Progress in Science Education, 2017
ISSN 2405-6057
DOI.10.25321/prise.2017.521

TOWARD A MORE COMPREHENSIVE FRAMEWORK FOR INVESTIGATING NOVELTY AT OUT-OF-SCHOOL LEARNING PLACES FOR SCIENCE AND TECHNOLOGY LEARNING

Rebecca Cors[a*], Andreas Müller[b], Nicolas Robin[a], Patrick Kunz[a]

[a]University of Teacher Education, Institute for Science Teacher Education, Notkerstrasse 27, 9000 St. Gallen, Switzerland

[b]Université de Genève, Fac. des Sciences/Sect. Physique, Institut Universitaire de Formation des Enseignants (IUFE), Boulevard du Pont d'Arve 40, 1211 Genève, Switzerland

*Address all correspondence to Rebecca Cors, University of Teacher Education, Institute for Science Teacher Education, Notkerstrasse 27, 9000 St. Gallen, Switzerland. rebeccarpcv@gmail.com.

ABSTRACT
Background. Out-of-school learning places (OSLePs), such as science centers and mobile laboratories, have become an important part of science and technology education. Some studies of OSLePs demonstrate that learner feelings of unfamiliarity present barriers to achieving educational outcomes. However, investigations of unfamiliarity, or perceived novelty, at OSLePs have followed several different, somewhat unconnected theoretical frameworks and have differently defined the novelty construct.

Aims. The aim of this paper is to describe a more comprehensive framework for studying perceived novelty at OSLePs.

Approaches. Through a literature review, we systematically reviewed the sample groups, novelty factors, and educational outcomes examined in studies of novelty at OSLePs. We also discuss the findings of these studies through the lenses of two general theories of educational science: self-determination theory and Yerkes-Dodson relationships.

Results. Measures of 'novelty influence' factors found in studies of novelty at OSLePs fell into five categories: cognitive, affective, setting familiarity, social, and capability. Another set of important, but less studied, novelty factors have to do with perceived 'novelty experience,' or what learners find new or unusual during their OSLeP experience. These variables were at-visit factors such as exploratory behavior, oriented feeling, curiosity, and cognitive load. Also, some studies showed that not only too much perceived novelty, but also too little perceived novelty, has been linked to poorer educational outcomes.

Conclusions. Investigations of novelty at OSLePs can provide more meaningful results if they examine how educational outcomes relate to both novelty influence factors, such as previous knowledge, and novelty experience factors, such as at-visit exploratory behavior. Self-determination theory and the Yerkes-Dododson Law provide important ideas for designing studies and interpreting results.

Keywords. informal learning, novelty, curiosity, motivation, science education, literature review

1 INTRODUCTION

Worldwide studies are finding that youth, particularly in developed countries, have relatively negative attitudes towards science and technology careers (Bybee, 2011; Sjøberg, 2010). This comes at a time when demand for science and technology graduates is growing and importing high-tech and industry workers has become necessary in many parts of Europe (High Level Group on Increasing Human Resources for Science and Technology in Europe, 2004). The trend may also have implications for development of society, according to the Relevance of Science Education (ROSE) report: "These negative attitudes may be long lasting and in effect rather harmful to how people later in life relate to science and technology as citizens" (Sjøberg, 2010, p. 4).

Informal environments for science learning
Informal learning programs have come to be recognized as an integral part of promoting science and technology learning. Definitions of informal learning vary and researchers find it most important to recognize informal learning experiences as part of an on-going, lifelong, cumulative learning process. Researchers generally agree that informal learning is something that occurs outside of

school and some have proposed categories for different out-of-school settings (Anderson, 2012; Dorie, 2012; Eschach, 2007; Rennie, 2007). For the purposes of this paper, informal learning refers to learning that occurs outside of school in designed settings, or environments that are developed with consideration for an educational agenda, such as museums and science centers (Anderson, 2012). The places where informal learning occurs will be referred to as out-of-school learning places (OSLePs).

Over the last 20 years, OSLePs in the form of science centers and mobile laboratories have been developed to rekindle the interest of youth in science and technology topics, aiming to direct them towards related careers that support our digital age societies. However, studies conducted in Europe and the United States show that, while visits with these OSLePs sometimes result in positive development of learners' science interest, attitude and knowledge immediately after a visit, any changes tend to fade over one or two months (Barmby, 2005; Brandt, 2008; Dowell, 2011; Gassmann, 2012; Jarvis, 2005; Pawek, 2009; Sasson, 2014). These same studies point to impact factors that likely affect the degree to which learners profit from science and technology-related OSLePs, as summarized by Cors (2013). Several of these factors, such as familiarity with OSLePs and before-visit knowledge, have been explored through a 'novelty' lens.

Experiences at OSLeP can be overwhelming and even intimidating for learners, distracting them from engaging in and benefitting from these programs. Museum researchers were the first to investigate how the unfamiliarity, or novelty, of learner experiences at OSLePs relates to outcomes such as science and technology interest, attitude and subject matter learning. Anderson and Lucas (1997) hypothesized that preparation can be a key to moderating the effects of novelty on informal learning:

> "Given that science museums are, for most people, settings which induce high levels of perceived novelty, and that high levels of perceived novelty have a deleterious effect on intended cognitive learning, it would appear to be important to reduce novelty levels experienced by students especially in the initial stages of a school excursion... If familiarity with a setting and its contents has the effect of moderating high levels of perceived novelty, it seems plausible that pre-orientation … may also have the same effect" (p. 486).

Studies about classroom preparation designed to optimize novelty in order to improve learner engagement and learning during OSLeP experiences have led to development of some research models. However, the novelty factors and educational outcomes described by these models, as well as basic definitions for novelty, vary considerably. For example, Falk et al. (1978) based their investigation of how novelty affected pupils' test scores and behavior during a nature center field trip on Piaget's concepts of assimilation and accommodation. Other studies have based their approach on Orion and Hofstein's novelty space model (Orion, 1989). The novelty space model describes three pre-visit novelty factors that, when optimized, should optimize learning: previous content knowledge, familiarity with the field trip area, and previous experience with field trip events. Note that in this strand of research, `optimizing´ novelty meant minimizing (reducing) it, based on the idea that perceived familiarity by learners during an OSLePs experience promotes educational effectiveness. In another study, Anderson and Lukas (1997) proposed a theory that links curiosity, novelty and educational outcomes to guide investigation of how novelty at a science center related to learner behavior and test scores. Their approach implied, in principle, the possibility of a non-monotonous relationship between novelty and outcomes, but their study did not explore this idea.

To address the lack of coherence among existing research, Part I of the present contribution presents a more comprehensive framework for investigating novelty at OSLePs. Through a review of literature, we examine how novelty factors and educational outcomes have been defined and measured in existing studies of novelty at OSLePs. Education and psychology researchers generally agree that something novel is something unfamiliar or not yet experienced (Anderson, 1997; Berlyne, 1951; Förster, 2010; Orion, 1991b). To complement this broad definition, specific terminology for novelty constructs are needed. Based on existing research, we propose terminology to describe two different types of factors that relate to novelty in informal learning contexts. We call one type 'novelty influence factors' (NIFs), which are factors that affect learners' at-visit novelty experience. Examples of NIFs are learners' disposition, previous experience, and/or aptitude. For example, Falk et al. (1978) compared pupils who were more and less familiar with a type of field trip area (a wooded area), to see if this NIF made a difference in their post-field trip test scores. A second type of factor is perceived ´novelty experience factors' (NEFs), which indicates how a learner experiences novelty during an OSLeP visit (e.g. anxiety, curiosity, or exploration). It is based on the description of perceived novelty experience from Anderson and Lucas as "a state of mind experienced by individuals when they are exposed to, or in a context where new or unusual sensory information is received" (1997, p 486). As an example, Kubota et al. (Kubota, 1991) found that exploratory behavior at a science center, an indicator of novelty experience, or NEF, was greater for pupils who watched in an orienting video than for pupils who did not watch the video.

Other conclusions from the literature review are that most studies of novelty at OSLePs have focused on cognitive and affective educational outcomes, that hands-on skills are relevant, and that many studies have not measured the strength of the relationship between novelty and educational outcomes. In addition, there is some evidence that not only too much perceived novelty, but also too little perceived novelty, has been linked to poorer educational outcomes. This final point has not been explored by most studies about novelty at OSLePs. Given these conclusions from the literature review, our proposed framework for studying novelty at OSLePs

Given these conclusions from the literature review, our proposed framework for studying novelty at OSLePs would be incomplete without some important links two more general theories of educational science, which are discussed in Part II. The second part of this article discusses two general educational theories that investigators can employ to better understand novelty experience at OSLePs. One model, Self-Determination Theory (Deci, 1991), suggests that, depending upon their personality and on the context, people who feel more autonomous, competent, and related are more motivated to engage in an activity. How do these 'basic needs' relate to novelty at OSLePs? Another, almost unexplored, effect is how perceived novelty can both increase and decrease motivation about and engagement in learning, a phenomenon that resembles relationships which are described in the literature as Yerkes-Dodson Law or 'inverted U-shaped relationships' (Baldi, 2005). For example, how much time-on-task fosters curiosity and, after how much more time, are learners overloaded, or bored? Finally, we suggest how future studies can use the results of this analysis to investigate novelty at OSLePs.

Methods for the Literature Review

The literature review examines studies of novelty at OSLePs. The main focus was on comparing what novelty factors were investigated, how they were measured, and how these factors were related to educational outcomes. The types and measures for educational outcomes were also reviewed and attention was given to the nature of the OSLeP. Using the research databases EBSCO, ERIC, FIS (German language database), Google Scholar and Science Direct, we searched for studies of novelty at OSLePs using combinations of the following list of keywords: novelty, informal learning, science learning, technology, science center, mobile laboratory, science interest. The studies in included in the literature review are presented in chronological order, to reflect how the research has evolved over time. In the interest of comparing results, we calculated absent effect sizes when possible (Wilson, 2015). Effect sizes (Cohen *d*) were calculated according to standard procedures (Cohen, 1988) and can be interpreted using the key at the bottom of Table 1.

Part I: Summary of studies about novelty at OSLePs

Since the 1970s, a handful of studies have explored how novelty at OSLePs relates to learners' at-visit behavior and to cognitive and affective outcomes. Table 1 provides a summary of studies included in the literature review. The table lists author names, the study sample size and subject ages, the novelty factors identified, and results for educational outcomes. A description of each study and a comparative discussion follows.

Progress in Science Education, 2017
ISSN 2405-6057
DOI.10.25321/prise.2017.521

Table 1: Summary of studies about novelty at out-of-school learning places (OSLePs).

Authors	N	Novelty Factors	Learners' cognitive, affective and behavioral outcomes
Falk et al., 1978	31 (20 girls) pupils who visited nature center in Maryland, ages 10-13	✓ Familiarity with wooded settings. *Note: Data confirmed knowledge of wooded setting was greater (p<.05) for Familiar group (TG) than Unfamiliar group.*	COGNITIVE: Test score improvements about foliage greater for Familiar than Unfamiliar group ($p<.05$). AFFECTIVE/ BEHAVIORAL: Unfamiliar group was rowdier, expressing more fears; less attentive to learning task than Familiar group.
Falk and Balling 1982	196 3rd (46 girls) and 5th (44 girls) graders in mid-Atlantic US	*TG: studied biology of trees at a nature center (@NC)* *CG: did same activity at woods next to school (@SCH)*	COGNITIVE: Knowledge gain means showed grade x location interaction: Gr5@NC > Gr3@SCH > Gr3@NC > Gr5@SCH. BEHAVIORAL: Gr3@SCH and Gr5@NC more on-task. AFFECTIVE: no significant differences between TG, CG.
Kubota and Olstad 1991	64 Seattle pupils (32 girls) at Pacific Science Center Science Playground, sixth grade (ages 11-13)	✓ Familiarity with interactive exhibits. *Compared pupils who watched orienting video about exhibits (VE=vicarious exposure (TG)) with not (P=placebo).*	COGNITIVE: VE boys scored better than P boys, VE girls, P girls ($p<.02$). VE test scores strongly linked to exploratory behavior ($r=0.56$, $d=1.3$). BEHAVIORAL: VE group exhibited more on-task exploratory behavior than the P group ($p<.001$, $d=1.0$), particularly VE boys ($p<.001$).
Orion and Hofstein 1991	296 geography pupils in Israel, classes 9-11	3 factors explain 22% of pupil attitude to learning: ✓ Content familiarity (cognitive) 10% ✓ Field trip seen as adventure versus learning (psychologic) 9% ✓ Geographic x-section (geographic) 3% *Intervention: different classroom preparations*	COGNITIVE: Pupils with a more complete preparation scored slightly better on rock identification test ($d=0.36$, $p=.002$) and on field trip science phenomena test ($d=0.29$, $p=.01$). AFFECTIVE: Slightly more pupils with a more complete preparation saw the field trip as a 'learning tool' ($d=0.29$, $p=.01$) that is for their 'individualized learning' ($d=0.36$, $p=.002$).
Anderson and Lukas 1997	75 (29 girls) pupils visiting Queensland Science Center, grade 8	✓ Pre-visit orientation (*treatment*) ✓ Previous visits to Center *TG: experienced pre-visit orientation.*	COGNITIVE: Pupils with pre-visit orientation ($p<.05$) and/or previously visited the Center ($p<.01$) scored moderately (both $d=0.5$) better on a science concepts knowledge post-visit test.
Jarvis and Pell 2005	300 pupils, ages 10-11, visiting the UK National Space Center	✓ Teacher attitude ✓ Classroom preparation for skills, schedule, roles, 'learning day,' content ✓ Interest of a parent, sibling	AFFECTIVE: More thorough prep & follow-up, positive teacher attitude related to 1) higher science enthusiasm scores that do not fade and 2) decreased anxiety that does not climb after the visit.
Cotton and Cotton 2009	37 undergraduate students, marine biology field course, South Africa	✓ Cognitive, psychological, geographical, social aspects of novelty. *TG: Watched new CD for preparation.*	AFFECTIVE: Students who used novelty-optimizing CD preparation found support materials more useful & had fewer difficulties adjusting to field trip environment. Cognitive, psychological, geographical, social aspects of novelty linked to learning.
Cors et al., 2014	208 (97 girls) pupils at a mobile laboratory, Switzerland, ages 12-16	✓ Technological capability ✓ Setting familiarity ✓ Content knowledge *TG: Treatment teachers received additional preparation materials.*	AFFECTIVE: Technological capability predicted positive changes in interest, attitude, self-concept to technology ($\eta_p^2=.05$). Also, longer classroom preparation predicted positive changes in affective outcomes for natural science ($\eta_p^2=.03$). Teacher interviews: familiarity with equipment supports learning.

TG: treatment group. NOTE: Conversion of r to d according to usual formula (cohen, 1988). The size of significant differences can be interpreted by Cohen's (1988) guidelines for effect siz. For t-test results: small ($d=0.2$), medium ($d=0.5$), large ($d=0.8$); for multivariate results: small ($\eta_p^2=.01$), medium ($\eta_p^2=.06$), large (($\eta_p^2=.14$).

Progress in Science Education, 2017
ISSN 2405-6057
DOI.10.25321/prise.2017.521

Early studies focused on novelty and exploratory behavior

Novelty of OSLeP settings has been described as something overwhelming or disconcerting, something that learners need to overcome. For example, Falk et al. (1978) conducted an experiment to test their hypothesis that "a person's ability to attend to a structured learning task in a novel setting improves with time because behaviors interfering with such learning decrease with time spent in the setting" (p. 128). The guiding model for their work was Piaget's concept of adaptation through assimilation and accommodation. That is, investigators describe how when a "setting is completely novel, a greater disequilibrium may occur, necessitating greater accommodation to the new information and the formation of entirely new structures before the learner reaches a state of relative equilibrium" (p. 128). Falk and Dierking (1978) explain that this process of adjustment occupies cognitive processes of the learner, distracting them from learning tasks. This adaptation process interferes with learning, so a person's ability to engage in a structured learning activity improves with time, as adjustment progresses. Similarly, educational psychologists describe the free exploration of novel, complex, unfamiliar environments, particularly without proper preparation or structure, as something that may generate a heavy working memory load that hinders learning (Kirschner, 2006). Educational strategies designed to "ensure that learners' working memory is not overloaded," are called cognitive load theory (CLT)-based instruction (Paas, 2010, p. 117) . De Jong (de Jong, 2009) explains what cognitive load is and how it has become important to educational researchers:

> "Cognitive load is a theoretical notion with an increasingly central role in the educational research literature. The basic idea of cognitive load theory is that cognitive capacity in working memory is limited, so that if a learning task requires too much capacity, learning will be hampered. The recommended remedy is to design instructional systems that optimize the use of working memory capacity and avoid cognitive overload" (p. 105).

Falk et al.'s study (1978) involved pupils who visited Maryland's Chesapeake Bay Center for Environmental Studies and participated in a half-day experience measuring foliage height diversity, an activity designed to increase understanding of ecosystem succession. Based on where they lived, researchers assumed that two of the four groups of pupils were more familiar with wooded settings than the other two groups. Data confirmed that the 'familiar' group was significantly more familiar with the characteristics of a wooded setting than the 'unfamiliar' group. The familiar pupils' scores increased significantly more between a pre- and post-test than the unfamiliar pupils' scores on three test questions about foliage height. Based on observations, investigators suggest that this was due to greater attention to the learning task by the familiar group. In contrast, the unfamiliar group "tended to spend more time in behaviors not related to the actual activity. The time difference, however, failed significance…" (p. 132). That is, observers reported that unfamiliar pupil groups were more 'rowdy' and teasing, spent less time on the field trip task and made more negative comments, mostly complaints about having to move off of the main trail and fears about snakes and poison ivy. Observations also show that the unfamiliar pupils gave warnings about poison ivy when it was not present, whereas the familiar pupils issued warnings when they saw the plant. Researchers remark that "perhaps significantly, the interfering behaviors seem to be more emotional in tone than cognitive" (p. 133). Falk and his team concluded that if pupils find a setting very novel, they first need to explore to become more familiar before they can concentrate on their assignments. They suggest that further research focus on better understanding pupils' experience with the OSLeP environments to leverage novelty in a way that augments learning:

> "Novelty, and the very powerful needs for exploration it generates, is an extremely important educational variable. The challenge for educators is to harness this variable to enhance rather than hinder our educational objectives. It is important to understand what is producing uncertainty and exploratory drives on the part of the child so that we can both stimulate it when useful and assuage it when necessary. The novel field-trip phenomenon should not be considered as a negative behavior to be overcome before "real" learning can occur, but rather as a dialogue between the child and his environment- something to understand and capitalize upon" (p. 133).

Similar results were found through a study of sixth-grade public school pupils, who participated in science museum field trips to the Pacific Science Center Playground, Seattle, where exhibits are designed for hands-on activity (Kubota, 1991). These investigators also framed their ideas about novelty in relation to exploratory behavior, explicitly referring to the definition from Berlyne (1960) of two types of exploratory behavior:

> "The purpose of specific exploration is to reduce uncertainty produced by a particular, novel stimulus. In a scientific museum this might be a particular object or exhibit. On the other hand, the purpose of diversive exploration has been seen as an effort to reduce the uncertainty of a novel environment. For example, in a science museum, diversive exploration reduced the uncertainty of the entire exhibit hall by providing orientation to the elements within that environment" (p. 226).

Vicarious Exposure group pupils (VE) experienced a novelty-reducing preparation in the form of a slide/tape presentation. The presentation showed children stating frequent questions and comments, including orienting remarks about the location of objects, and 'how-to' remarks such as, "You have to be careful when..." Placebo group pupils (P) watched a slide/tape presentation about exhibits at another venue at the Pacific Science Center. Exploratory behavior was measured as number of seconds in meaningful interaction with an exhibit and knowledge was measured through a post-test about the physical sciences. Results for exploratory behavior and for the knowledge test showed the same pattern: VE boys outscored all other pupils in the study, and P boys scored the lowest, whereas girls' scores from the two groups were not significantly different. Based on a correlation analysis, investigators suggest that VE pupils have more positive outcomes because they spend more time with on-task behaviors. That is, while correlation between exploratory behavior and test scores for all subjects was quite low (r=0.32), the VE group correlation coefficient (r=0.56) was higher that of the P group (r=0.07). The authors conclude that,

> "Reducing the novelty of the site apparently had the desired orienting effect upon the students in the VE group. Diversive exploration which normally occurs during the orientation period was minimized and the on-task exploration rose, resulting in high exploratory behavior scores. With greater time spent gathering information cognitive scores also increased. On the other hand, the placebo group's low correlation coefficient indicates little correlation between exploratory behavior and cognitive learning." (p. 231)

Regarding the group by gender interaction, the authors speculate sex-role socialization and/or gender-specific explorative tendencies were at play.

Novelty of place

By comparing learning by pupils at a nature center with learning by other pupils experiencing the same lesson in a wooded area near their school, Falk and Balling (Falk, 1982) found evidence that setting affected learning. Like many other studies, evidence showed that too much novelty was overwhelming for learners. However, findings also showed that too little novelty lead to behavior that suggested pupils were bored. The study involved 196 pupils from two suburban schools in the mid-Atlantic area of the U.S. Participants were in 3rd (46 girls, 52 boys) and 5th (44 girls; 54 boys) grades and were studying the biology of trees. One class from each grade level went on a field trip to a nature center to collect and discuss tree data and the other class conducted the same activity at a wooded area next to their school. Each participant completed a pre-visit survey, four weeks before the activity, and post-visit surveys, one the day after the field trip and again one month later. Observers recorded the behavior of each pair of pupils during data collection, noting where their attention was directed. Results indicate a significant knowledge gain for all pupils from before to after the field trip, or from pre- to post-test, $t(195)=23.00$, $p<.001$. Comparing mean score improvements from pre- to post- test showed that knowledge gain for the 5th grade students at the nature center was greatest, albeit not significantly so. The order of mean change in scores, from greatest to least, was: 5th grade at nature center > 3rd grate at school > 3rd grade at nature center > 5th grade at school. For long-term knowledge gain, or pre- to second post-test, there was just one significant effect. That is, 5th grade girls who visited the nature center retained more knowledge content than any other group of pupils, shown through an interaction of sex by grade by location, $F(1,176) = 6.24$, $p < .025$. Analysis of behavioral data showed that that 3rd grade pupils spent significantly more time in on-task behaviors at the woods next to their school than their 3rd grade peers at the nature center, and 5th graders were moderately more on-task when working at the nature center, $x^2=(1)13.47$, $p<.001$, $d=0.5$. The authors conclude that "this result tends to confirm the hypothesis that the environment itself was influencing behavior or the ability with which children could allocate their attention to the learning task. The fact that the locations in which 'attending to setting' was high were different for the two age groups, suggested that the older and younger children were responding differently to the environment" (p. 26). They also pointed out how behavioral data mirrored results from test scores. Data from attitude items on the survey showed some differences between grade levels with regard to knowledge recall and enjoyment, but there were no significant differences between the groups that depended upon setting.

Investigators noticed that there were two different types of off-task behavior and that "simply dividing behavior into 'on-task' and 'off-task' components is insufficient for a clear understanding of children's behavior or their underlying motivations" (1982, p. 27). To interpret the differences in exploratory behavior of and learning by pupils, they employed an inverted-U, as shown in Figure 1. The 5th grade group working outside of school, Group A on the graph, exhibited off-task behavior that investigators described as looking around for something more stimulating, that of people who are bored. This group also showed a relatively low improvement in content learning. The other 5th grade group, who was at the nature center, Group C, showed the greatest improved score on a content test and exhibited the lowest level of off-task behavior. Also with relatively high content gains and low off-task behavior was Group B, 3rd graders at the school. The other group of 3rd graders had smaller test score improvements and more off-task behavior. Falk and Balling likened the behavior of Group D pupils, that of affiliating more closely with one another and/or expressing a need to know where one another are, as typical of groups in an uncomfortably novel situation.

The explain that, "…the best way to integrate these data is to suggest a curvilinear model…. That hypothesizes task learning and off-task behaviors as inverse functions both of which are influenced by their setting novelty" (p. 27).

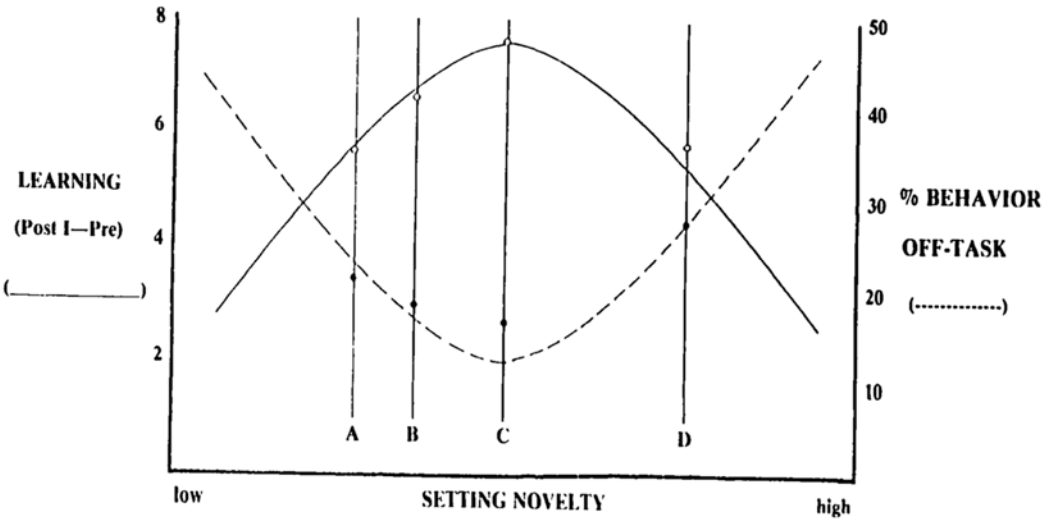

Figure 1: Early work by Falk and Balling (1982) suggests an 'inverted-U' relation between learning, behavior at out-of-school learning places, and setting novelty.

Orion and Hofstein's 'novelty space' model

Based in part on the work of Falk et al. (1978), Orion proposed that three factors define pupils' 'novelty space' for a field trip (Orion, 1989). The main hypothesis (Figure 2) was that pupils' field trip experience will be more productive if they have more relevant previous knowledge (*cognitive* aspect), feel more familiar with the field trip area (*geographic* aspect), and have a more Appropriate attitude to field trips (*affective* aspect[1]).

Orion describes the importance of preparation to optimize novelty space:

> "The idea of 'novelty space' emphasizes the importance of adequate preparation for a field trip, which will reduce the novelty space to a minimum and thus facilitate meaningful learning during the field trip" (Orion, 1993, p. 326).

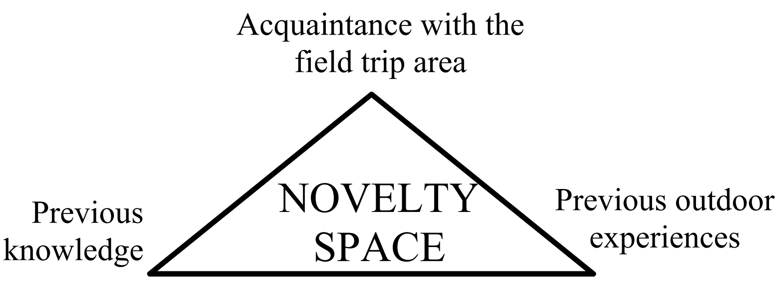

Figure 2: Orion's 'novelty space' model suggests the field trip experience depends upon previous knowledge, acquaintance with the field trip area, and previous field trip event experience (Orion 1989).

Orion and Hofstein tested how these three novelty space factors, teacher factors and field trip factors affected pupils' knowledge gains and their attitudes towards field trips and towards geology (Orion, 1991a, 1994). Geology pupils in grades 9 to 11, experienced either an OptimalConcrete Preparation (OCP) of 10 hours of cognitive, geographic and psychological preparation; a Minimal Concrete Preparation (MCP) of 4 hours of only (cognitive) rock and soil Identification activity; or no novelty-reducing preparation (0 hours), called Traditional Frontal Preparation (TFP). A content knowledge test was administered during the last classroom preparation lesson and once several days after the field trip. Pupils also completed inventories about their attitude towards field trips in general and towards geology several days before and after the field trip. They completed a questionnaire about their attitude towards the geology field trip several days after the field trip. Data was also collected through pupil interviews, observations, and teachers' post-field trip reports about preparation, the field trip experience, and speculation about how the field trip experience influenced pupils' affective and cognitive learning.

Data from teacher reports suggested that preparation and place of the field trip in the curriculum were important factors for success on assignments during the field trip and post-trip knowledge tests and assignments. Data from questionnaires and tests, supported by observational data, showed that a better preparation related to significantly better post-trip knowledge test performance and also more positive post-trip attitudes. That is, significantly more OCP pupils than TFP pupils saw the field trip as a 'learning tool' that is 'for their individualized learning.' However, when one calculates the strength of these relations, they are small (d=0.29 and d=0.36, respectively; N=296). And OCP pupils scored significantly better than TFP pupil on rock identification and questions related to field trip phenomena, again with small effect sizes (d=0.36 and d=0.29 respectively; N=296). It is worth noting that while OCP pupils showed better test performance and more positive attitudes toward the field trip, they did not differ significantly from the TFP group in their attitude towards the discipline of geology, measured through survey items about its difficulty, their interest and its importance.

explained about one-5th of the variation in pupils' attitude towards their learning experience during the field trip. A closer look the individual novelty influence factors, described as 'pre field trip variables' (p. 1115), clarifies their relation to the dependent variable.
The cognitive novelty factor referred to which preparation pupils experienced, which reflected "the type of knowledge the student acquires before the field trip, … related to students' cognitive readiness for the event" (p. 1116). This cognitive factor explained ten percent of differences in pupils' attitudes. The geographic impact factor, differences in OCP and TFP pupil scores on drawing a geographic cross section of the field trip area, explained three percent of variations in pupil's attitudes. The affective ('psychologic') impact factor[1] was defined as whether pupils viewed the field trip as a 'social-adventurous event' or a 'learning activity.' Differences in pupils' view of the purpose of the field trip explained nine percent of the variation in their attitudes. Investigators concluded that "Preparation that deals with the three novelty factors can reduce the novelty space to a minimum, thus facilitating meaningful learning during the field trip." (p. 1117) and give examples for classroom activities that are useful for optimizing each novelty space factor.

Novelty and curiosity

Based on ideas from Falk (1982) and Berlyne (1960), Anderson and Lucas (1997) hypothesized that too little or too much novelty would not produce the appropriate amount of curiosity behavior and exploratory behavior needed for learning from a science center visit. They illustrated their theory about the relations between novelty, curiosity, and learning in a diagram, shown as Figure 3. They define curiosity in the OSLeP context as "a stimulus to explore, manipulate and interact with the environment, which is generated by the individual's feelings of perceived novelty." They explain that "Low levels of perceived novelty result in low levels of curiosity behaviour and low levels of on-task behaviour, which are likely to result in potentially low levels of learning. Very high levels of perceived novelty result in high levels of exploration and setting information gathering, which take precedence over on-task, institutionally intended learning, and this is likely to result in low levels of learning" (p. 486).

[1]Orion (1991) and later studies about novelty space use the term 'psychologic' or 'psychological' to describe learner characteristics such as attitudes towards a field trip or apprehension and tiredness, which have to do with emotion. We instead use the term `affective´ to describe these learner characteristics, because it is more in line with established terminology.

Progress in Science Education, 2017
ISSN 2405-6057
DOI.10.25321/prise.2017.521

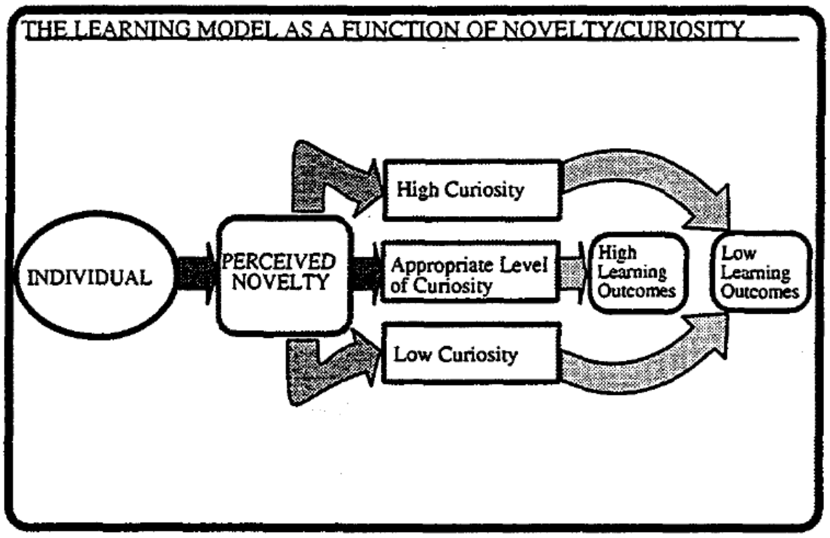

Figure 3: Hypothesized relations between perceived novelty, curiosity and educational outcomes from Anderson and Lucas (1997).

This hypothesis from Anderson and Lukas (1997) introduced novelty as something that, at the right level, can be attractive and appealing to learners, something central to models about interest development in learning environments. That is, Krapp's person-object theory of interest development (POI) (Krapp, 1999) and Hidi and Renninger's Four-Phase Model of Interest Development (Hidi, 2006) describe interest development as something that occurs through interactions between a person and the object of potential interest. The development of enduring dispositional interest occurs when situation interest is triggered by some appealingly novel aspect of the object and lasts for long enough to become internalized. Developed to pique people's curiosity and then engage them in an activity, OLSePs are designed support this 'catch-hold' process (Priemer, 2014).

Anderson and Lucas (1997) tested their theory about novelty and curiosity behavior at OSLePs with 75 grade 8 pupils visiting the Queensland Science Center, Brisbane, Australia. The study was based on the premise that museums introduce high levels of perceived novelty, which "result in high levels of exploration and setting information gathering, which take precedence over on-task, institutionally intended learning" (p. 486). About half of the pupils experienced a Pre-orientation program of slides and descriptions of the science center, exhibits, and visit schedule, whereas the remaining no-orientation pupils viewed a video about another science center. An analysis of variance test showed significantly better performance on test questions about science concepts by pre-orientation pupils, pupils who had previously visited the science center; Pre-orientation pupils who had previously visited the science center performed better than other groups. The strength of these relations is reported as medium, with effect sizes a "little in excess of 0.5" (p. 489). Even though their main findings do not support their thesis about links between novelty, curiosity and learning, they suggest that better test scores from pupils who found exhibits memorable reflect an effect of novelty as an appealing factor.

Teachers' attitude and quality of preparation

Harnessing novelty to promote learning at OSLePs depends in large part on well-designed preparation, and it is here where teachers play an important role. In a study about pupils visiting a science center, Jarvis and Pell (2005) found evidence of this influence of classroom preparation and teacher attitudes on pupils' attitudes about science. The study involved a pupil pre-visit survey and three post-visit surveys; observations of teachers, pupils and assisting adults; and teacher and pupil interviews

Jarvis et al. (2005, p. 74) developed a teacher typology in order to compare pupil groups (Figure 4). An example of a Type 1 teacher's "very good" preparation involved watching a video about the sun and moon, practicing skills including using a compass for navigation, choosing the role they would play in the space ship simulation, direction that the visit 'wasn't a fun day, it was a learning day,' and discussion of what they could expect during the visit. Pupils also received structured at-visit and after-visit assignments. Type 2 teachers varied in the amount of time they devoted to preparation and/or follow-up, either because of poor planning or due to time constraints. Classes with Type 3 teachers had less personal enthusiasm for the space center and sometimes a focus on national standard assessment tasks. Through a cluster analysis, investigators identified evidence of a 'teacher effect:'

Progress in Science Education, 2017
ISSN 2405-6057
DOI.10.25321/prise.2017.521

Teacher Type 1. These classes started with high means for science enthusiasm (before the space center visit) and had consistently high means for science enthusiasm. Variation in science enthusiasm after the visit was insignificant, and scores remained high after 5 months

Teacher Type 2. These classes started with fairly low enthusiasm for science, but this increased significantly after the visit (effect size=0.44 with p<0.01, paired t-test). Mean scores were still significantly elevated after 2 months.

Teach Type 3. Classes with low mean pre-visit enthusiasm scores, which remained at a low level or declined over the 5 months without any apparent effect due to the visit.

Figure 4: Descriptions of three teacher types that Jarvis and Pell identified and related to pupils' science enthusiasm during a visit to space center (adapted from Jarvis and Pell, 2005, p. 73).

Jarvis and Pell (2005, p. 73) report that at least one Type I teacher's class showed a "noticeable decline in anxiety levels" during the 5-month study, while exemplar Type 2 and Type 3 classes reported some increases in anxiety, measured as the degree to which pupils worry about schoolwork being difficult, being wrong, or being alone in school. Jarvis and Pell note that the Type 1 preparation addressed all three novelty space factors:

> "The children had been acquainted with the trip area and introduced to initial skills and knowledge beforehand. They were also ''psychologically'' prepared by being given an expectation that the visit would be a learning experience. "Consequently," investigators explain, "these three "novelty space'' factors that can inhibit learning, identified by Orion and Hofstein (1994), were addressed" (p. 79).

Investigators conclude that "teachers' personal interest, preparation, action during the visit, and follow-up were important factors in influencing children's short- and long-term attitudes {towards science}" (p.77). Pupil interviews revealed that pupils' attitudes towards science were also shaped by reading science books at home and watching science television programs, especially with parents or grandparents.

The social aspect of novelty

Cotton and Cotton (2009) explored the social aspect of novelty, along with Orion and Hofstein's three novelty space factors (1994), for British university students on a field trip in South Africa, using videos, audio-diaries, field logs and a post-course questionnaire. Students identified cognitive aspects of novelty, which they reported distracted them from learning: unfamiliar scientific names, new math and statistics concepts, and conflicting views from tutors. Affective novelty aspects[1], such as apprehension and tiredness mostly having to do with uncomfortable accommodation, were described as factors that "may influence {students'} ability to engage with the curriculum. Students who are feeling tired, hungry or ill are unlikely to be working at their best" (p 171). The social aspect of novelty was defined as the impact of personal relationships on the field trip experience. Investigators noted that the social aspects of the field trip "encompassed the widest range of positive and negative responses" (p. 172). For example, the opportunity of getting to know other students and lecturers was seen as positive, while homesickness and working with others could be frustrating. Investigators conclude that "there is also clear evidence, in the accounts of group work and of their relationship with lecturers, of the impact of social relationships on learning in this context" (p 172). Similarly, Falk and Dierking (Falk, 2011) bring together results from a number of studies that show that novelty of place seems to cause anxious and nervous behavior in children, and suggest that social interaction can attenuate these feelings.

For this study, Cotton and Cotton (2009) also surveyed students about the effectiveness of a novelty-optimizing preparation in the form of a CD (compact disk). By comparing extreme groups who responded with 'strongly agree' or 'strongly disagree,' they concluded that those students who used the CD found materials more useful and adjusted more easily to field trip conditions. However, lack of data about the less extreme groups, and apparent arbitrary cut-off choices for groupings, does not allow the reader to generalize these extreme results to all students, limiting the meaningfulness of the comparison.

Novelty at a technology-related OSLeP

Recently, Cors et al. (2015) investigated how classroom preparation for a mobile laboratory visit, pupils' novelty influence factors, and teacher attitudes related to pupils' educational outcomes, measured as their interest in, attitude to and self-concept to science and technology (S&T). Based on a background investigation of the mobiLLab program (Cors 2013), investigators identified three novelty influence factors: 1) previous knowledge, a cognitive impact factor, measured as pupils' grades, 2) a setting familiarity factor measured as pupils' previous experiences at OSLePs; and 3) a technological capability factor that indicated whether pupils tended to explore and tinker, or to seek direction and support, when interacting with technology. The technological capability novelty influence factor became part of the research design in response to interviews with mobiLLab program faculty and staff. They explained that a core goal of the program is to promote pupils' positive attitudes towards science experimentation using technology. They provide teachers with materials for a classroom preparation that should give pupils a sense of familiarity with mobiLLab experimental equipment and procedures before their visit. The technological capability construct used in the mobiLLab study is based on the capabilities dimension of technological literacy measured by Luckay and Collier-Reed's *Technological Profile Inventory* (TPI) (Luckay, 2011).

The study involved nine teachers and their pupils (N=208), who completed pre- and post-visit surveys. Investigators also observed mobiLLab school visits and conducted teacher interviews. Results of a multivariate analysis of covariance (MANCOVA) showed that two factors, technological capability and length of preparation, explained variations in learning. That is, pupils who saw themselves as more technologically capable reported significantly more positive changes in their educational outcomes related to technology, F (3,197)=3.37, p=.020, η_p^2 =.05. And, pupils who experienced longer preparation times reported more positive changes in their educational outcomes related to natural science, F (3,192)=3.085, p=.029, η_p^2 =.05. The theme of technological capability also surfaced in teacher interviews, where several teachers described how pupils need to lose their nervousness about using equipment, so that they could better engage in the mobiLLab experience. The mobiLLab research-faculty team recommended a future investigation explore both pupils' (dispositional) technological capability and at-visit comfort level with mobiLLab experimental equipment.

Conclusions from the literature review about novelty at OSLePs

Findings from these eight studies, which include four studies with samples sizes of about 200 and above, demonstrate that optimized novelty relates to positive educational outcomes at OSLePs. Referring back to the summary matrix of study parameters (Table 1), allows for further comparisons. From this literature review, we draw several conclusions about investigations of novelty at OSLePs: cognitive and affective educational outcomes are most interesting to researchers; hands-on skills relate to more positive educational outcomes; too much novelty overwhelms learners, while too little novelty potentially bores them; and many studies have not measured the strength of the relationship between novelty and learning outcomes. Drawing on the work of these studies, we derive a comprehensive list of novelty influence factors (NIFs) that have been related to educational outcomes. We also propose a list of novelty experience factors (NEFs), which would shed light on learner motivation and behavior and how it relates to NIFs and educational outcomes.

Cognitive and affective educational outcomes. Educational outcomes explored by these studies included greater enthusiasm, reduced anxiety, better test scores, more positive science and technology attitudes, more time-on-task and exploratory behavior, and improvements in learning and attitudes about science and technology. The more recent studies included in the literature review investigated primarily affective outcomes. This reflects how researchers and educators recognize OSLeP visits as one-off, transient events that are primarily meant to spark interest in science and contribute to learning content over time in combination with other programs, rather than as tool for focused content instruction (R. Cors, 2013; Rennie, 2007; Tran, 2011). This was demonstrated by a recent study of involving 1773 pupils at a Science Center Outreach Lab (SCOL), which showed that the science center offered no significant advantage over classroom instruction for gains in content knowledge (Itzek-Greulich, 2015). The authors of the study speculate that, at out-of-school learning events, "student's attention is often drawn to specific features of the learning environment rather than the learning material itself" and that this novelty could have produced a greater learner cognitive load that hindered learning (2015, p. 49).

Hands-on skills. The same study showed that learners in the OSLeP environment had better 'Experimental Specific Knowledge' test scores than those who experience only classroom instruction (Itzek-Greulich, 2015), indicating the former acquired experimentation skills. This echoes findings from the two studies in this literature review that linked learners' hands-on skills to more positive affective educational outcomes. That is, Jarvis and Pell described how pupils who experienced an optimal preparation, which involved "practicing skills using compasses and coordinates as a basis for the navigation activities," reported steadily decreasing anxiety scores (2005, 74). Similarly, Cors et al. (2015) found that a dispositional tendency to tinker, rather than seek support, to interact with technology related to more positive interest in, attitude to, and self-concept related to technology: "Most striking is the strong link (large MANCOVA effect) identified between pupils' tendency to explore technology and their S&T outcomes" (p. 56). This was supported by interviews with teachers, who explained how, for pupils to profit from the mobiLLab experience, it was important for them to become comfortable with experimental equipment.

Too much or too little novelty can be problematic. Evidence from all studies included in the literature review showed that when learner perceive less novelty, or feelings of greater familiarity, their educational outcomes are more positive. However, findings from Falk and Balling's study (1982), also linked too little novelty to boredom and stimulation-seeking behaviors, and to more negative educational outcomes. No theory about novelty at OSLePs has addressed this idea that too much *and* too little perceived novelty are problematic. This idea that novelty have negative effects when too great or too little, suggests that pre-visit activities developed to familiarize learners with OSLeP settings should be described as 'novelty-optimizing' rather than 'novelty-reducing.' We try to exemplify this language shift in this article.

Another observation is that *the strength of the effect* from novelty-optimizing strategies on educational outcomes in these studies is not always clear. That is, while six of the studies showed statistically significant results, effect sizes (or data to calculate them) were often unavailable.

The literature review also shows that studies have focused on *five types of novelty impact factors (NIFs)*. Table 2 shows in the left-hand column our proposed categories for these factors that influence learners' novelty experience, listing in the right-hand column descriptions of how various studies have measured each. For a Cognitive impact factor, studies assessed pupils' relevant content knowledge through grades and tests. For an Affective impact factor[1], studies measured pupils' attitudes, particularly whether they expected a learning experience or fun and adventure, and their emotions, such as anxiety about doing things right. Some studies employed a Setting familiarity factor to

describe how much practical knowledge learners had for navigating the OSLeP. It is worth noting that the geographic cross-section test score from Orion and Hofstein's study (1991) could be a categorized as a Cognitive factor, indicating how well pupils knew the content relevant to the field trip, or a Setting familiarity factor, indicating how prepared they were to navigate the landscape. Similarly, on could categorize Falk and Dierking's (1978) test score about a wooded setting as previous content knowledge or as a gage of familiarity with the setting. Through interviews and student diaries, Cotton and Cotton (2009) identified aspects of a Social impact factor, which they define as the impact of personal relationships on learners' field trip experience. For a Capabilities impact factor, Cors et al. (2015) identified links between pupils' dispositional comfort with technology and their at-visit comfort with experimental equipment, and also between their dispositional comfort with technology and their affective outcomes related to technology; Jarvis and Pell (2005) described skills training as part of optimal preparation that supported learning.

Table 2: Studies have identified five types of novelty impact factors (NIFs) that affect learners' novelty experience at OSLePs

Novelty factor category	How studies defined and measured novelty impact factors
Cognitive	*Previous content knowledge* – Knowledge test about core content of a given OSLeP, such as o Wooded setting characteristics test score (Falk, 1978) o Geology-related science phenomena test score (Orion, 1991a) o Geographic cross-section test score (Orion, 1991a) – Math and science grades (Cors, 2015)
Affective	*Attitudes about and impressions of OSLeP experience* – Purpose of field trip: learning versus social-adventure (Orion, 1991a) – Apprehension and tiredness mostly having to do with uncomfortable accommodation (Cotton, 2009)

Novelty factor category	How studies defined and measured novelty impact factors
Setting familiarity	*Practical knowledge for navigating OSLeP* – Whether learner experienced pre-visit orientation (Anderson, 1997; Jarvis, 2005; Kubota, 1991; Orion, 1991a) – Whether learner previously visited that or similar OSLePs (Anderson, 1997; Cors, 2015; Falk, 1978) – Wooded setting characteristics test score (Falk, 1978) – Geographic cross-section test score (Orion, 1991a)
Social	*Impact of personal relationships on learner experience (Cotton and Cotton, 2009)* – Homesickness, adjusting to close company – Experiences with group work – Building closer relationships with lecturers
Capabilities	*Ability to work with OSLeP objects/ activities* – Skills using compasses, coordinates for navigation activities (Jarvis, 2005) – Technological capability: tendency to explore technology, rather than seek direction when working with technology (Cors, 2015)

These five novelty factors that affect educational effects at OSLePs according to existing research can be compared with independent variables studied by the broader informal learning research community by referring to Falk and Dierking's (Falk, 2000) Contextual Model of Learning (CML) framework, described in Table 3. The CML includes twelve critical factors that are categorized into one of the three contexts. It is a holistic framework that emphasizes how these contexts overlap and interact over time. Cognitive, Affective, and Capability novelty factors are individual variables that fit into the Personal Context category of CML. Setting familiarity belongs to the Physical Context and is similar to the 'Orientation to the physical space' factor. And the Social novelty factors match the Sociocultural Context.

We see a twofold advantage to linking various conceptualizations of and results about of novelty as a key factor of OSLePs to the general framework of the Contextual Model of Learning: (a) Conceptual parsimony and coherence; as the literature review and the discussion above revealed, novelty at OSLePs can well be captured by five NIFs, which in turn are closely related to the three larger contexts of the CML. (b) Enhancement of the evidence-based approach in science education in general and OSLeP practice in particular (Millar et al. 2002; Salmo, 2010); as surprisingly few (quantitative) empirical studies about the CML factors per se exist, it is of considerable interest to link them to other variables (such as the NIFs), where such evidence can be increasingly found.

Table 3: The Contextual Model of Learning consists of three contexts and twelve factors that affect learning in informal learning environments (Falk, 2000).

Personal Context	Sociocultural Context	Physical Context
1. Visit motivation and expectations 2. Prior knowledge 3. Prior experiences 4. Prior interests 5. Choice and control	6. Within group social mediation 7. Mediation by others outside the immediate social group	8. Advance organizers 9. Orientation to the physical space 10. Architecture and large-scale environment 11. Design and exposure to exhibits and programs 12. Subsequent reinforcing events and experiences outside the museum

What about learner motivation and behavior? Measuring novelty experience factors (NEFs)

While the studies included in the literature review measured novelty impact factors (NIFs) and how they related to pupils' educational outcomes, fewer examined how NIFs related to learners' at-visit OSLeP experiences. Findings from several studies showed that learners who were more familiar with relevant knowledge about the setting, which in some cases could also be described as setting familiarity, exhibited more on-task behavior (Falk, 1978; Falk, 1982; Kubota, 1991).

Also, interviews from one study suggests that learners' comfort level with experimental equipment would improve their at-visit engagement (Cors, 2015). Also, only the study by Cotton and Cotton (2009) related novelty experience to learning. That is, they report evidence of influence from social factors, described as homesickness, group work experiences, and relations with lecturers, on learning. Left relatively unexplored are exploratory behavior and other novelty experience factors (NEFs), which would help us better understand the degree to which learners perceive their OLSeP experience as new or unfamiliar. But what are meaningful measurements of learners' perceived novelty at OSLePs?

Clues about how to measure learners' NEFs lie in the models and theories that guided the studies described in this literature review. For example, some studies describe how novelty experience causes a disequilibrium, or an overload with working memory, in learners, something that has been measured by educational psychologists as *cognitive load*. Also, since five of the studies organized interventions through classroom preparation to orient learners to the OSLeP setting, it would be interesting to learn how *oriented to the setting* learners feel during the OSLeP visit. Finally, most studies relate novelty to *curiosity* and *exploratory behavior*, measures that would provide insight into learner motivations and behaviors, respectively. Such research designs could help us untangle the effects of NIFs from the many other variables that affect learners' experiences.

PART II: Lenses for better understanding at-visit novelty

The studies included in our literature review describe NIFs that have to do with learners' previous knowledge, attitudes, setting familiarity, social experience, and capabilities, as well as NEFs such as exploratory behavior and other experience factors during the visit. In this second part of the paper, we describe how two more general theories of educational science – self-determination theory and Yerkes-Dodson relationships – can provide further insights into novelty and its affective and cognitive effects at OSLePs. Deci and Ryan's (1991) Self-Determination Theory (SDT), which links personality to motivation and behavior, offers insights into what motivates learners' engagement at OSLePs and how they behave at OSLePs. In a second discussion, we review how study research has shown that, depending upon how much novelty learners perceive at an OSLeP visit, they find the experience either overwhelming, appealing, or boring. To describe how these three types of novelty relate to behavior at and learning from OSLePs, the Yerkes-Dodson (or inverted-U type) relationship (YDR) is useful. SDT and YDRs offer frameworks that can guide investigations of novelty at OSLePs and how it relates to learner motivation and behavior.

Self-Determination Theory: Individual factors that drive motivation and behavior

Understanding the individual learner factors that drive their behavior at OSLePs can inform studies of novelty at OLSePs and, in particular, development of specific and meaningful measures for novelty experience factors (NEFs). Deci and Ryan's Self-Determination Theory (1991) provides a useful lens for relating human personality to motivation and behaviors at OSLePs. SDT defines intrinsic and extrinsic sources of motivation and how they drive behavior. For example, a learner who is motivated intrinsically engages because the task is interesting and would, for example, join a science club because she likes experimenting. An additional key aspect of SDT is how social and cultural context can support or 'thwart' people's potential. The degree with which humans are motivated to engage in an activity are, according to SDT, driven primarily by conditions supporting a learner's experience of autonomy, competence, and relatedness, known as the 'basic needs' for well-being and optimal functioning. The quality of engagement, in turn, affects the quality of learner performance, persistence, and creativity.

Educational psychologists see a fundamental link between SDT's basic needs and the development of interest. In a functional description of the Person-Object Theory of Interest development (POI), Krapp (Krapp, 2005) describes how the 'basic needs' defined by SDT are key influencers of interest development. POI is based on the idea that humans are motivated by a dual-regulation system that consists of cognitive rational and also (partly subconscious) emotional control mechanisms. In such a cognitive-emotional system, the basic needs of SDT play a crucial role in the emotional mechanism. The hypothesis here is that interest development will only occur if both cognitive-rational and emotional feedback are experienced in a positive way. A good account of the role of SDT/POI in out-of school learning contexts was given by Pawek (2009).

Evidence of a link between SDT's basic needs and learner interest at OSLePs has indeed been found. For example, Glowinski and Bayrhuber (2011, p. 385) showed that whether learners' basic needs were fulfilled at a student laboratory for molecular biology had a considerable influence on several components of science related interest (for autonomy and competence: $r \approx 0.2$-0.4 ($d \approx 0.4$-0.8); for interest in research and application contexts and in experiments, respectively; relatedness: $r \approx 0.3$-0.4 ($d \approx 0.6$-0.8); for interest in research and

[2] We use the term Yerkes-Dodson *relationship* to distinguish it from the original Yerkes-Dodson *law* which had arousal as independent variable.

application contexts, the authentic OSLeP environment, and in experiments, respectively). Interestingly, their results show moreover that, for pupils who had a low interest in science, meeting their basic needs for well-being was dependent upon pre-visit instruction, while their peers who were more interested in science did not link their basic needs to pre-visit instruction. Thus, 'taming' novelty is more important for the low interest group than for the high interest one. These results underscore the key role of pre-visit preparation as a key for an adequate novelty setting at OSLePs.

According to SDT, the basic needs of autonomy and competence are necessary for people to experience intrinsic motivation, or motivation that is based on internal goals and wishes and that supports self-regulated learning. In this vein, Boekarts (1999) proposes that because OSLePs involve more learner choices and fewer teacher-initiated goals and assessments than classroom experiences, they optimize learning. She explains how, at OSLePs, people more often develop their own goals in alignment with their needs and, therefore, there is a better chance for achieving desired educational outcomes:

> "What sets informal learning contexts apart from formal learning contexts is the perception of choice. Self-regulation, in the true sense of the word, will only emerge when students are allowed to learn in a context where they can weigh the feasibility and desirability of alternative actions and goals … using their own criteria. … most informal learning contexts are more powerful for developing criteria for success, progress, and satisfaction, which are in accordance with the students' own need structure. It should be evident that a dominant focus on developing and using one's own criteria will help students to develop and maintain specific educational outcomes" (p. 542).

Yerkes-Dodson relationships: Novelty experience has three faces

When considering peoples' experiences with unfamiliar objects, events and settings, existing studies and common experience suggest that novelty elicits one of three types of responses, or has 'three faces.' This holds true for experiences in general and for learning contexts in particular, and very specifically for novelty as an aspect of the OSLeP experience. Both Förster et al. (2010) and Falk et al. (1978, 1982) describe how the level of novelty of events can elicit interest and increase curiosity, be threatening because it is overwhelming or carries some risks, or be boring, causing an off-task search for stimulation.

One the one hand, some studies at OSLePs support that perceived novelty can promote interest and curiosity. For example, Dohn (2010) describes how employing surprise, variety and novelty as instructional strategies were triggers for pupil interest during a field trip to an aquarium. An earlier study by Sandifer (2003) explored how the characteristics of interactive exhibits at a science museum are effective in attracting and holding the attention of visitors. One the other hand, there is also strong evidence that too much novelty can lead to cognitive overload, confusion and anxiety. Falk et al. (1978, p. 128), for example, assert that "extreme novelty leads to less exploration and even fear." In a 3rd case, novelty has been shown to relate to boredom (Falk et al., 1982).

The way that the three faces of perceived novelty relate to exploration at and learning from OSLePs is described by a general 'law' of psychology, the Yerkes-Dodson relationship[2] (YDR) (Baldi, 2005; Roeckelein, 2006). YDRs describe an inverted-U relationship (∩) between arousal (or motivation, anxiety, novelty) and performance (e.g. attention, memory, problem solving). This kind of relationship states that there is an optimal level of arousal for performance, that is, increasing arousal will increase performance (ascending leg of ∩), but only up to a certain point (highest point of ∩), beyond which there is a decrease of performance (descending leg of ∩). In mathematical terms, Yerkes-Dodson or inverted-U relationships are thus simply a function with a single maximum. YDRs have also been employed to investigate non-cognitive psychological functions, such as aesthetic appraisal (Berlyne, 1963).

In conventional terms, the an YDR suggests that without some motivating tension we have no reason to act. In this way, stress or tension can be thought of as a good thing. We are built to be motivated by stress. The problem is that too much stress can cause performance to decline again. The behavior in the downturn of the inverted-U has been called 'satisficing' and is motivated quite differently from the earlier stages of arousal/ stress. Rather than gain satisfaction or reward from actions, a person who is satisficing seeks any way of reducing their stress, sometimes choosing sub-optimal solutions and exhibiting performance decline. For example, researchers found for complex way-finding tasks that people indeed learn only what is just necessary (Iyengar, 2012).

Similarly, Berlyne writes that "we are indifferent to things that are either too remote from our experience or too familiar" (1960, p. 21). Lee and Crompton (1992) describe Berlyne´s findings (in the context of animal behaviour) about the relation between novelty of objects and exploratory behavior as having an inverted-U shape:

> "Berlyne reported … {that} novel stimuli increase the extent of the exploratory behavior. However, extremely novel stimuli may

> discourage exploration. The relationship between exploratory behavior and novelty was found to be an inverted-U shaped function, with the maximum level of exploratory behavior being exhibited in the presence of moderately novel stimuli." (p. 743)

However, we have only found two examples of investigations about science learning that have employed an YDR to interpret findings about science learning. In one example, Falk and Balling (Falk, 1982) used an 'inverted-U' to described the relation between novelty, exploratory behavior and learning at an OSLeP, as discussed in the first part of this paper. Also, Sliva (2013), referred to YDRs to describe results about the relation between classroom physics test performance and workload. It seems that YDRs and their empirical underpinnings have not yet been fully explored as a tool for investigating the relation between learning, novelty, motivation, and behavior at OSLePs.

Looking forward

Research has demonstrated that reducing novelty influence factors (NIFs), such as unfamiliarity with the setting, promotes learning through OSLeP experiences. However, because NIFs are seldom related with much depth to novelty experience, it is not always clear that learners' outcomes improve because of reduced at-visit novelty, or because other factors that affect learning at OSLePs. Interestingly, several studies have shown evidence of links between NIFs and exploratory behavior. Also, a few studies have identified possible relations between learner outcomes and at-visit variables including curiosity and exploratory behavior. Moreover, Self-Determination Theory (Deci, 1991) and an inverted-U function have proved to be useful in describing learner experience and outcomes related to OSLePs. Future studies can go further by measuring and linking four aspects of learners' OSLeP experience: 1) NIFs, such as previous content knowledge and previous OSLeP visits, 2) at-visit motivation indicators, such as curiosity, 3) at-visit novelty experience factors (NEFs), such as exploratory behavior and how oriented pupils feel to the setting, and 4) educational outcomes, such as interest in science. An example of an investigation designed for examining relations among NIFs, NEFs, and learning is shown in Figure 5.

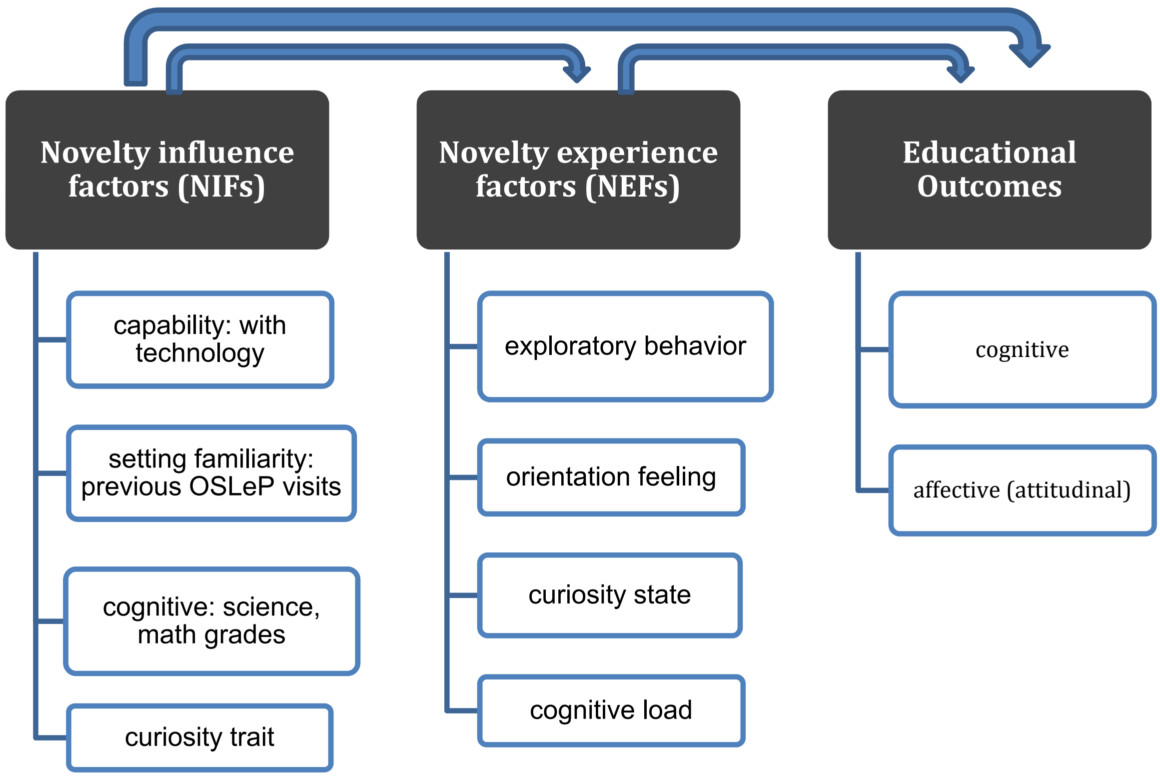

Figure 5: Example of novelty influence factors (NIFs) and novelty experience factors (NEFs), which studies about OLSePs can relate to learning.

Progress in Science Education, 2017
ISSN 2405-6057
DOI.10.25321/prise.2017.521

By reducing overwhelming novelty and leveraging intriguing novelty, OSLePs are uniquely positioned to bring us closer to realizing the benefits of discovery learning. That is, by encouraging learner autonomy and engagement in learning, thus promoting creativity and problem-solving skills, we develop a more agile workforce that our globalized, Digital Age societies need (Castranova, 2002). Moreover, these education approaches have been recognized as critical for developing skills needed for businesses and societies to move forward sustainably (R. Cors, Matsubae, K., Street, A. , 2013; Scholz, 2011).

References

Anderson, D., Ellenbogen, K. (2012). Learning Science in Informal Contexts – Epistemological Perspectives and Paradigms. In B. Fraser, K. Tobin, C. McRobbie (Ed.), *Second International Handbook of Science Education* (pp. 1179-1187). New York: Springer.

Anderson, D., Lucas, K. (1997). The Effectiveness of Orienting Students to the Physical Features of a Science Museum Prior to Visitation. *Research in Science Education, 27*(4), 485-495.

Baldi, E., Bucherelli, C. (2005). The inverted 'u-shaped' dose-effect relationships in learning and memory: modulation of arousal and consolidation. *Nonlinearity in Biology, Toxicology, and Medicine, 3*(1), 9-21.

Barmby, P., Kind, P. M., Jones, K., Bush, N. (2005). Evaluation of Lab in a Lorry (Vol. Final Report): CEM Center and School of Education, Durham University.

Berlyne, D. E. (1951). Novelty and Curiosity as Determinants of Exploratory Behavior. *The British Journal of Psychology, 41*, 68-80.

Berlyne, D. E. (1960). *Conflict, Arousal and Curiosity*. New York: McGraw-Hill.

Boekaerts, M., Minnaert, A. (1999). Self-regulation with respect to informal learning. *International Journal of Educational Research, 31*, 533-544.

Brandt, A., Möller, J., Kohse-Höinghaus, K. (2008). Was bewirken außerschulische Experimentierlabors? Ein Kontrollgruppenexperiment mit Follow up-Erhebung zu Effekten auf Selbstkonzept und Interesse (What's the Effect of Science Laboratories? A Control Group Experiment with Follow-up Data on Self-Concept and Interest). *Zeitschrift für Pädagogische Psychologie, 22*(1), 5-12.

Bybee, R., McCrae, B. (2011). Scientific Literacy and Student Attitudes: Perspectives from PISA 2006 science. *International Journal of Science Education, 33*(1), 7-26.

Castranova, J. A. (2002). Discovery Learning for the 21st Century: What is it and how does it compare to traditional learning in effectiveness in the 21st Century? *Action research exchange, 1*(1).

Cohen, J. W. (Ed.). (1988). Statistical power analysis for the behavioral sciences (2nd ed.). Hillsdale, NJ: Lawrence Erlbaum Associates.

Cors, R. (2013). MobiLLab Program Background Investigation: Directions for Program Improvement and Evaluation Research (Verschaffen eines Überblicks des mobiLLabs) (pp. 32). St. Gallen, Switzerland: University of Teacher Education (Pädagogische Hochschule St. Gallen).

Cors, R., Matsubae, K., Street, A. . (2013). Chapter 8: How MFA, transdisciplinarity, complex adaptive systems thinking, and education reform are keys to better managing P: P is for Parity. In K. Wyant, J. Corman, J. Elser (Ed.), *Phosphorus, Food, and Our Future*. New York City, New York, USA: Oxford University Press.

Cors, R., Müller, A., Robin, N. (2015). Advancing Informal MINT Learning: Preparation and Novelty at a Mobile Laboratory. In: Pixel Associazione Culturale (Edt.)(2015). "New Perspectives in Science Education" (Limena: libreriauniversitaria.it) 53-58.

Cotton, D. R. E., Cotton, P. (2009). Field biology experiences of undergraduate students: the impact of novelty space. *Journal of Biology Education, 43*(4), 169-174.

de Jong, T. (2009). Cognitive load theory, educational research, and instructional design: some food for thought. *Instructional Science, 38*, 105-134.

Deci, E. L., Valleran, R. J., Pelletier, L. G., Ryan, R., M. (1991). Motivation and Education: The Self-Determination Perspective. *Educational Psychologist, 26*(3&4), 325-346.

Dohn, N. B. (2010). Situational Interest of High School Students Who Visit an Aquarium. In L. Dierking, J. Falk (Ed.), *Science Learning in Everyday Life*: Wiley Periodicals, Inc.

Dorie, B. L., Dankenbring, C.A., Denick, D.L, Ferguson, D., Huff, J., Phillips, C., Schimpf, C., Cardella, M.E. (2012). *File: A Taxonomy of Formal and Informal Learning Environments*. Paper presented at the American Society for Engineering Education, Valparaiso University, Valparaiso, Indiana.

Dowell, K. (2011). 2010-2011 Evaluation of the MdBioLab Program. In EvalSolutions (Ed.), (pp. 33): Prepared for: MdBio Foundation, Rockville, Maryland.

Eschach, H. (2007). Bridging In-school and Out-of-school Learning: Formal, Non-Formal, and Informal Education. *Journal of Science Education and Technology, 16*(2), 171-190.

Falk, J., Dierking, L. (Ed.). (2000). *Learning from Museums*. Lanham, Maryland: AltaMira Press.

Falk, J., Dierking, L. (Ed.). (2011). *The Museum Experience*. Walnut Creek, CA: Left Coast Press.

Falk, J., Martin, W.M., Balling, J.D. (1978). The Novel Field-Trip Phenomenon: Adjustment to Novel

Settings Interferes with Task Learning. *Journal of Research in Science Teaching, 15*(2), 127-134.
Falk, J. H., Balling, J.D. (1982). The Field Trip Milieu: Learning and Behavior as a Function of Contextual Events. *Journal of Educational Research, 76*(1), 22-28.
Förster, J., Marguc, J., Gillebart, M. (2010). Novelty Categorization Theory. *Social and Personality Psychology Compass, 4*(9), 736-755.
Gassmann, F. (2012). Das Schülerlabor iLab des Paul Scherrer Instituts (pp. 2). Switzerland: Paul Scherrer Institute.
Glowinski, I., Bayrhuber, H. (2011). Student labs on a university campus as a type of out-of-school learning environment: Assessing the potential to promote students' interest in science. *International Journal of Environmental & Science Education, 6*(4), 371-392.
Hidi, S., Renniger, K.A. (2006). The Four-Phase Model of Interest Development. *Educational Psychologist, 41*(2), 111-127.
High Level Group on Increasing Human Resources for Science and Technology in Europe. (2004). Europe Needs More Scientists. Retrieved on 9. January 2013 from http://ec.europa.eu/research/ conferences/2004/sciprof/pdf/final_en.pdf: European Commission.
Itzek-Greulich, H., Flunger, B., Vollmer, C. Nagengast, B., Rehm, M., Tratwein. (2015). Effects of a science center outreach lab on school students' achievement -Are student lab visits needed when they teach what students can learn at school? *Learning and Instruction, 38*, 43-52.
Iyengar, S. R. S., Madhavan, C. E. V., Zweig, K. A., Natarajan, A. (2012). Understanding Human Navigation Using Network Analysis. *Topi{CS} - {T}opics in {C}ognitive {S}cience, 4*(1).
Jarvis, T., Pell, A. (2005). Factors Influencing Elementary School Children's Attitudes toward Science before, during, and after a Visit to the UK National Space Centre. *Journal of Research in Science Teaching, 42*(1), 53-83.
Krapp, A. (1999). Interest, motivation and learning: an edutional-psychological perspective. *European Journal of Psychology of Education, XIV*(1), 23-40.
Krapp, A. (2005). Basic needs and the development of interest and intrinsic motivational orientations. *Learning and Instruction, 15*, 381-395.
Kubota, C. A., Olstad, R. G. (1991). Effects of novelty-reducing preparation on exploratory behavior and cognitive learning in a science museum setting. *Journal of Research in Science Teaching, 28*(3), 225–234.
Lee, T.-H., Crompton, J. (1992). Measuring Novelty Seeking in Tourism. *Annals of Tourism Research, 19*, 732-751.
Luckay, M., Collier-Reed, B. (2011, 10-12 August). *Admitting Engineering Students with the Best Chance of Success- Technological Literacy and the Technological Profile Inventory (TPI).* Paper presented at the 1st Biennial Conference of the South African Society for Engineering, Sellenbosch.
Millar, R., Leach, J., Osborne, J., Ratcliffe, M., Hames, V., Hind, A., ... & Scott, P. (2002). Towards evidence-based practice in science education. School science review, 84, 19-34.
Orion, N. (1989). Development of a High-School Geology Course Based on Field Trips. *Journal of Geological Education, 37*, 13-17.
Orion, N. (1993). A Model for the Development and Implementation of Field Trips as an Integral Part of the Science Curriculum. *School Science and Mathematics, 93*(6), 325-331.
Orion, N., Hofstein, A. (1991a). *Factors which influence learning ability during a scientific field trip in a natural environment.* Paper presented at the Proceedings of the annual convention of the National Association for research in Science Teaching, Fontana, IL.
Orion, N., Hofstein, A. (1991b). The Measurement of Students' Attitudes Towards Scientific Field Trips. *Science Education, 75*(5), 513-523.
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), 1097-1119.
Paas, F., van Gog, T., Sweller, J. (2010). Cognitive Load Theory: New Conceptualizations, Specifications, and Integrated Research Perspectives. *Educational Psychology Review, 22*, 115-121.
Pawek, C. (2009). *Schülerlabore als interesseférdernde ausserschulische Lernumgebuhngen für Schülerinnen und Schüler aus der Mittel- und Oberstufe.* Christian-Albrechts-Universität zu Kiel.
Priemer, B., Pawek, C. (2014). *Out-of-school STEM learning in Germany: Can we catch and hold students' interest?* Paper presented at the NARST (National Association for Research in Science Teaching) Annual International Conference Pittsburg.
Rennie, L. J. (2007). Learning Science Outside of School. In S. K. Abell, N.G. Lederman (Ed.), *Handbook of Research on Science Education*. Mahwah, New Jersey: Lawrence Erlbaum Associates.
Roeckelein, J. (Ed.) (2006) Dictionary of Psychological Theories. Amsterdam: Elsevier.
Salmi, H. (2010). Bridging the Gap between Formal Education and Informal Learning: Towards Evidence Based Science Education. In: M. Kalogiannakis, D. Stavrou & P. Michaelidis

(Eds.) Proceedings of the 7th International Conference on Hands-on Science. 25-31 July 2010, Rethymno-Crete, pp. 35 – 41

Sandifer, C. (2003). Technological Novelty and Open-Endedness: Two Characteristics of Interactive Exhibits That Contribute to the Holding of Visitor Attention in a Science Museum. *Journal of Research in Science Teaching, 40*(2), 121–137.

Sasson, I. (2014). The Role of Informal Science Centers in Science Education: Attitudes, Skills, and Self-efficacy. *Journal of Technology and Science Education, 4*(3).

Scholz, R. W. (2011). *Environmental Literacy in Science and Society: From Knowledge to Decisions*. New York: Cambridge University Press.

Sjøberg, S., Schreiner, C. (2010). The ROSE project: An overview and key findings (pp. 31): University of Oslo.

Sliva, Y. (2013). *In search for Instructional Techniques to Maximize the Use of German Cognitive Resources: A Case of Teaching Complex Tasks in Physics.* (Doctor of Philosophy), Old Dominion University. (UMI: 3580483)

Tran, N. A. (2011). The Relationship between Students' Connections to Out-of-School Experiences and Factors Associated with Science Learning. *International Journal of Science Education, 33*(12), 1625-1651.

Wilson, D. B. (2015). Practical Meta-Analysis Effect Size Calculator Retrieved last accessed 1. April, 2105, George Mason University, from http://www.campbellcollaboration.org/escalc/html/EffectSizeCalculator-SMD-main.php