouse, 2007). Therefore, it is important to understand the effects of both formal and informal science learning, especially in cases where one influences the other. Historically, there has been a focus in research on science education in formal science learning in schools. But increasingly research has expanded to informal science learning experiences and their effects on students' science learning. Furthermore, informal science learning experiences may influence the development of science interest and motivation to learn science more broadly. Indeed, early informal science learning experiences have been highlighted in analyses of why students made science-related curriculum and career choices (Fortus & Vedder-Weiss, 2014; Kong, Dabney, & Tai, 2014; Maltese & Tai, 2011; Simpkins, Davis-Kean, & Eccles, 2006). Researchers have argued that informal

CONTACT Pei-Yi Lin hanapeiyi@gmail.com Department of Education, National Chengchi University NO.64, Sec.2, ZhiNan Rd., Wenshan District, Taipei City 11605, Taiwan

science learning experiences such as doing science activities at home or going to out-of-school programmes/clubs, visiting a science museum, and playing in nature are essential to advance students' science abilities and attitudes (Dabney et al., 2012; Henriksen, Jensen & Sjaastad, 2015; Knox, Moynihan, & Markowitz, 2003; Markowitz, 2004; Paris, Yambor, & Packard, 1998). We follow-up on this research to examine which kinds of commonly occurring informal science learning experiences have effects on students' science abilities and attitudes.

2. Literature review

2.1. Defining informal science learning

Students can learn science in either formal or informal ways. Formal science learning is usually defined as learning science in a school context, while informal science learning usually refers to students' learning experiences in various out-of-school contexts such as museums, out-of-school or after-school clubs or programmes, science camps, and various media (Hofstein & Rosenfeld, 1996; Ramey-Gassert & Walberg, 1994). Informal science learning has also been connected to other labels such as free-choice or outdoor education, with a common emphasis on such activities as being more self-directed, rather than strongly facilitated by parents or teachers. The US National Research Council's consensus report, *Learning science in informal environments: People, places and pursuits* (Bell, Lewenstein, Shouse, & Feder, 2009), argued that informal learning practices are critical for students to learn about the natural world and develop important skills for science learning. They noted that science-designed spaces such as museums, science centres, zoos, aquariums, and environmental centres can provide rich sources of science learning experiences more closely related to the real world that are commonly found in school learning experiences. Scientific camps and after-school programmes were described as venues that can invoke students' passion in science, and build interests for science-related career choices. Furthermore, various media sources such as the Internet, television, and magazines were noted as offering science information to very broad audiences. In sum, different learning contexts have been identified as part of informal science learning, and these different contexts may have different affordances for learners. We investigate different possible domains of effects of informal science learning experiences.

2.2. Domains to be influenced by informal science experiences

In the next sections, we consider the various domains that might change through informal science experiences (i.e. scientific reasoning ability and attitudes towards science).

2.2.1. Scientific sense-making

Scientific reasoning ability has been framed in various ways in the literature, ranging from a logical framework to a way of modelling the world (Lehrer, Schauble, & Petrosino, 2001). More generally, it can be thought of as a sense-making process which enables learners to interact with various information sources to extract useful knowledge (Bathgate, Crowell, Schunn, Cannady, & Dorph, 2015; Warren, Ballenger, Ogonowski, Rosebery, & Hudicourt-Barnes, 2001). Such a conception is consistent with science learning in diverse formal and informal contexts, both as what habits of mind students might acquire from informal learning and how students may productively learn science knowledge from informal and formal sources. Scientific sense-making involves cognitive actions such as being able to interpret common data representations, focusing on mechanisms underlying empirical relationships, considering alternative explanations, and using evidence to select among explanations, which are aligned with the practices of science. As such, it can serve as a critical starting point for developing more scientific ways of thinking, engaging in an adaptive process to progressively reconstruct experiences and ideas (Savolainen, 1993), and to connect experiments, arguments, and representations in science (Lehrer et al., 2001). Through scientific sense-making, students practice and express beliefs, moving along a trajectory of epistemological development towards sophisticated views of professional science, thereby positioning students to engage in increasingly more complex science learning (Sandoval, 2005).

2.2.2. Science interest

Science interest (also called intrinsic motivation) refers to both emotions and cognitions inherently evoked by science content, which then serve as drivers of engagement and content mastery goals during learning (Hidi & Renninger, 2006). Researchers focused on curiosity to learn science have found that students who were exposed to an environment that emphasises student-directed learning became curious and wanted to know more about science by discovering and exploring the world themselves (Paris et al., 1998). Greater exposure to science activities can increase interest in science (Sheridan, Szczepankiewicz, Mekelburg, & Schwabel, 2011; Stake & Mares, 2005; Zoldosova & Prokop, 2006), and thereby help to gain mastery in science (Knox et al., 2003).

2.2.3. Valuing science for self and society

In addition to being motivated by science content itself, students can also be motivated by the indirect benefits of having science knowledge and skills (i.e. it can serve as an extrinsic motivator). Specifically, students who value science knowledge and skills (either for its contribution to society or its contribution to the student's own goals) are more motivated to positively engage during science learning in and out of school (Paris et al., 1998) and enrol in more science courses and informal science-enhancement programmes, which increase their science knowledge (Stake & Mares, 2005). Moreover, valuing science is also associated with pursuing it as a possible career (Knox et al., 2003; Markowitz, 2004; Simpkins et al., 2006; Tai, Liu, Maltese, & Fan, 2006). Participation in informal learning activities that highlight the purposes/effects of science may improve the perceived value of science (Kong et al., 2014).

2.2.4. Science competency beliefs

Students hold beliefs about whether they are capable of completing or successfully participating in science-related activities, which we call science competency beliefs (Deci and Ryan, 2008), but are sometimes also called science self-efficacy beliefs (Bandura, 1993; Meece, Wigfield, & Eccles, 1990). These competency beliefs are not necessarily well aligned with their actual abilities and it is the beliefs, rather than the actual abilities, which drive decisions to participate in science (Simpkins et al., 2006). In general, competency beliefs are an important predictor of many types of achievement behaviours, including choosing a science-related career (Bischoff, Castendyk, Gallagher, Schaumloffel, & Labroo, 2008). Participating in informal science learning experiences can increase student competency beliefs, and thereby increase science-related career interest (Knox et al., 2003; Markowitz, 2004; Simpkins et al., 2006; Stake & Mares, 2005).

In sum, there are a number of different abilities and attitudes in science that shape successful future participation in science and may be influenced by informal learning experiences. We now turn to ways of characterising different forms of informal science learning that could differentially shape these abilities and attitudes.

2.3. Contexts for informal science learning

In general, central characteristics of informal science learning include the location being out of school, the time being outside of the school hours, the activities being optional, and the details of participation being heavily student directed. But there is no single, shared definition of informal science learning; informal science learning can even happen within formal learning environments as an enrichment to school science or to bridge the gap between formal and informal science education (Hofstein & Rosenfeld, 1996). Learning science in informal environments consists of a wide range of activities such as learning from science-related materials such as books, or toys at home; attending science camps/clubs or out-of-school programmes; visiting science museums/aquaria/zoos; or spending time with nature. These diverse informal science activities can benefit students in a variety of ways. They are often described as more inspirational than school science and contributing to a stable interest in science or science-related fields (Henriksen et al., 2015). But there the different forms of informal science learning may be differentially accessible to students, offer differential amounts of student control, require different amounts of support from adults, make different information salient, and thus generally have different effects on learners. We enumerate common forms of informal experiences that are importantly different in affordances for learning. There are other forms of informal science experience, but these may be less commonly available (e.g. public participation in research, such as documenting wildlife numbers or behaviours).

2.3.1. Semiformal experiences

Some optional science learning experiences have a number of characteristics in common with formal school learning. In particular, summer, weekend, or after-school camps often have pre-planned, structured activities that students are expected to complete while attending the programme. We therefore call these semiformal because of this relatively high level of structure. These science camps/clubs can enrich school curriculum, provide ideal opportunities for students to master new skills, and enrich their interest in science by contributing in building students' positive impact on their understanding of the nature of science and scientific inquiry. Some researchers have found that students who attended particular programmes being studied felt more confident in their ability and interest in learning science (Hofstein & Rosenfeld, 1996; Knox et al., 2003; Markowitz, 2004). For example, science camp participation was significantly associated with future career interest in science and engineering (Kong et al., 2014). Some of these positive effects are found even years later (Gibson & Chase, 2002). However, adult providers of these kinds of programmes may be less well prepared in instruction than are science teachers, and they may choose to organise the programmes to be too similar to formal science classes (i.e. not allow children sufficient freedom to explore their interests). Finally, the evaluation studies on the effect of particularly high-quality semiformal experiences may not represent the typical semiformal experiences. In analyses of the large-scale Programme for International Student Assessment data set, Suter (2016) found a negative relationship between attending after-school science programmes and science achievement.

2.3.2. Informal home experiences

Within the science learning that takes place out of school, diverse in-home experiences have been argued to be an important ingredient in cultivating and guiding interest in science learning. For instance, the growth of specialty-channel television, newspapers, magazines, and the Internet now offers rich sources of high-quality and attractively presented information about science and related areas (Braund & Reiss, 2006; Hofstein & Rosenfeld, 1996). In addition, youth can run experiments/collect scientific data on their own, typically with simple kits or basic everyday materials. With some support from adults in the home, children and youth can deepen personal interests through such materials (Barron, Martin, Takeuchi, & Fithian, 2009).

2.3.3. Museum visits

Science museums, science centres, and zoos play an important role and provide an environment for students to observe and discover by themselves (Braund & Reiss, 2006; Hofstein & Rosenfeld, 1996; Semper, 1990). These spaces provide opportunities for students to experience science, particularly aspects that are hard to experience at home (Eberbach & Crowley, 2005), and they have been argued to promote science motivation (Paris et al., 1998). However, some support from adults is likely to be important in increasing the impact of the visits (Crowley & Jacobs, 2002), and not all youth may have access to supporting adults (Kim & Crowley, 2010).

2.3.4. Being in nature

Since many areas of science involve understanding the natural world, being in the natural environment (e.g. forest, parks, and lakes) can motivate students to learn more about natural phenomena as well as acquire new information about the natural environment (Braund & Reiss, 2006; Orion & Hofstein, 1994) through direct interaction with the very concrete features of the natural environment (Zoldosova & Prokop, 2006). Past research has shown that out-of-school nature experiences were an important predictor of students' interest in biology (Uitto, Juuti, Lavonen, & Meisalo, 2006).

In sum, all of these different informal science activities have been previously associated with student science learning or student motivation outcomes, but rarely have researchers considered the possible correlations (and thus confounds of effects) among these variables. Collectively, they clearly have a positive effect on students' science learning, including effects on attitudes, engagement and interest, enjoyment, a sense of identity and belonging in relation to science, and the development of long-term feelings, information, and values that encourage further thinking and taking part in science such as the selection of a STEM (Science, Technology, Engineering, and Mathematics)-related career (Dabney et al., 2012; Henriksen et al., 2015). But to better leverage these effects to improve science learning outcomes more broadly, it is important to understand what role each kind of experience tends to play. Table 1 summarises potential feature differences in the affordances of the different forms of informal science learning experiences, focusing on key dimensions that influence learning and motivational development: (1) learner autonomy has been associated with interest development (Black & Deci, 2000); (2) adult support in informal learning has been connected to both placing value on a learning domain and amount of learning (Crowley & Jacobs, 2002); and (3) some kinds of experiences are accessible by most learners, and others depend upon family socio-economics or accidents of location (e.g. living on a farm or near a zoo). Related to the dimension of access, it is not known how different forms of informal science learning tend to co-occur. For example, do the various forms of semiformal science tend to co-occur more highly than each in informal science in the home? That is, are these types of informal science learning experiences as categories useful descriptors of coherent differences across learners?

2.4. Changing landscape of informal science learning experiences from tweens to teens

In charting the developmental trajectory of students' continuously evolving motivation for science learning, many researchers have focused on the transition from primary to secondary school (Galton, 2009; Sheridan et al., 2011). This transition commonly involves changing academic expectations, changes in school structure, critical intellectual changes, and large physical changes with puberty. For informal learning, especially salient is the growth in child independence and autonomy in determining where and how informal learning time is spent.

It is also worth mentioning that a number of studies have revealed that students' interest and motivation for science learning during the middle school years are an important predictor for their choice of later science career and education (Tai et al., 2006; Maltese & Tai, 2011; Osborne, Simon, & Collins, 2003; Simpkins et al., 2006). Also, students who had a sustained expression of science interests over time are better able to learn from science texts and have enhanced science achievement (Alexander, Johnson, & Kelley, 2012).

In sum, past research on informal science learning suggests positive effects on interest in science (Alexander et al., 2012; Renninger, 2007), perceived value of science (Kong et al., 2014), competency beliefs about themselves in doing science (Simpkins et al., 2006), and science achievement and reasoning (Gerber, Cavallo, & Marek, 2001), which in turn influence long-term participation in science (Markowitz, 2004). But we know little about the relative contributions of different forms of informal science learning, especially as learners typically experience them (rather than ideal forms), and also how the timing of these

Table 1. Differences in the relative affordances for learning and motivation support among the four types of informal science learning experiences.

Type	Autonomy	Adult support	Access
Semiformal	Low	High	Varied
Home	High	Varied	High
Museum	Moderate	Varied	Low
Nature	High	Varied	Varied

experiences matter (prior to the critical middle school period vs. during the middle school period).

Therefore, we focus on the following research questions in a cross-sectional study of 6th (who just entered middle school) and 8th graders (who have already been in middle school for multiple years), connecting different prior informal science learning experiences with the different student motivation and skill outcomes:

(1) What are the common patterns of participation among different forms of informal science learning experiences (i.e. do particular activities co-occur as factors of home, museum, semiformal, and nature dimensions)?
(2) What forms of prior informal science experiences are associated with science scientific sense-making, fascination, value, and competency beliefs?
(3) Do the effects of informal science experiences change from early to late middle school?

Addressing the first research question is a logical prerequisite to addressing the second and third research questions.

3. Methods

3.1. Participants

The effective sample size was 2943 children from the ALES14 data set, including 6th-grade ($N = 1417$) and 8th-grade ($N = 1526$) students from six public schools in one large school district in Pittsburgh, Pennsylvania (a mid-sized urban area with a historical focus on manufacturing) and from five public schools across three school districts in the San Francisco/Bay Area of California, an area where a great deal of industry is focused on technology and innovation. Schools were selected using publicly available demographic information to represent a wide range of students in terms of ethnicity (e.g. from 32% to 97% under-represented minorities in a school) and socio-economic status (e.g. from 38% to 84% eligible for free/reduced lunch in a school; see Table 2). These schools were recruited by obtaining permission from district officials. Within schools, teachers were recruited at professional development events, outlining the goals and requirements of study participation. Most of the contacted teachers agreed to participate.

Based on student self-reported data: (1) 67% of students always spoke English at home and only 3% never spoke English at home; (2) 26% had mothers who were college graduates (bachelor or associates degree) and only 6% had mothers who did not graduate from high school; (3) 22% had fathers who were college graduates (bachelor or associates degree) and only 6% had fathers who did not graduate from high school; and (4) the

Table 2. Participant information across locations.

Location	6th grade	8th grade
California	758 (54%)	917 (60%)
Pennsylvania	659 (46%)	609 (40%)
Total	1417	1526
Gender	52% Female	51% Female

ethnicities of students were 47% Caucasian, 32% Black or African American, 20% Hispanic/Latino/Mexican, 11% Asian, 6% Indian/Middle Eastern, and 8% Native American/Pacific Islander.

3.2. Measures

All measures used in the study were developed by the Activation Lab for use in science education research and evaluation (Bathgate, Schunn, & Correnti, 2014; Sha, Schunn, & Bathgate, 2015; Sha, Schunn, Bathgate, & Ben-Eliyahu, 2016). (See http://activationlab.org/tools for detailed reports on each measure.) Each measure involved items adapted from multiple prior sources, with a focus on creating measures that had high validity for 6th and 8th graders from diverse backgrounds. Cognitive interviews with diverse students made sure that the items were interpreted as designed. Factor analyses were conducted to ensure that the items associated with key constructs as designed as well separating across scales. Item response theory analyses were conducted to ensure that the range of item 'difficulties' were sufficient to measure students with sufficient discriminability across the range of levels observed in this population. Finally, differential item functioning analyses using a two-parameter model framework verified that none of the items had differential discrimination by gender or by ethnicity (contrasting those under-represented in science vs. other ethnicities). Other than the demographic variables and the sense-making scales, the measures involved ordinal Likert-type scales (e.g. YES!, yes, no, NO! or more than once, once, never). For such measures, it is recommended to use polychoric correlations and ordinal alpha (Gadermann, Guhn, & Zumbo, 2012); these were computed using the psych package in R (Revelle, 2014).

3.2.1. Prior informal science experiences

This survey included 15 items (see Table 3 in the Results section) related to experiences with science activities at home (e.g. 'Played with science toys/objects/kits'), semiformal science activities such as going to camps or participating in out-of-school science activities (e.g. 'Participated in a school family science night'), experiences with nature (e.g. 'Taken care of a pet/animals'), and visiting science museums (e.g. 'Gone to science activities/museums (zoo, aquarium, garden, etc.) when I am on a trip away from where I live'). A 3-point Likert scale (more than once, once, or never) was used to sample levels of participation without requiring detailed (and likely unreliable) memories for frequency, timing, or nature of these experiences. Because of the central nature of this survey to the current study, factor analyses and subscale performance will be presented in the Results section.

3.2.2. Science fascination

Reflecting the multicomponent nature of the theoretical construct that drives intrinsic motivation towards science, this survey consisted of nine items covering curiosity about science (e.g. 'I wonder about how nature works'), positive high-arousal affect when interacting with science content (e.g. 'In general, when I work on science I have a lot of fun!'), and mastery of science (e.g. 'I want to read everything I can find about science'). As appropriate, several different 4-point Likert scales were used across items: every day, once a week, once a month, never; love it, like it, don't like it, hate it; always, sometimes, rarely, never; very interesting, interesting, boring, very boring; and YES!, yes, no, NO!.

Table 3. The EFA and CFA factor loadings for each item in each prior experiences dimension, along with mean (and SD) values, corrected item to total correlations, and ordinal alphas.

			EFA ($N = 1255$)			CFA ($N = 1421$)	
Items	Ordinal alpha	Corrected item-total correlation	*M* (SD)	Rotation factors loadings	% Variance	*M* (SD)	Rotation factors loadings
Informal home science					28		
Played with science toys/ objects/kits	0.86	0.58	2.28 (0.78)	0.56		2.28 (0.76)	0.79
Done science experiments even when I am not at school	0.87	0.55	2.02 (0.85)	0.61		2.07 (0.84)	0.74
Read books about science	0.87	0.51	2.11 (0.84)	0.77		2.18 (0.83)	0.69
Watched audio/video/TV programmes about science	0.87	0.50	2.31 (0.82)	0.73		2.33 (0.81)	0.67
Visited websites about science	0.87	0.54	1.99 (0.84)	0.72		2.00 (0.84)	0.71
Semiformal science					13		
Gone to a science camp	0.87	0.37	1.29 (0.61)	0.67		1.30 (0.62)	0.74
Participated in an after-school programme where I did science	0.87	0.34	1.40 (0.67)	0.61		1.39 (0.65)	0.63
Participated in a school family science night	0.87	0.35	1.30 (0.60)	0.68		1.33 (0.64)	0.63
Participated in a community festival/ event related to science	0.87	0.39	1.38 (0.65)	0.62		1.41 (0.67)	0.69
Attended a robotics camp or club	0.87	0.33	1.36 (0.67)	0.69		1.31 (0.63)	0.61
Nature					8		
Taken care of a pet/ animals	0.88	0.26	2.69 (0.64)	0.74		2.71 (0.62)	0.52
Taken care of a garden	0.87	0.45	2.17 (0.83)	0.67		2.23 (0.82)	0.72
Spent time in nature	0.87	0.43	2.62 (0.68)	0.69		2.64 (0.67)	0.84
Museum					6		
Gone to science activities/ museums (zoo, aquarium, garden, etc.) when I am on a trip away from where I live	0.87	0.39	2.54 (0.71)	0.79		2.56 (0.68)	0.70
Gone to science activities/ museums (zoo, aquarium, garden, etc.) near my home	0.87	0.44	2.51 (0.76)	0.59		2.42 (0.80)	0.79

The scale ordinal alpha is 0.87. Using diverse scale types increases attention to each item within a scale.

3.2.3. Values science

This survey consisted of 10 items to capture two theoretically important components: the importance of science knowledge to self (e.g. 'Science will be useful in my life') and the importance of science knowledge to society (e.g. 'I think science ideas are valuable'). The items used 4-point Likert scales: this week, in the next month, this year, never; all jobs, most jobs, a few jobs, no jobs; all the time, most of the time, sometimes, never; this week, in the next month, this year, never; all my classes, most of my classes, a few classes, none of my classes; and YES!, yes, no, NO! The scale ordinal alpha is 0.84.

3.2.4. Science competency beliefs

This survey consisted of 10 items to capture competency beliefs from the perspective of being able to do science activities (e.g. 'I can do the science activities I get in class') and from the perspective of having science skills (e.g. 'Figuring out how to fix a science activity'). The items used 4-point Likert scales: all the time, most of the time, half the time, rarely; all areas, most areas, a few areas, none of it; all websites, most websites, a few websites, none of them; excellent, good, ok, poor; all, most, some, a little; and YES!, yes, no, NO! The scale ordinal alpha is 0.85.

3.2.5. Scientific sense-making

This survey involved 12 multiple-choice items intended to measure students' use of scientific skills to make sense of science-related situations. The questions were embedded with a scenario involving dolphins at risk. It was chosen because it is broadly interesting to middle school students across gender and diverse backgrounds (Bathgate et al., 2014). Further aspects of the scenario involved content knowledge that is broadly available to students (i.e. this was not a test of content knowledge). The scale ordinal alpha is 0.78. The items covered five component skills:

(1) asking investigable questions (e.g. 'Elijah wonders if the temperature of the water makes a difference in how much dolphins play. Which question is the best to ask to investigate this?');
(2) valuing mechanistic explanations (e.g. 'What would make one scientific explanation better than another for why dolphins play?');
(3) using appropriate evidence to support scientific argumentation (e.g. 'You are wondering which type of dolphin eats the most amount of food per day. What is the best evidence you could get to answer this question?');
(4) interpreting scientific data (e.g. 'Based on the graph, how many pounds of food would you expect a dolphin to eat if given 9 pounds?'); and
(5) understanding the nature of science practices (e.g. 'Dr. Powers is investigating how dolphins communicate with each other. Which of these would be an important part of her work as a scientist?').

3.2.6. Home resources for science learning

This scale asked about the availability to the students at home of seven different resources such as technological products (e.g. 'Calculator') or books (e.g. 'Dictionary') that could support students in science learning at home. A 4-point Likert scale (Always, Most of the time, Rarely, Never) was used for all items. The scale ordinal alpha is 0.72.

3.2.7. Family learning support

This scale had five items related to family expectations (e.g. 'My learning in school is important to someone in my family') and support for students' science learning (e.g. 'When I work on homework at home, I have someone who can help me with it if I need help'). A 4-point Likert scale (YES!, yes, no, NO!) was used for all items. The scale ordinal alpha is 0.78.

3.3. Procedures

The surveys were administered in paper-and-pencil formats in students' science classrooms, across two days (approximately one full 50-minute class period on each day) near the beginning of the school year by the research team. On the first day, students completed surveys for fascination, values, competency beliefs, scientific sense-making, and prior informal science experiences on day 1. On the second day, students completed surveys regarding home resources, family learning support, and demographic information. Surveys across days were linked via an anonymous ID that also contained information about district, school, teacher, and classroom period. Because students were occasionally absent or were not able to complete all items on a given survey in the available time, Ns will vary across analyses, and are indicated in each analysis. More complex analyses involving more scales will experience the greatest loss; consistency of patterns across simple and more complex analyses provides an indication of whether systematic losses by student characteristics influence the obtained results.

4. Results

4.1. Overview of analyses

The results are presented in three sections. First, we present the psychometric validation of the prior experiences measures. Second, we examine simple associations of prior experiences with motivational variables, reasoning ability, and demographic variables. Third, we present multiple-regression models, testing the ability of prior experiences to predict each of the motivational variables and reasoning ability as outcomes, while controlling for demographic variables and other outcome variables.

4.2. Validation of prior experiences measures

Given the creation of a new survey instrument for measuring various forms of prior informal science learning experiences, it is important to conduct exploratory factor analysis (EFA) and confirmatory factor analysis (CFA) to build coherent and reliable model indicators of underlying latent factors. We use EFA with part of our data as a useful heuristic strategy for model specification, and then turn to cross-validation using CFA applied to the rest of our data (Gerbing & Hamilton, 1996; Brown, 2006).

To avoid circularity, we conducted an EFA on one subset of the data and then validated the factors using a CFA on a different subset. In particular, we conducted an EFA with the Pittsburgh subset of the participants ($N = 1255$). The measures of sampling adequacy were acceptable: Kaiser-Meyer-Olkin = 0.87 (which should be >0.5) and Bartlett's test of sphericity = 3936.85 ($df = 105$, $p < .001$). Four factors emerged describing the students' prior experiences in science activities explained 53% of variance. Each factor was named according to the loaded items: informal science experiences at home (e.g. playing with science kits, reading science; 0.56–0.77, explained 27% variance); semiformal science experiences (e.g. going to science camps, participating in after-school science programmes; 0.61–0.69, explained 12% variance); science experiences related to nature (taking care of a pet, spending time in nature; 0.67–0.74, explained 7% variance); and museum experiences (e.g. going to science museums on trip or near home; 0.59–0.79, explained 5% variance). See Table 3 for the reliability ordinal alpha and explained factor variance.

We then conducted a CFA on this model using MPlus with data from the remaining participants ($N = 1421$). This model produced a good model fit: Root Mean Square Error of Approximation = 0.039 (<0.05 indicates a good model fit), Comparative Fit Index = 0.977 (>.9 is acceptable), Tucker–Lewis Index = 0.97 (>.90 is acceptable). Table 3 presents the factor loadings in the CFA for each item; all loadings were acceptable.

4.3. Relationships among scales

Correlations were computed to examine relations among the four types of prior experiences, the motivational variables (fascination, value, and competency beliefs), scientific sense-making, and demographic variables (home resources, family support, and parental education). Separate correlations were computed for the 6th and 8th grades (see Table 4 for 6th-grade correlations and 8th-grade correlations). Most of the correlations were positive and statistically significant.

The four forms of prior informal experiences were correlated with one another. However, the correlations were low enough (i.e. all <.46) that their separable effects could be separated through multiple regressions. Overall, each of the types of prior experiences is positively significantly related with the motivational variables of fascination, value, and competency beliefs. These correlational relationships were stronger in the 8th grade than the 6th grade (all $ps < .05$ using Fisher z-tests; see the inner rectangle within Table 4).

Turning to associations with scientific sense-making, prior experiences such as informal home activities, experiences with nature, and museum visit were significantly related (see the lower rectangle within Table 4). Here, semiformal experiences were not significantly correlated.

All three of the demographic variables (home resources, perceived family support, and parental education) were significantly related with the various forms of prior informal experiences, the motivational variables, and scientific sense-making. Therefore, it is important to conduct multiple regressions that tease apart the effects of prior informal science experiences and other factors associated with demographic variables.

4.4. Modelling the effects of prior experiences

In the multiple-regression model analysis, we separated students into groups by grade, to examine the different roles of informal science experiences during elementary (i.e. prior to the 6th grade) vs. middle school (i.e. leading up to the 8th grade).

Tables 5–8 present the standardised coefficients of the multiple-regression model predicting scientific sense-making ability and the three motivational variables. For each dependent variable, we first entered the prior experience subscales as independent variables (Model 1). Next, we introduced in Model 2 the other motivational variables/scientific sense-making, as appropriate (i.e. all excluding the predicted variable). Last, we controlled the demographic information such as gender, ethnicity, schools, home resources, family support, and parental education (Model 3). All of the models were statistically significant, accounting for 35–58% of the variance. None of the Variance Inflation Factors exceeded the recommended values, particularly when focusing on the conceptually important predictors.

In the multiple-regression model for Scientific sense-making, prior experiences such as informal home and experiences with nature were significant positive predictors.

Table 4. Selected descriptive statistics and correlation matrix for 6th (upper right corner) and 8th (bottom left corner) grade survey.

6th and 8th grade	6th M	6th SD	8th M	8th SD	1	2	3	4	5	6	7	8	9	10	11
1.Informal Home	2.27	0.56	2.09	0.60	1.00	0.38**	0.43**	0.42**	0.45 **	0.43 **	0.51**	0.32**	0.26**	0.25**	0.17**
2.Semiformal	1.39	0.45	1.31	0.40	0.42**	1.00	0.17**	0.29**	0.27 **	0.26 **	0.30**	0.02	0.17**	0.20**	0.24**
3.Nature	2.54	0.50	2.52	0.54	0.46**	0.18**	1.00	0.42**	0.18 **	0.17 **	0.34**	0.32**	0.26**	0.26**	0.23**
4.Museum	2.51	0.59	2.47	0.62	0.44**	0.22**	0.42**	1.00	0.18 **	0.21 **	0.37**	0.32**	0.30**	0.31**	0.28**
5.Fascination	2.86	0.57	2.56	0.55	0.51**	0.30**	0.25**	0.24**	1.00	0.68**	0.63**	0.08**	0.15**	0.24**	0.03
6.Value	2.70	0.50	2.52	0.53	0.53**	0.31**	0.29**	0.30**	0.70**	1.00	0.60**	0.14**	0.17**	0.23**	0.11**
7.Competency Beliefs	2.91	0.53	2.79	0.54	0.54**	0.36**	0.42**	0.39**	0.62**	0.62**	1.00	0.27**	0.29**	0.31**	0.27**
8.Scientific Sense-making	9.13	3.41	9.87	3.40	0.38**	0.04	0.43**	0.33**	0.20**	0.28**	0.38**	1.00	0.22**	0.17**	0.28**
9.Home Resources	3.33	0.57	3.37	0.54	0.30**	0.19**	0.28**	0.30**	0.21**	0.24**	0.38**	0.32**	1.00	0.49**	0.28**
10.Family Support	3.55	0.49	3.40	0.57	0.23**	0.12**	0.23**	0.24**	0.21**	0.20**	0.32**	0.17**	0.44**	1.00	0.25**
11.Parent's Education	3.66	1.24	3.67	1.24	0.19**	0.22**	0.21**	0.30**	0.09**	0.17**	0.27**	0.25**	0.37**	0.22**	1.00

$p < .01$**.

Table 5. Multiple-regression models predicting scientific sense-making.

Scientific sense-making	6th grade			8th grade		
	Model 1 (*N* = 1158)	Model 2 (*N* = 993)	Model 3 (*N* = 580)	Model 1 (*N* = 1362)	Model 2 (*N* = 1219)	Model 3 (*N* = 828)
Informal home	0.22***	0.17***	0.10*	0.26***	0.20***	0.19***
Semiformal	−0.15***	−0.14***	−0.10*	−0.14***	−0.16***	−0.18***
Nature	0.17***	0.15***	0.10*	0.28***	0.24***	0.18***
Museum	0.21***	0.17***	0.08	0.13***	0.08**	−0.00
Fascination		−0.18***	−0.09		−0.16***	−0.05
Value		0.07	0.05		0.11**	0.05
Competency beliefs		0.19***	0.16**		0.23***	0.17***
Gender			0.01			0.09**
Ethnicity			0.22***			0.18***
Schools			[0.06∼−0.17]			[−0.04∼−0.15]
Home resources			−0.02			0.13***
Family support			−0.03			−0.04
Parent's education			0.07			0.02
R^2	0.19	0.20	0.35	0.26	0.29	0.39
F-value	67.18***	34.37***	13.37***	116.24***	68.95***	24.71***
Max VIF	1.48 (InfH)	2.19 (F)	3.24 (School7)	1.60 (InfH)	2.29 (F)	2.82 (School6)

p < .05*, *p* < .01**, *p* < .001***.

Competency beliefs were also a positive predictor. Interestingly, semiformal experiences were a significant negative predictor. All of these effects occurred with both grades, although with somewhat larger effects in the 8th grade.

In the multiple-regression model for Science Fascination, informal home science activities were the only kind of significant experience predictor in the final model. Value and competency beliefs are also significantly predictors. These effects occurred with both grades at similar magnitudes.

In the multiple-regression model for Valuing Science, informal home science activities were again the only kind of significant experience predictors in the final model, and fascination and competency beliefs were also significant predictors. Similarly, these effects occurred in both grades, but with a larger effect of informal science experiences in the 8th grade.

Table 6. Multiple-regression models predicting science fascination.

Fascination	6th grade			8th grade		
	Model 1 (*N* = 1130)	Model 2 (*N* = 993)	Model 3 (*N* = 580)	Model 1 (*N* = 1333)	Model 2 (*N* = 1219)	Model 3 (*N* = 828)
Informal home	0.43***	0.14***	0.13***	0.46***	0.16***	0.15***
Semiformal	0.11***	0.01	0.04	0.11***	0.00	0.03
Nature	0.00	−0.02	−0.03	0.02	−0.01	0.02
Museum	−0.04	−0.06*	−0.04	−0.01	−0.07**	−0.03
Value		0.43***	0.42***		0.47***	0.45***
Competency beliefs		0.35***	0.35***		0.31***	0.34***
Scientific sense-making		−0.10***	−0.06		−0.09***	−0.03
Gender			−0.05			−0.08**
Ethnicity			−0.03			−0.06*
Schools			[0.13∼0.00]			[0.08∼−0.05]
Home resources			0.02			−0.04
Family support			0.05			0.04
Parent's education			−0.12***			−0.07**
R^2	0.22	0.55	0.56	0.27	0.57	0.58
F-value	77.01***	172.33***	31.87***	124.50***	228.48***	52.26***
Max VIF	1.49 (InfH)	1.90 (CB)	3.24 (School7)	1.59 (InfH)	2.02 (CB)	2.82 (School6)

p < .05*, *p* < .01**, *p* < .001***.

Table 7. Multiple-regression models predicting valuing science.

Value	6th grade			8th grade		
	Model 1 (*N* = 1121)	Model 2 (*N* = 993)	Model 3 (*N* = 580)	Model 1 (*N* = 1338)	Model 2 (*N* = 1219)	Model 3 (*N* = 828)
Informal home	0.39***	0.11***	0.08*	0.44***	0.14***	0.17***
Semiformal	0.11***	0.03	0.03	0.11***	0.02	0.03
Nature	−0.02	−0.05	−0.03	0.03	−0.02	−0.05
Museum	0.03	−0.01	0.01	0.06*	0.02	0.02
Fascination		0.47***	0.49***		0.48***	0.48***
Competency beliefs		0.25***	0.17***		0.21***	0.16***
Scientific sense-making		0.04	0.04		0.07**	0.03
Gender			0.02			−0.01
Ethnicity			0.10**			0.12***
Schools			[0.04∼−0.06]			[0.10∼−0.01]
Home resources			0.00			0.00
Family support			0.00			−0.01
Parent's education			0.04			0.02
R^2	0.20	0.51	0.48	0.29	0.56	0.55
F-value	68.60***	148.53***	23.38***	137.10***	223.96***	46.61***
Max VIF	1.46 (InfH)	2.05 (CB)	3.24 (School7)	1.59 (InfH)	2.13 (CB)	2.81 (School6)

$p < .05$*, $p < .01$**, $p < .001$***.

In the multiple-regression model for Science Competency Beliefs, the models varied by grade. In the 6th grade, informal home experiences, experiences with nature, and museum visits were significant predictors, whereas in the 8th grade, semiformal experiences and experiences with nature were significant predictors. In both grades, fascination, values, and scientific sense-making were also significant predictors.

5. General discussion

5.1. Dimensions of informal science

From this exploration of students' science-related opportunities, our findings showed that informal science activities are divided into four coherent dimensions of informal science

Table 8. Multiple-regression models predicting science competency beliefs.

Competency beliefs	6th grade			8th grade		
	Model 1 (*N* = 1142)	Model 2 (*N* = 993)	Model 3 (*N* = 580)	Model 1 (*N* = 1343)	Model 2 (*N* = 1219)	Model 3 (*N* = 828)
Informal home	0.37***	0.10**	0.09*	0.33***	0.06*	0.04
Semiformal	0.10***	0.06*	0.04	0.17***	0.12***	0.12***
Nature	0.11***	0.10***	0.12**	0.16***	0.10***	0.07*
Museum	0.14***	0.11***	0.13***	0.14***	0.12***	0.04
Fascination		0.36***	0.37***		0.32***	0.34***
Value		0.24***	0.16***		0.22***	0.15***
Scientific sense-making		0.11***	0.11**		0.14***	0.12***
Gender			−0.06			0.00
Ethnicity			−0.04			0.04
Schools			[0.07∼−0.06]			[0.01∼−0.08]
Home resources			0.00			0.12***
Family support			0.03			0.09**
Parent's education			0.11**			0.06*
$R^2$1	0.31	0.54	0.53	0.36	0.55	0.57
F-value	124.47***	165.59***	28.65***	184.21***	213.91***	50.72***
Max VIF	1.48 (InfH)	1.94 (F)	3.24 (School7)	1.59 (InfH)	2.19 (V)	2.83 (School6)

$p < .05$*, $p < .01$**, $p < .001$***.

activities: informal science activities done in the home, semiformal science activities, experiencing nature, and visiting science museums. At the macro-scale, since these measures were of cumulative prior experiences (rather than recent prior experiences), students' prior experiences cohere along these four dimensions. That is, students who tend to do one kind of science activity at home will also tend to do another kind of science activity at home, students who tend to do one kind of semiformal science activity will tend to do another kind of semiformal science activity, and so on. All the informal activities were positively correlated with one another, but the factor analyses suggested that these four dimensions were especially coherent co-occurring forms of informal activity. This finding is important both for understanding how informal science naturally occurs in the world and for studies that seek to examine the impact on students.

The causes of these coherent dimensions of informal science are not revealed by the current study and will have to be the subject of future research. The cause may be partially in the students' environment: whether certain kinds of experiences are readily available (e.g. whether the family generally goes to museums, or whether the family generally makes informal science experiences available in the home); whether friends tend to engage in certain informal science behaviours; whether the family values science in general; or whether the family has identified certain patterns of behaviour as desirable for the child. But the cause may also be in the child, especially given the growth of autonomy in middle school. That is, the student may have discovered one form of activity that s/he viewed as interesting or valuable, and thus tend to seek out similar forms of activity.

Regardless of the cause, the implication for science education research is that these stable tendencies can be measured using tools such as the ones we have created and validated in this study, and then these dimensions can be studied for their impacts (as in this study). Other studies may also construct scales about student preferences for these different dimensions of informal science (e.g. extending the work on science choice preferences by Sha et al., 2015) and examine how manipulations of student attitudes change these choice preferences.

5.2. Impacts of informal science

Building upon these new scales of informal science learning activities, our results suggest that relative amounts of those activities are associated with students' relative levels of scientific sense-making, fascination, value, and competency beliefs in both the 6th and 8th grades. Since these data are correlational and obtained at a single point in time, no strong causal claims can be drawn. Nonetheless, the multiple-regression analyses controlled for a number of likely important 3rd variable confounds (e.g. home demographics), and indeed a number of large first-order correlations disappeared when control variables were added to the regressions. Furthermore, such analyses narrow down possible independent contributions of each kind of activity with each dimension of impact. That is, when there is no significant partial correlation between an activity and an attitude, then it is unlikely that the attitude was influenced by participation in such an activity. Although theoretically possible, it is unlikely that those with low prior attitudes systematically participate in impactful informal learning experiences to produce a net zero correlation.

Another important caveat is that this study provides a look at typically occurring informal science learning activities within these two urban contexts. There are likely specific instances of informal science learning (e.g. an especially well-designed and executed science camp) that have greater impacts than the typical case. However, from a larger policy perspective, it is useful to understand the effects of typically occurring programmes if new policies are put in place encouraging more experiences without substantially changing the character of those experiences. Furthermore, these patterns of effects provide clues into the affordances of different forms of informal learning, and possibly common challenges.

A third important caveat is the reliance on students' memories for participating in informal science learning and coarse measurement of the amount and timing of such experiences. The coarse units were purposefully selected in order to not rely on precise memories of distant events, which would then be very subject to memory biases. Future studies will have to explore experience sampling techniques to further validate our instrument and to explore the effects of different temporal patterns of participation (e.g. the relative benefits of intense experiences in one summer vs. less intense experiences distributed across multiple years). Despite all of these conceptual/methodological caveats, a number of interesting patterns emerged, which we now discuss in turn, connecting back to possible affordances or weaknesses of each type of informal science learning activity.

5.2.1. Informal science at home

Participation in informal science activities at home was generally associated with higher scientific sense-making, fascination, and values. In fact, informal science activities at home were the only informal activities associated with higher fascination and values. Furthermore, there is also a positive association for 6th-grade students' competency beliefs. This suggests that families should provide more resources such as science-related books, toys, and science media at home to build knowledge about the practices and contents of science as well as grow students' positive attitudes towards science. The high levels of autonomy associated with informal science activities at home may be especially powerful for building abilities and attitudes, allowing learners to follow their diverse interests across topics and be exposed to advanced forms and purposes of science. Alternatively, it might be the pervasiveness of informal science learning (i.e. can be done year round, across many years) that is especially powerful.

5.2.2. Semiformal science activities

After adjusting for covariates, there were no general positive correlations between semiformal science activities and ability or attitudes. However, it was a positive predictor of competency beliefs in the 8th grade, and given the high importance of competency beliefs (especially for girls and under-represented minorities) for continued participation in science in high school (Fortus & Vedder-Weiss, 2014), this effect is an important positive effect. Especially worrisome, though, is the significant negative association (across all models) between semiformal science activities and scientific sense-making. Related to previous research (Vedder-Weiss & Fortus, 2012), attending too many science camps, clubs, and out-of-school activities may reduce students' interest and motivation in science, which may in turn reduce attitudes, or perhaps compete with science homework time. Future research needs to examine the character of these typically occurring activities and possible explanations (e.g. low learner autonomy potentially with weak support from adults who sometimes have low science background knowledge). Autonomy might be particularly important, as some studies suggest that a democratic science learning environment appears to prevent the commonly occurring declines in attitudes towards science (Vedder-Weiss & Fortus, 2011, 2012).

5.2.3. Engaging in nature

The three-item scale of engaging in nature was predictive of both scientific sense-making and competency beliefs. Retrospective interviews with scientists have also previously noted that early experiences in nature were often an initial step in the path towards those science careers (Sadler, Burgin, McKinney, & Ponjuan, 2010). When children explore in nature, they may observe interesting patterns, which leads to posing questions and finding solutions by themselves. Many children begin with a relatively strong interest in biology topics (Bathgate et al., 2014), and thus the kinds of science made salient by engaging in nature might connect well to that pre-existing topic of interest, but not necessarily grow overall fascination in science. And the high levels of autonomy afforded by engaging in nature may be especially useful for fostering growth in sense-making and competency beliefs.

5.2.4. Visiting science centres and zoos

Relative amount of visits to science activities/aquarium/zoo had only one significant partial correlation, which was a positive connection to 6th grade students' competency beliefs. As noted earlier, such positive effects may be very important. Why were there not larger effects? It may be the relatively short experience involved in a half or full day visit is not large enough to produce meaningful change on its own. Alternatively, the quality of those visits may vary widely by the goals of the visitors and the supporting

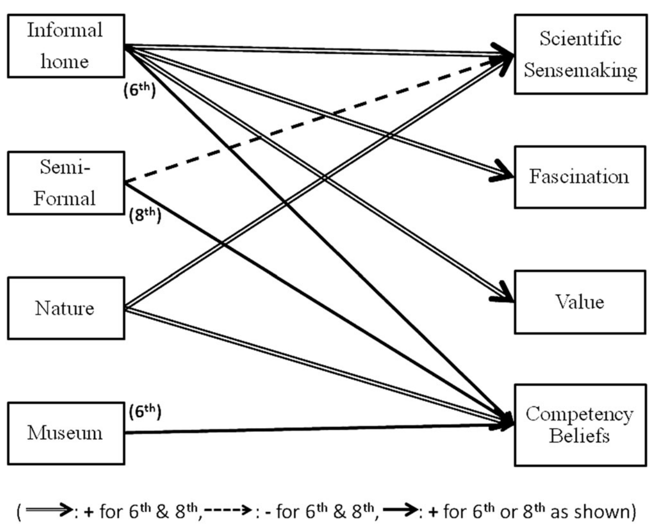

Figure 1. The relationships among 6th- and 8th-grade students' informal science learning as well as scientific sense-making, fascination, value, and competency beliefs.

behaviours of the adults accompanying the children. Considerable prior research has noted that many families visit those locations with entertainment rather than with learning goals (Behrendt & Franklin, 2014), and that the supportive talk of parents or caregivers is important for producing long-term learning effects (Fender & Crowley, 2007). Thus, there may be a large gap between what could be learned and what typically is learned.

5.3. Differences between the 6th and 8th grades

Although the pattern of significant partial correlation was generally similar across the 6th and 8th grades, there were three notable differences (see Figure 1), all connected to competency beliefs. In particular, competency beliefs appeared to be driven by informal home activities and science museum visits in the 6th grade, but by semiformal science experiences in the 8th grade. It may be that the experiences in the home activities or science museum are perceived as somewhat difficult by younger children, and thus mastery experiences in those environments produce increases in competency beliefs. But for the 8th graders, it is semiformal experiences in the older grades that are the relatively challenging experiences, and thus a source of increases in competency beliefs. Alternatively, it may be the messages given by adults in those spaces that are the source of the differences (e.g. adults giving messages of children being smart for participating in home activities and museum visits for younger children and in camp activities for older children). Such early hypotheses should be the targets of future investigations.

6. Conclusion

In this study, we collected data from a large group of 6th- and 8th-grade students in two distinct regions with different informal science learning opportunities. The surveys were focused on out-of-school science learning experiences as well as their influences on students' science-related abilities. Factor analyses revealed that there are four dimensions or factors of variation in commonly occurring informal science learning experiences: informal home science, semiformal science, nature, and museums. Follow-up analyses examined connections of these experience categories with motivational variables (fascination, value, and competency beliefs) and scientific sense-making. Most simple correlations were positive effects in both age groups as were the correlations with all of the examined demographic variables (home resources, perceived family support, and parental education). Therefore, it was important to conduct regression analyses to tease apart direct effects from indirect/confounded relationships.

The regression analyses isolated particular significant connections once confounds were addressed, and these varied by the type of experience, the type of outcome, and, to a lesser extent, the grade level. The findings suggest that there are unique benefits from students' informal science learning experiences across the different forms, reflecting their unique affordances, and that creating equitable opportunities for students to learn science will involve documenting barriers to access and broadening opportunities to all four forms.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

This work was supported by the US National Science Foundation [grant number DRL-1348468].

References

Alexander, J. M., Johnson, K. E., & Kelley, K. (2012). Longitudinal analysis of the relations between opportunities to learn about science and the development of interests related to science. *Science Education*, *96*(5), 763–786.

Bandura, A. (1993). Perceived self-efficacy in cognitive development and functioning. *Educational Psychologist*, *28*(2), 117–148.

Barron, B., Martin, C. K., Takeuchi, L., & Fithian, R. (2009). Parents as learning partners in the development of technological fluency. *The International Journal of Learning and Media*, *1*, 55–77.

Bathgate, M., Crowell, A., Schunn, C., Cannady, M., & Dorph, R. (2015). The learning benefits of being willing and able to engage in scientific argumentation. *International Journal of Science Education*, *37*(10), 1590–1612.

Bathgate, M., Schunn, C. D., & Correnti, R. J. (2014). Children's motivation towards science across contexts, manner-of-interaction, and topic. *Science Education*, *98*(2), 189–215.

Behrendt, M., & Franklin, T. (2014). A review of research on school field trips and their value in education. *International Journal of Environmental and Science Education*, *9*(3), 235–245.

Bell, P., Lewenstein, B., Shouse, A. W., & Feder, M. A. (Eds.). (2009). *Learning science in informal environments: People, places, and pursuits* (pp. 9–26). Washington, DC: National Academy Press.

Bischoff, P. J., Castendyk, D., Gallagher, H., Schaumloffel, J., & Labroo, S. (2008). A science summer camp as an effective way to recruit high school students to major in the physical sciences and science education. *International Journal of Environmental & Science Education*, *3*(3), 131–141.

Black, A. E., & Deci, E. L. (2000). The effects of instructors' autonomy support and students' autonomous motivation on learning organic chemistry: A self-determination theory perspective. *Science Education*, *84*(6), 740–756.

Braund, M., & Reiss, M. (2006). Towards a more authentic science curriculum: The contribution of out-of-school learning. *International Journal of Science Education*, *28*(12), 1373–1388.

Brown, T. (2006). CFA with equality constraints, multiple groups, and mean structures. In T. Brown (Ed.), *Confirmatory factor analysis for applied research* (pp. 236–319). New York, NY: Guildford Press.

Crowley, K., & Jacobs, M. (2002). Building islands of expertise in everyday family activity. In G. Leinhardt, K. Crowley, & K. Knutson (Eds.), *Learning conversations in museums* (pp. 333–356). Mahwah, NJ: Lawrence Erlbaum Associates.

Dabney, K. P., Tai, R. H., Almarode, J. T., Miller-Friedmann, J. L., Sonnert, G., Sadler, P. M., & Hazari, Z. (2012). Out-of-school time science activities and their association with career interest in STEM. *International Journal of Science Education*, *2*(1), 63–79.

Deci, E. L., & Ryan, R. M. (2008). Self-determination theory: A macrotheory of human motivation, development, and health. *Canadian Psychology*, *49*(3), 182–185.

Duschl, R. A., Schweingruber, H. A., & Shouse, A. E. (Eds.). (2007). *Taking science to school: Learning and teaching science in grades K-8*. Washington, DC: National Academies Press.

Eberbach, C. E., & Crowley, K. (2005). From living to virtual: Learning from museum objects. *Curator*, *48*(3), 317–338.

Fender, J. G., & Crowley, K. (2007). How parent explanation changes what children learn from everyday scientific thinking. *Journal of Applied Developmental Psychology*, *28*(3), 189–210.

Fortus, D., & Vedder-Weiss, D. (2014). Measuring students' continuing motivation for science learning. *Journal of Research in Science Teaching*, *51*(4), 497–522.

Gadermann, A. M., Guhn, M., & Zumbo, B. D. (2012). Estimating ordinal reliability for Likert-type and ordinal item response data: A conceptual, empirical, and practical guide. *Practical Assessment, Research & Evaluation*, *17*(3), 1–13.

Galton, M. (2009). Moving to secondary school: Initial encounters and their effects. *Perspectives on Education*, *2*(2009), 5–21.

Gerber, B. L., Cavallo, A. M., & Marek, E. A. (2001). Relationships among informal learning environments, teaching procedures and scientific reasoning ability. *International Journal of Science Education*, *23*(5), 535–549.

Gerbing, D. W., & Hamilton, J. G. (1996). Viability of exploratory factor analysis as a precursor to confirmatory factor analysis. *Structural Equation Modeling: A Multidisciplinary Journal*, *3*(1), 62–72.

Gibson, H. L., & Chase, C. (2002). Longitudinal impact of an inquiry-based science program on middle school students' attitudes toward science. *Science Education*, *86*(5), 693–705.

Henriksen, E. K., Jensen, F., & Sjaastad, J. (2015). The role of out-of-school experiences and targeted recruitment efforts in Norwegian science and technology Students' educational choice. *International Journal of Science Education*, *5*(3), 203–222.

Hidi, S., & Renninger, K. A. (2006). The four-phase model of interest development. *Educational Psychologist*, *41*(2), 111–127.

Hofstein, A., & Rosenfeld, S. (1996). Bridging the gap between formal and informal science learning. *Studies in Science Education*, *28*, 87–112.

Kim, K. Y., & Crowley, K. (2010). Negotiating the goal of museum inquiry: How families engineer and experiment. In M. K. Stein & L. Kucan (Eds.), *Instructional explanations in the disciplines* (pp. 51–65). New York, NY: Springer.

Knox, K. L., Moynihan, J. A., & Markowitz, D. G. (2003). Evaluation of short-term impact of a high school summer science program on students' perceived knowledge and skills. *Journal of Science Education and Technology*, *12*(4), 471–478.

Kong, X., Dabney, K. P., & Tai, R. H. (2014). The association between science summer camps and career interest in science and engineering. *International Journal of Science Education*, *4*(1), 54–65.

Lehrer, R., Schauble, L., & Petrosino, A. J. (2001). Reconsidering the role of experiment in science education. In K. Crowley, C. D. Schunn, & T. Okada (Eds.), *Designing for science: Implications from everyday, classroom, and professional settings* (pp. 251–278). Mahwah, NJ: Lawrence Erlbaum.

Maltese, A. V., & Tai, R. H. (2011). Pipeline persistence: Examining the association of educational experiences with earned degrees in STEM among US students. *Science Education*, *95*(5), 877–907.

Markowitz, D. G. (2004). Evaluation of the long-term impact of a university high school summer science program on students' interest and perceived abilities in science. *Journal of Science Education and Technology*, *13*(3), 395–407.

Meece, J. L., Wigfield, A., & Eccles, J. S. (1990). Predictors of math anxiety and its influence on young adolescents' course enrollment intentions and performance in mathematics. *Journal of Educational Psychology*, *82*(1), 60–70.

Orion, N., & Hofstein, A. (1994). Factors that influence learning during a scientific field trip in a natural environment. *Journal of Research in Science Teaching*, *31*(10), 1097–1120.

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

Paris, S. G., Yambor, K. M., & Packard, B. W. L. (1998). Hands-on biology: A museum-school-university partnership for enhancing students' interest and learning in science. *The Elementary School Journal*, *98*(3), 267–288.

Ramey-Gassert, L., & Walberg, H. J. (1994). Reexamining connections: Museums as science learning environments. *Science Education*, *78*(4), 345–363.

Renninger, K. A. (2007). Interest and motivation in informal science learning. *Commissioned Paper for Learning Science in Informal Environments Committee*. Washington, DC: Board on Science Education, The National Academies.

Revelle, W. (2014). Psych: Procedures for psychological, psychometric, and personality research. *Northwestern University, Evanston, Illinois, 165*.

Sadler, T. D., Burgin, S., McKinney, L., & Ponjuan, L. (2010). Learning science through research apprenticeships: A critical review of the literature. *Journal of Research in Science Teaching*, *47* (3), 235–256.

Sandoval, W. A. (2005). Understanding students' practical epistemologies and their influence on learning through inquiry. *Science Education*, *89*(4), 634–656.

Savolainen, R. (1993). The sense-making theory: Reviewing the interests of a user-centered approach to information seeking and use. *Information Processing & Management*, *29*(1), 13–28.

Semper, R. J. (1990). Science museums as environments for learning. *Physics Today*, *43*, 50–56.

Sha, L., Schunn, C. D., & Bathgate, M. (2015). Measuring choice to participate in optional science learning experiences during early adolescence. *Journal of Research in Science Teaching*, *52*(5), 686–709. doi:10.1002/tea.21210

Sha, L., Schunn, C. D., Bathgate, M., & Ben-Eliyahu, A. (2016). Families support their children's success in science learning by influencing interest and self-efficacy. *Journal of Research in Science Teaching*, *53*(3), 450–472. doi:10.1002/tea.21251

Sheridan, P. M., Szczepankiewicz, S. H., Mekelburg, C. R., & Schwabel, K. M. (2011). Canisius College summer science camp: Combining science and education experts to increase middle school students' interest in science. *Journal of Chemical Education*, *88*(7), 876–880.

Simpkins, S. D., Davis-Kean, P. E., & Eccles, J. S. (2006). Math and science motivation: A longitudinal examination of the links between choices and beliefs. *Developmental Psychology*, *42*(1), 70–83.

Stake, J. E., & Mares, K. R. (2005). Evaluating the impact of science-enrichment programs on adolescents' science motivation and confidence: The splashdown effect. *Journal of Research in Science Teaching*, *42*(4), 359–375.

Suter, L. E. (2016). Outside school time: An examination of science achievement and non-cognitive characteristics of 15-year olds in several countries. *International Journal of Science Education*, *38* (4), 663–687.

Tai, R. H., Liu, C. Q., Maltese, A. V., & Fan, X. (2006). Planning early for careers in science. *Science*, *312*, 1143–1144.

Uitto, A., Juuti, K., Lavonen, J., & Meisalo, V. (2006). Students' interest in biology and their out-of-school experiences. *Journal of Biology Education*, *40*(3), 124–129.

Vedder-Weiss, D., & Fortus, D. (2011). Adolescents' declining motivation to learn science: Inevitable or not? *Journal of Research in Science Teaching*, *48*(2), 199–216.

Vedder-Weiss, D., & Fortus, D. (2012). Adolescents' declining motivation to learn science: A follow-up study. *Journal of Research in Science Teaching*, *49*(9), 1057–1095.

Warren, B., Ballenger, C., Ogonowski, M., Rosebery, A. S., & Hudicourt-Barnes, J. (2001). Rethinking diversity in learning science: The logic of everyday sense-making. *Journal of Research in Science Teaching*, *38*(5), 529–552.

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