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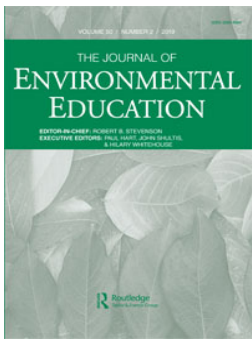
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RESEARCH ARTICLE



## Role of environmental interaction in interdisciplinary thinking: from knowledge resources perspectives

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### ABSTRACT

This article examined the role of environmental interaction in interdisciplinary thinking and the use of different knowledge resource types. The case study was conducted with two classes ( $N=40$ ) of 8th-grade students, ages 13 to 14. The outdoor trail aimed to help students synthesize history, geography, and science knowledge. Two groups' discourse from each class was audio-recorded and transcribed for content analysis. We coded the discourse to examine: (i) the use of different knowledge resource types (i.e., *contextual resource*, *new conceptual resource*, *prior knowledge resource*); (ii) the relationship among these knowledge resource types; and (iii) evidences of interdisciplinary thinking. Findings showed that contextual resources enhanced students' capacity to develop new conceptual resources and to activate prior knowledge resources. Further, about 80% of students' discourse demonstrated interdisciplinary connections of two subjects.

### KEYWORDS

environmental interaction;  
interdisciplinary thinking;  
knowledge  
co-construction;  
knowledge resources;  
outdoor learning

### Introduction

Empirical research on outdoor learning has evidenced that interaction with the real-world environment enables learners to contextualize and to concretize learning (e.g., Alagona & Simon, 2010; Bunting, 2006; Dillon et al., 2006; Kerawalla et al., 2012; Maulucci & Brotman, 2010; Maynard & Waters, 2007; Orion & Hofstein, 1994). The growing body of literature on outdoor learning epitomizes the authenticity of the learning platform to engage learners and to enhance the meaning-making process. Sibthorp (2003) attributes the authenticity of learning to two fundamental features of outdoor learning: the *inherent properties of the real-world environment* and the *authenticity of the social environment* present learners with real tasks that foster real-world application and acquisition of skills individually and collectively.

The review on outdoor learning also accentuates the significance of the outdoor settings as a valuable resource in the teaching of all subjects, especially in facilitating interdisciplinary education (Rickinson et al., 2004). Eaton's (2000) study on a field trip to the farming industry found that students demonstrated better understanding about the consumption and production of food after the visit to the farms and the hands-on experience with plants and animals. Further, the students were able to engage in interdisciplinary thinking by perceiving the relations of concepts across environmental science disciplines. This mirrors Bunting's (2006) definition of outdoor learning that it is about relationships "within the natural environment and between the environment and the human society" (p. 4). Outdoor learning presents students "emerging learning opportunities" (Rahm, 2002, p. 175) beyond the planned activity to explore new knowledge and concepts and has redefined learning spaces to embrace learning beyond the four walls of the classroom.

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Notwithstanding the multitude of studies on the rich potential of outdoor learning, research remains unclear on the meaning-making process during the interaction with the physical environment, such as (a) how learners use the different types of knowledge resources available in an outdoor learning setting to co-construct knowledge; (b) how learners interact with the outdoor learning environment to enhance and/or advance the different types of knowledge resources; and (c) how interaction with the outdoor environment engages learners in interdisciplinary thinking. We adopted the theoretical framework on knowledge resources proposed by Fischer and Mandl (2005) to address students' use of different types of knowledge resources in outdoor learning and the role of environmental interaction in interdisciplinary thinking. The contribution of this study lies in that we move forward Fischer and Mandl's framework to explore the relationships between different couplings of knowledge resources in outdoor learning contexts, especially for investigating learners' interaction with the physical environment to co-construct knowledge and to make interdisciplinary knowledge connections.

## Theoretical framework

### *Learning in the outdoors: environmental interaction*

The classic definition of outdoor education is “education in, about, and for the outdoors” (Donaldson & Donaldson, 1958, p. 63 in Priest, 1986). Education *in* the outdoors refers to the location; Education *about* the outdoors means the subject matter (content knowledge); Education *for* the outdoors refers to the development of an appreciation of nature. Adding to this classic definition, Bunting (2006) amplifies education *through* the outdoors where he likens outdoor learning to a teaching method using activities to help learners develop skills and concepts, which might otherwise remain abstract and unrelated. On a similar note, Brown and Fraser (2009) works on adventure education and outdoor learning, accentuate the importance of harnessing the affordances of the “pedagogical opportunities” to create authentic learning situations for students to engage in activities at both the individual and collective level. That is, the locus of learning resides with the learners and learners' interaction with the surrounds—both the physical and social elements (Lave & Wenger, 1991). Outdoor learning places the learners in the forefront of the meaning-making process. Learners, therefore, are no longer passive recipients of information and consumers of knowledge, but active agents in affirming, advancing and/or creating new knowledge.

What, essentially, do learners gain by being outdoor, beyond the four walls of the classroom? We present two core benefits of outdoor learning experiences (a) sensory learning; (b) authentic learning and real-life problem solving. First, outdoor learning appeals to the sensory awareness where learners are required to make full use of all the six senses (i.e., sight, sound, taste, touch, smell and intuition) to make observations and perceptions where Priest (1986) calls it an *experiential learning* process, which epitomizes a “full sensory rather than an abstract approach to learning” (p. 14). Hence, learning in the outdoor goes beyond content learning: the concrete learning opportunities fosters reflection and application (Kolb, 1984) as learners make firsthand observations to test and/or affirm preconceived ideas/concepts and/or to advance those ideas/concepts.

Second, the rich affordances of the outdoor environment present practical, experiential, and authentic learning opportunities that are absent from the classic classroom. In outdoor learning, learners assume an active role in constructing information from the environment where the “direct experience with concrete phenomena and materials” (Orion, 1993, p. 325) becomes key in the meaning-making process. Sibthorp's (2003) study found that by being in the natural authentic environment living on a boat in the ocean with their peers, students were “forced to learn” owing to the authenticity of the activity. What appear as abstract instructions in the classroom became applicable when students were able to *learn by doing*. By assuming an active role, students acquired skills and knowledge in sailing, scuba diving, and boat living skills. Also, the presence of peers and staff providing verbal feedback and modeling was equally instrumental in the outdoor learning process. The appropriation of knowledge in the real-world environment becomes contextualized and assumes meaning through authentic use.

The interaction with the physical environment concretizes the otherwise, inert or abstract concept, knowledge and skills acquired within the confines of the classic classroom. Thus, environmental interactions form a significant signpost in an outdoor learning context to help students make sense of the world around them.

### ***Interdisciplinary thinking through environmental interaction***

Learning in the outdoors can engage learners in interdisciplinary thinking (e.g., Alagona & Simon, 2010; Bunting, 2006; Rickinson et al., 2004; Sibthorp, 2003). Whereas the term “multidisciplinary” refers to approaching a problem from different disciplinary angles, interdisciplinary thinking aims for a higher level of coherence and integration where different disciplinary perspectives are integrated to create “own theoretical, conceptual and methodological identity” (van den Besselaar & Heimeriks, 2001, p. 705). Bunting (2006) argues that learning in the outdoor environment is interdisciplinary in nature as the outdoor setting itself presents learners “naturally occurring opportunities” to see interrelationships and to make interdisciplinary connections. Outdoor learning promotes an interdisciplinary curriculum where learners perceive the interrelationships, not only between natural resources, but also between people and society (Ardoin, 2006; Priest, 1986), thereby creating awareness that human activities at the individual and societal level also shape these relationships (Bunting, 2006).

Fostering interdisciplinary connections remains one of the greatest affordances of outdoor learning where more than one discipline is embedded in the learning experience. Several studies on outdoor learning have evidenced that the interaction with the physical and social environment has engendered deep learning when learners *directly experienced* those inter-relationships. For instance, a study by Alagona and Simon (2010) found that college students who participated in the environmental studies field course about the High Sierra region were able to engage in a coherent and constructive discourse. These students were able to integrate knowledge from the natural sciences, social sciences, and humanities. The interdisciplinary nature of the learning setting encouraged learners to move beyond compartmentalized learning (Christensen & Crimmel, 2008) where learners had to bridge theoretical knowledge with practical applications and to make connections between and among different disciplines. Learners’ interest and engagement increased as they saw more relevance and congruence between concepts and contexts. Similarly, Morris (2007) found that in a school program on historical blacksmithing, students had the opportunity to work with community members who worked with metal either as a hobby or a profession. The field experience enabled the students connect the metalworking experience of their daily lives to the historic process of blacksmithing.

However, being in the outdoor environment does not necessarily promise the occurrence of interdisciplinary thinking and learning. Rather, the meaning-making process is contextualized and concretized through learners’ participation of activities and tasks nested in these “naturally occurring opportunities” in the real-world environment. The authenticity of the tasks is critical to foster interdisciplinary thinking and to facilitate a holistic understanding by removing disciplinary academic barriers where learners are able to draw connections between relationships (Alagona & Simon, 2010). In a similar fashion, Lim and Barton (2006) underscore the importance of maximizing the presence of a real-world platform, engaging learners in meaningful knowledge creation and production where the process of learning is informed by sense of place. Here, the term “place” means more than a geographical location, and refers to the ecological, interdisciplinary system that includes “physical, biological, social, cultural, and political factors with history and psychological state of the person who share the location” (Lim & Barton, 2006, p. 107). Previous research has shown that such a sense of place developed with authentic tasks is critical to foster interdisciplinary thinking and to make connections across abstract concepts. For example, Rahm’s (2002) study on outdoor science and environmental studies showed that students developed deeper scientific understanding of the food cycle, evolution, and environmental management where they were involved in the planting, harvesting, and marketing activities. The interaction with the gardeners and marketers

affords a firsthand experience, which enhances interdisciplinary thinking. What appears as an abstract and autonomous content is now made concrete and connected by being immersed in the real-world environment.

### ***Knowledge resources in environmental interaction***

The interaction with the outdoor environment engages learners in reinterpreting and recontextualizing during the meaning-making process: attaching new values and meanings to the objects and surrounds (Pachler, 2009). As learners interact with each new outdoor environment, learners must renegotiate prior known meanings and concepts to draw new relationships and to create new meanings. This meaning-making process is aptly exemplified by Bunting (2006) who posits that learners in the outdoor learning setting experience a cycle of experiencing, reflecting, generating, and applying known concepts/knowledge and acquiring new ones. The situated nature of outdoor learning and the affordances of the “naturally occurring opportunities” require learners to employ different knowledge resources to negotiate, to affirm, and/or advance knowledge individually and/or collectively.

From the perspectives of knowledge resources in collaborative learning settings, it is important to examine how learners leverage different types of knowledge resources available to them for knowledge construction and knowledge convergence. The body of knowledge resources could be conceived of as a tool that allows learners to have flexibility and manipulation where the different knowledge resource types can be restructured and approximated to respond and to react to new situations. Fischer and Mandl (2005) examined how students in different collaboration conditions (i.e., videoconferencing vs. face-to-face) used a range of knowledge resources for process and outcome convergence. University students in their study were asked to evaluate case studies about teacher management of collaborative learning situations. Their study identified three core knowledge resource types and their relationships in the meaning-making process to construct knowledge: contextual resource, new conceptual resource, and prior knowledge resource. *Contextual resource* refers to the case information in the given case description texts; *new conceptual resource* refers to new theoretical concepts that students learn within a theory text; and *prior knowledge resource* means theoretical concepts not taught in a theory text, but which arises from students’ prior learning experiences. Of equal significance would be two other categories of knowledge resource: the relationship between contextual resource and new conceptual resource, as well as the relationship between contextual resource and prior knowledge resource.

The notion of knowledge resources is closely linked to the body of literature concerning the emergence of knowledge divergence and convergence for shared understanding, particularly in computer-supported group discourse contexts (e.g., Jeong & Hmelo-Silver, 2010; Kapur, Voiklis, & Kinzer, 2011; Suthers, Dwyer, Medina, & Vatrappu, 2010). It should be noted that these prior studies emphasized the role of resources in the process of knowledge convergence and divergence in problem-solving contexts, and the types of resources refer to not only knowledge (cognitive aspects), but also to a combination of linguistic, gestural, and physical resources to generate new ideas and to support shared understanding. To illustrate learners’ use of these different knowledge resources in an outdoor learning context, which is the main focus of this study, we also draw upon the works of Choi and Hannafin (1995) on situated cognition and the learning environment where they posit that the authentic context enables learners to “develop a sense of situational intent” (p. 56). Here, the authentic context cues the learners to the situational resources (e.g., social climate, physical features, and mediating agents), and learners learn how to harness such contextual resources to achieve their goals where they identify, consolidate, evaluate, and apply information in authentic tasks (Choi & Hannafin, 1995). Hence in an outdoor learning setting, contextual resources include both what students learn from the case information, as well as the situational resources they use during the interaction with the outdoor environment. Contextual resources also form the primary base from which learners’ prior knowledge is activated. Further, new meanings ensue when learners see new relationships between contextual resources and prior knowledge resources, as well as between contextual resources and new theoretical concepts acquired in the given learning materials.

## Methodology and methods

### *Research questions and methodological approach*

This study examines how students in a mobile outdoor learning context utilize different knowledge resources to build ideas and to make connections across different disciplinary areas. The following three research questions were formulated:

- Research question 1: What type of knowledge resources do students use on an inquiry-based outdoor learning trail?
- Research question 2: What is the relationship between the different types of knowledge resources and environmental interaction?
- Research question 3: What is the effect of environmental interaction on interdisciplinary connections in the different types of knowledge resources?

Methodologically we employed a case study approach to unpack the process of meaning-making and interdisciplinary knowledge connections in the outdoor environment. In this study, a case study was chosen as a methodological approach since we aimed to provide in-depth descriptions and analysis of a phenomenon under the inquiry (Merriam & Tisdell, 2015; Yin 2017). Because the main research focus is on the role of different knowledge resources in the meaning-making process during students' participation in the outdoor mobile learning trail, it was essential to take qualitative methodological approaches to analyze group discourse and interaction. Due to the microlevel nature of discourse analysis and the amount of discourse and interaction data, we selected two groups for in-depth analysis. Although the smallness of scale may limit the generalization of findings, we believed that the qualitative approaches could provide valuable insight into the dynamics of various couplings and roles of knowledge resources.

### *Participants and research setting*

The research study was implemented with two classes ( $N=40$ ) of 8th-grade students (13–14 years old) at one of the future schools in Singapore. The outdoor mobile learning trail took place at the Singapore River where students could learn about the history of the Singapore civilization, the importance of the river location and the measurement of water quality and conditions. We chose the Singapore River as an ideal location for interdisciplinary learning as students could explore various topics of inquiry by synthesizing history, geography, and science knowledge. The outdoor learning trail was conducted in small groups of four to five members, resulting in eight groups from the two classes. The collaborating teachers randomly did the grouping.

### *Design of the outdoor learning trail*

We position the outdoor learning trail not as a stand-alone, one-day event, but as an integral part of the formal curriculum with a pre-trail and post-trail phase. All learning activities were codesigned by the research team and the six collaborating teachers from the geography, history, and biology department.

The design of the mobile outdoor learning gave due consideration to the activity types and the knowledge construction process. First, the whole mobile learning trail consists of three phases, namely pre-trail (in class), trail (outdoor), and post-trail (in class). [Table 1](#) presents the overview of the learning outcomes and lesson activities for each phase. The pre-trail activities facilitate the integration of conceptual understanding of the three different subjects on river, civilization, and change with an overarching BIG (Beyond Information Given) question on “why does civilization begin at the mouth of a river?” Students in small groups then developed their own line of inquiries relating to the BIG question that they want to pursue during the unstructured learning activity (see [Table 1](#)) at the Singapore River Trail.

The outdoor learning trail includes both structured and unstructured learning activities at the three learning stations along the river. *Structured learning activities* refer to the series of tasks designed a priori by the teachers and researchers whereas *unstructured learning activities* refer to the inquiry tasks that

**Table 1.** Overview of the lesson design from pre- to post-outdoor learning trail.

Phase	Desired Learning Outcomes	Lesson Activities
BIG Question: Why does civilization begin at the mouth of a river?		
Pre-trail (in class)	Students should be able to: <ol style="list-style-type: none"> <li>1. Develop group pre-trail inquiry and/ or hypothesis relating to the BIG question.</li> <li>2. Draw connections to similar inquiries and hypotheses at the class level.</li> <li>3. Provide constructive feedback on inquiries and hypotheses presented by other groups.</li> </ol>	<ol style="list-style-type: none"> <li>1. List three famous rivers in the world, their common features and functionalities.</li> <li>2. Develop one group pre-trail inquiry/ hypothesis relating to the BIG Q on river and civilization in the web-based platform.</li> </ol>
Trail (Singapore River - showing only the learning station Clarke Quay)	Structured Learning Activities in the Learning Trail <ol style="list-style-type: none"> <li>1. Transfer skills and concepts acquired in the classroom to the outdoor learning environment in the undertaking of performative task types.</li> <li>2. Apply the integrated conceptual understanding of the three different subject areas in the knowledge generative and synthesis task types.</li> </ol> Unstructured Learning Activities in the Learning Trail Students pursue their own pre-trail inquiry leveraging on the physical affordances of the technological tools and the learning environment. They are free to move around in the vicinity of the river site.	Performative tasks <ol style="list-style-type: none"> <li>1. Measure the river water conditions</li> <li>2. Determine the location for ideal water conditions</li> </ol> Knowledge generative & synthesis tasks <ol style="list-style-type: none"> <li>3. Explain why location has ideal water conditions</li> <li>4. Discuss the importance of water quality</li> </ol> Students in small groups pursue their own line of inquiry in this unstructured learning activity (30 min.), to investigate the pre-trail inquiry (i.e., the research questions they developed) and the hypothesis (each pair in the small group of four to five shares an iPad and data-logger).
Post-trail (in class)	<ol style="list-style-type: none"> <li>1. Identify new ideas/concepts developed (during the unstructured learning activity) relating to the BIG question.</li> <li>2. Synthesize and evaluate findings (pre-trail inquiry and trail tasks) in response to the BIG question.</li> </ol>	<ol style="list-style-type: none"> <li>1. Class session where students share their collated findings and new concepts developed in response to the BIG question.</li> <li>2. Students attempt a rise above to the BIG question in the knowledge forum, identify new knowledge and concepts and advance their ideas at the class level.</li> </ol>

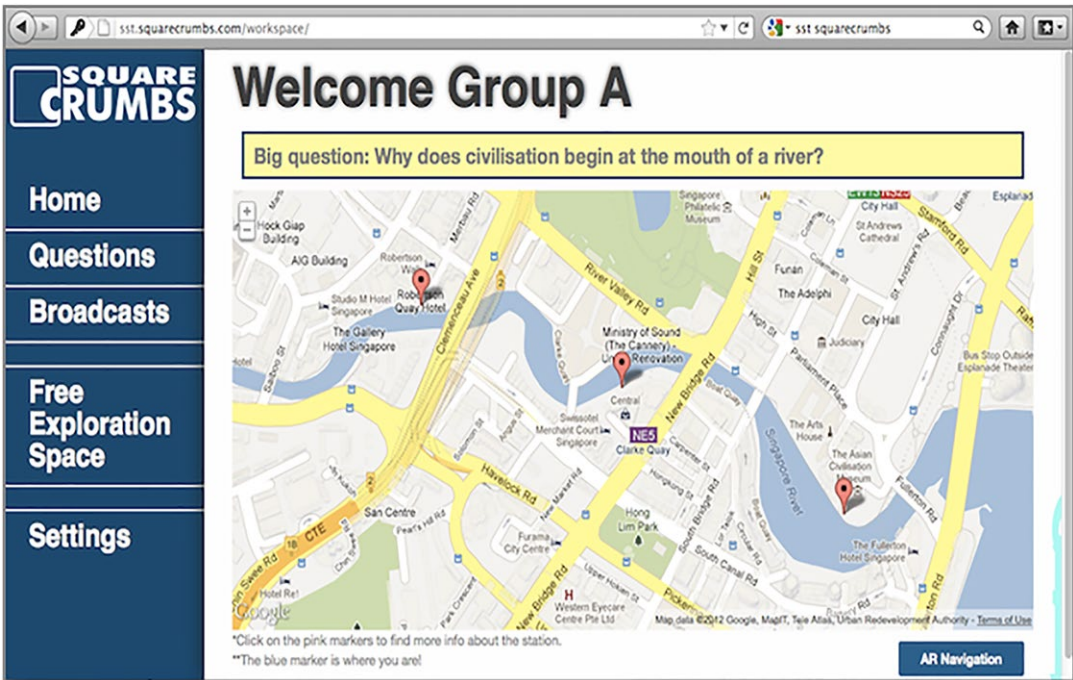
students want to pursue, which were generated during the pre-trail stage in class. The structured learning activities were designed with a gradual progression from well-structured task-types (performative and applicational) to less-structured task-types (knowledge generative and synthesis) (see Table 1 for a brief overview of the trail and task design). Performative and applicational tasks refer to the type of tasks where students can directly apply what they learn in class, and problems with fixed answers and procedures. On the other hand, knowledge generative and synthesis tasks require higher-order thinking skills where students need to go beyond textbook information and to integrate multiple concepts and ideas for problem solving. After completing all structured trail activities, students in a small group of four or five were given 30 to 40 minutes to pursue their own line of inquiry (generated in the pre-trail phase) during the unstructured activity along the river vicinity.

Last, post-trail activities were a measure for summary of learning, followup, and debrief, allowing groups to share their findings, and to attempt a “rise-above” phase of the progressive inquiry cycle of knowledge building.

### **Technology mediation**

Each small group of four to five members was equipped with two iPads and two data-loggers and probes to measure the water condition. To reduce the physical presence of the teacher and frontal loading of information, all trail activities (structured and unstructured activities) were hosted on the web-based platform called SquareCrumbs. As shown in Figures 1 and 2, this platform presents a series of questions/tasks that students need to perform at each station on the Google Maps, and allows students to host all their findings and collated artifacts (e.g., pictures, data, etc.). The provision of the broadcast alerts and feedback features seeks to enable immediacy of teacher facilitation and intergroup communication during the learning trail.





**Figure 1.** Web-based platform provided all trail activities and customized Google map of trail site.



**Figure 2.** Students used GPS coordinates to locate the next learning station at the trail site.

### **Data collection and analytical approach**

To examine students' use of knowledge resource types and how students make interdisciplinary connections in the meaning-making process, we observed two groups of students from each of the two classes. The two groups chosen for this study had a good gender balance and mixed ability levels. Group A had four students (two boys and two girls) and Group B had five students (two boys and three girls).

During the pre-trail activities in class, the two groups under investigation developed the following inquiries for the unstructured learning activity:

- Group A: What happened to the Singapore River as a trading point? Why was it removed?
- What is it now?
- Group B: Why did the cleaning of the river not change at an earlier or later time?

Group discourse and interaction was video- and audio-recorded and transcribed (approximately 38 pages) for quantitative content analysis, where “the communication is coded, summarized and frequencies/percentages are used for comparison” (Strijbos, Martens, Prins, & Jochems, 2006, p. 30). Excluding nontask talk and the sporadic private conversations, we analyzed 113 segments of content- and task-related statements (questions statements inclusive) in the group’s discourse. We were aware of the data reduction problem in qualitative research approaches where the observed data is reduced, classified, and coded for interpretation, and this procedure may lead to unsubstantiated claims and conclusions (Goetz & LeCompte, 1981). To minimize this problem and draw valid meaning, we closely followed the analytical protocol proposed by Chi (1997) that delineates the mechanics of analyzing and quantifying the content of verbal utterance. Chi (1997) proposes the use of semantic boundaries to determine the unit of analysis as an idea may require a few sentences to clarify meaning. Moreover, similar ideas could be surfaced several times by team members who are more vocal. Hence, each of the 113 segments forms a unit of analysis and may contain one or more statements/question statements depending on the discussion threads, ideas, and turn of talks.

In quantitative content analysis, a coding scheme is developed to guide the systematic descriptions and categorization of the content of text (Boréus & Bergström, 2017). To analyze students’ discourse, we adapted the coding scheme from Fischer and Mandl (2005) study where they investigated the knowledge resource types learners use in the group discourse. Table 2 shows the three categories of knowledge resources defined in this study. First, we define *Contextual Resources* (CR) as a type of knowledge resource made available at the pre-trail activities, the overarching Big Question, the trail activities that provide students with the contextual information, as well as the situational resources (e.g., environmental artifacts). Second, *New Conceptual Resources* (NCR) refers to theoretical concept(s) of the three subjects (i.e., history, geography, and biology) in the given learning materials. Basically, NCR targets interdisciplinary thinking and conceptual understanding learned theoretically in class. Last, *Prior Knowledge Resources* (PKR) refers to a theoretical concept not explicitly covered in the given learning materials, but to the prior knowledge and information that students gained from previous experiences. We also examined (a) the relations between contextual resources and new conceptual resources (CR & NCR), and (b)

**Table 2.** Coding categories of knowledge resource dimension (adapted from Fischer & Mandl, 2005).

Categories of Knowledge Resources	Content Dimension Descriptor and Sample Statements from Group Discourse
Contextual Resources (CR)	Statement and question statement that explicitly refer to the case information, i.e., pre-trail activities, the BIG Question, as well as the trail activities and situational resources arising from interaction with the trail site. e.g., “Are we supposed to go up with this curve...there’s a lot of commercial buildings.”
New Conceptual Resources (NCR)	Statement and question statement that refer to theoretical concept(s) of the three subjects (i.e., History, Geography & Biology) in the given learning materials. e.g., “Now the dissolved oxygen...do what... other than promote marine life?...”
Prior Knowledge Resources (PKR)	Statement and question statement that make explicit reference to theoretical concept (s) of the three subjects, not included in the given learning materials but from previous experiences. e.g., “Student Y: Why did the clean river campaign happen - before or later? Student T: You know the 1980s right? ”
Relations between Contextual Resources & New Conceptual Resources (CR & NCR)	Statement and question statement that link theoretical concept(s) within the given learning materials to the contextual resources. e.g., “no the trading port wasn’t removed. It was replaced, it was replaced to make way for tourist attractions and others.”
Relations between Contextual Resources & Prior Knowledge Resources (CR & PKR)	Statement and question statement that link theoretical concept(s) not in the given learning materials, but from prior knowledge to the contextual resources. e.g., “This is the south of Singapore. There are a lot of awesome things happening at the same time also.”

**Table 3.** Coding categories for integration of interdisciplinary concepts.

Categories of Interdisciplinary Concepts	Descriptor and Sample Statements from Group Discourse
Concepts from a single subject	Statement and question statement that contain theoretical concept(s) from only one subject area (e.g., geography) where students make connection between the study of places and the relationships between people and their environments. e.g., "Take a picture of the boat and all the food, etc., around here to show how busy the place is."
Concepts from integration of two subjects	Statement and question statement that contain theoretical concept(s) from two subject areas (e.g., history and geography) where students make connection between historical events and physical geography of people and their living environments. e.g., "I know what... 1960s, 1970s, Singapore was still a very new country ... so they would rather spend that time building up residencies and industrial areas, businesses rather than focusing on arts and culture and entertainment."
Concepts from integration of three subjects	Statement and question statement that contain theoretical concept(s) from three subject areas (e.g., history, geography and biology) where students connect historical events to the study of places (physical & human geography), as well as environmental biology on human activities in a particular area. e.g., "Clarke quay fell silent. So he decided to make it into a commercial residential and entertainment precinct. So they cleared the river because it was very polluted at that time".

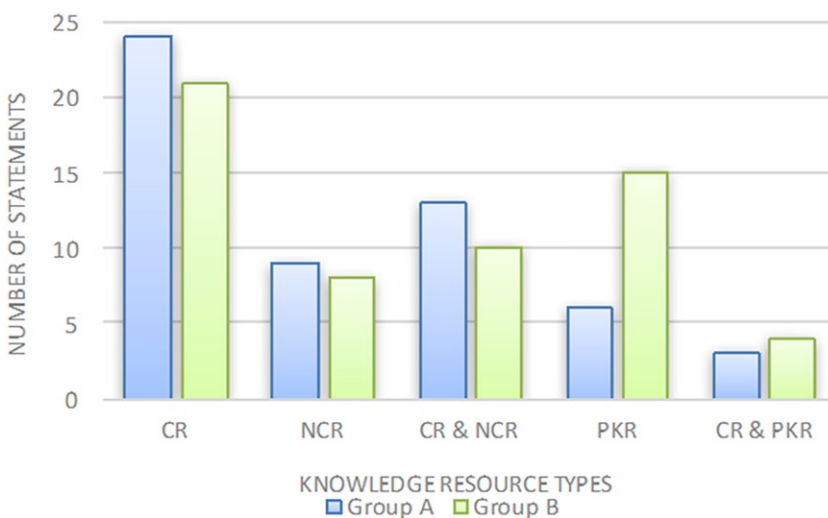
the relations between contextual resources and prior knowledge resources (CR & PKR). The relation between new conceptual resources and prior knowledge resources was not examined, as these two types of resources are mutually exclusive.

To identify evidences of interdisciplinary connections in the meaning-making process, we also coded the 113 segments (Group A had 55 segments and Group B had 58 segments) for integration of concepts from biology, geography, and history. Table 3 shows the coding categories and the respective sample statements taken from group discourse: statements showing (1) concepts from only a single subject; (2) concepts from the integration of two subject areas; and (3) concepts from the integration of three subject areas.

## Findings

### *Student use of different knowledge resource types*

Concerning the first research question about students' use of different knowledge resources during the outdoor learning trail, Figure 3 shows the frequency of the range of knowledge resources for Group A

**Figure 3.** Frequency of knowledge resource types used in group discourse.

Note: CR=Contextual Resources, NCR=New Conceptual Resources, CR & NCR=Relations between Contextual Resources and New Conceptual Resources, PKR=Prior Knowledge Resources, CR & PKR=Relations between Contextual Resources & Prior Knowledge Resources.

and Group B. Both groups showed higher use of contextual resources (CR) as compared to other knowledge resource types. For both groups, contextual resources were chiefly instrumental in the meaning-making processes. Content analysis of students' utterances showed them making constant references to physical affordances of the environment in negotiating meanings and affirming findings to their inquiries (see Excerpt 1). The location of the riverbanks and the activities enabled group A to contextualize the discussion of the changes at the Singapore River from a trading port to the tourist attraction with shops, eateries, and entertainments.

Excerpt 1: Group A's discussion on Singapore as a trading port in the early years.

Student	Statement	Knowledge Resource Type
Student C	No. The trading port was not removed; it was just replaced.	CR
Student I	Oh, this is the inner bank.	CR
Student G	It was removed because they wanted to replace it.	CR
Student I	Now, it's a tourist attraction.	CR

Another noteworthy finding is that students were able to affirm new conceptual resources (NCR) learned from the given learning materials in class by harnessing contextual resources in the outdoor setting (CR & NCR) (see Excerpt 2). As evident in the discourse, students reviewed known concepts and recontextualized them as they interacted with the contextual resources embedded in the outdoor environment. This led to the collaborative co-construction of new meanings/ideas. The *immediacy* of contextual resources (structured trail activities took place prior to the unstructured activity) and the *currentness* of the interaction with the learning environment enabled learners to make connections between contextual resources and new conceptual resources acquired in the given learning materials.

Excerpt 2: Group B's discussion on the timing of the clean river campaign

Student	Statement	Knowledge Resource Type
Student T	... why it didn't happen then, is because that the Singapore has plans for tourist attraction.	NCR
Student E	No, because he wanted it to be a flourishing commercial and entertainment.	CR
Student Y	See, it was all part of the plan to turn the river into more of commerce and trade center.	CR & NCR
Student E	but they wanted to ship the historical things here.	CR & NCR

One distinguished difference between both groups lies in the activation and application of prior knowledge resources (PKR). Group B generated a higher number of statements (question statements inclusive), showing a higher usage of prior knowledge resources than Group A did (see Figure 3). We attribute this phenomenon to the nature of pre-trail inquiry generated by each group. Group B's pre-trail inquiry focused on the "timing of the clean river campaign starting in the late 1970s for a period of 10 years" and they hypothesized that some significant events could possibly explain the occurrence of the clean river campaign. Analysis of the discourse moves in Group B's discussion and field notes showed them referring to significant events and developments in Singapore during the researched period (see Excerpt 3). Contextual resources drawing on the structured activities were insufficient for their line of inquiry. They had to affirm these inferences with authoritative sources on the Internet to advance existing prior knowledge on the location of museums near the Singapore River.

Excerpt 3: Group B's discussion on the location of the museums

Student	Statement	Knowledge Resource Type
Student E	The google map. On the surrounding. The surrounding here has a lot of museums right? So it shows that it is a tourism area. So naturally naturally you have to clean it because tourists will come here.	PKR
Student T	That's the thing. This is the south of Singapore. There are a lot of awesome things happening like at the same time also.	CR & PKR

Next, the activation of prior knowledge resources and the application of contextual resources enabled the students to see the relations between the two types of knowledge resources. As aforesaid, Group B activated more prior knowledge resources and showed a greater number of statements showing relationships between context resources and prior knowledge resources (CR & PKR) as compared to Group A (see Figure 3). The interaction with the physical features of the environment enabled them to leverage contextual resources such as environmental artifacts to concretize prior knowledge and to support their hypotheses and affirm findings on the clean river campaign.

### **Relationships between environmental interaction and use of knowledge resources**

Concerning the relationship between the different types of knowledge resources and students' interaction with the environment (in research question two), we examined (a) the relationship between contextual resources and new conceptual resources, and (b) the relationship between contextual resources and prior knowledge resources.

#### **Relationship between contextual resources and new conceptual resources**

By positioning the outdoor learning trail as an integral part of the formal curriculum, the pre-trail activities in the classroom and the structured activities during the outdoor learning trail form a significant repository of contextual resources that can be integrated with new conceptual resources. First, the provision of pre-trail tune-in activities on famous rivers and the introduction of the BIG question on "Why civilization start at the mouth of a river" are both critical platforms for students to generate their line of inquiry and hypothesis that they intended to pursue during the unstructured learning activity. Albeit that the eight groups from the two classes formulated varied inquiries and hypothesis, yet their intended research inquiries fall within the parameters of the BIG question and the integrated conceptual understanding of the three different subject areas on river, civilization and change. Contextual resources were instrumental for the development of new conceptual resources.

Second, structured trail activities ranging from well-structured tasks on measuring water conditions to ill-structured tasks on the importance of water quality also form a critical component of the contextual knowledge resources students could use during the unstructured activity where they pursued their own line of inquiry. Figure 3 shows a high usage of contextual resources in contrast to other knowledge resource types. Another reason is the 'immediacy' of contextual resources (structured trail activities took place prior to the unstructured activity) and the 'currentness' of the interaction with the learning environment where learners are empowered to develop new conceptual resources and draw sound relations between contextual resources and their new conceptual understanding.

Apart from leveraging contextual resources on water quality, environmental interaction was key to the use of contextual resources and the development of new conceptual resources. As evident in Group A's discourse (see excerpt 4), contextual resources on water quality led to the development of new conceptual resources on sedimentation and pollution. Students were able to apply theoretical knowledge about water and pollution learned in the given materials. They attached new meanings to the context and construct new knowledge and concepts arising from tourism, boats, and pollution.

Excerpt 4: Group A's discussion on transforming the Singapore River from a trading port to a tourist site

Student	Statement	Knowledge Resource Type
Student C	No, no, the trading port wasn't removed. It was replaced ... it was replaced to make way for tourist attractions and others.	CR & NCR
Student G	There's more pollution around the sedimentation...this area because of the...	NCR
Student K	I thought there's more pollution on the other side.	CR & NCR
Student G	There should be more here because there's a lot of ... boats.	CR & NCR
Student C	There are more tourists around here, so //the boat has to ferry more.	

### ***Relationship between contextual resources and prior knowledge resources***

Students' capacity to draw valid inferences is largely contingent on the environmental interaction to make sense of the contextual resources and prior knowledge resources. Interaction with the physical features of the environment enabled them to activate and concretize prior knowledge during the meaning-making process. This is evident in the discourse (see Excerpt 5) between Students E and G, as well as Students T and E where the group recontextualized and reinterpreted the surrounds of the Singapore River: they were able to attach new values and meanings to the objects and the features (Pachler, 2009). Next, the activation of prior knowledge resources and the application of contextual resources enabled the students to see the relations between the two types of knowledge resources, as shown in the discourse moves: Student E spoke of the vanishing trade of the street hawkers and the plan for more expensive tenants; Student Y further advanced this knowledge with his prior knowledge on location, the use of land, and the price of land (see Excerpt 5).

Excerpt 5: Group B discusses possible reasons for relocating the port in the clean river campaign

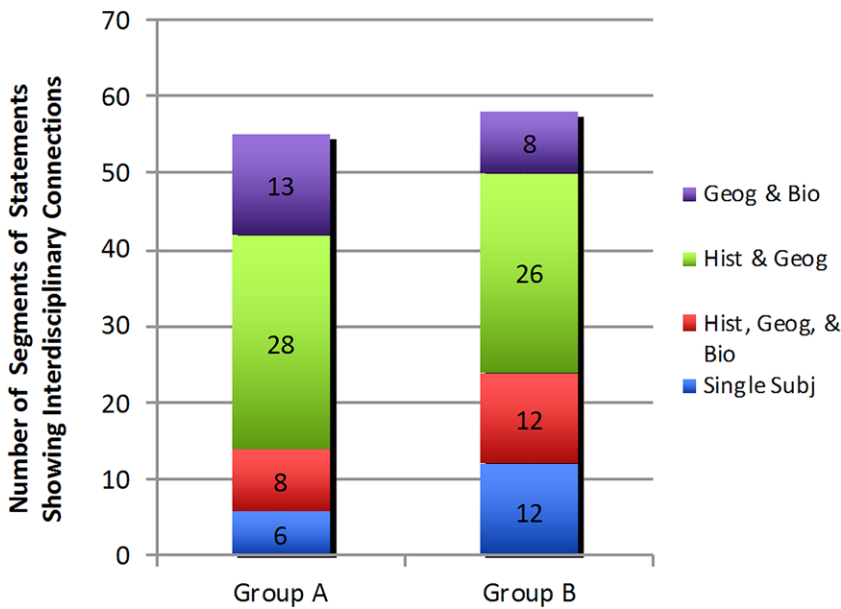
Student	Statement	Knowledge Resource Type
Student E	Oh because Pasir Panjang had new modern facilities. So they decided to relocate the cargo services.	PKR
Student G	Near my house, near the west.	
Student T	Then what happened to the port here?	PKR
Student E	And also, they renovate the place. So that ... so that there will	
Student T	Better tenant because it's a very modern thing.	
Student E	Because at that time, there were a lot of street hawkers, so then, they decided to have people who are good at art ... more expensive tenants. So they decided to conserve it and organize the place. Get it?	CR & PKR
Student Y	The basic is that they are trying to raise the price of the land?	CR & PKR

However, the scope and subject matter of the various groups' pre-trail inquiries to a considerable measure influenced the use of the knowledge resources types in their group discourse. Group B activated more prior knowledge resources to make valid inferences to their inquiries, as illustrated in [Figure 3](#). Further, in the absence of the physical presence of teachers, Group B made use of the authoritative sources via the Internet to affirm their prior knowledge resources relating to the contextual resources and to draw new inferences. Environmental interaction such as the location mapping and navigational possibilities (e.g., bearings, distance, and scale, etc.) has given them greater agency to test their hypothesis about the clean river campaign and possible significant events. They were able to locate environmental artifacts as evidences to support their hypotheses and affirm findings.

### ***Effect of environmental interaction on interdisciplinary connections with knowledge resources***

To address research question three on interdisciplinary connections, we analyzed the discourse of both groups at two levels. First, we looked at the number of segments of statements demonstrating the integration of two or three subject areas as compared to statements showing only one subject area. Next, we examined the interdisciplinary connections in the different types of knowledge resources in both groups' discourse. Finally, we provide an excerpt of the students' discourse to illustrate how environmental interaction fostered interdisciplinary thinking, i.e., how students were able to see relations and draw valid inferences to create new meanings by integrating concepts/knowledge of two or more disciplines.

First, [Figure 4](#) provides an overview of the frequency of statements showing evidences of interdisciplinary thinking in the group discourse for Group A and Group B respectively. Group A made 55 statements, 41 of which were statements demonstrating two interdisciplinary connections of either a combination of history and geography or geography and biology. Group B had 58 segments of statements, where 34 segments of statements showed two interdisciplinary connections. For statements showing evidences of three interdisciplinary connections, Group A made 8 statements and Group B made 12 statements. Overall, almost 80% of the statements in both groups' discourse were interdisciplinary with

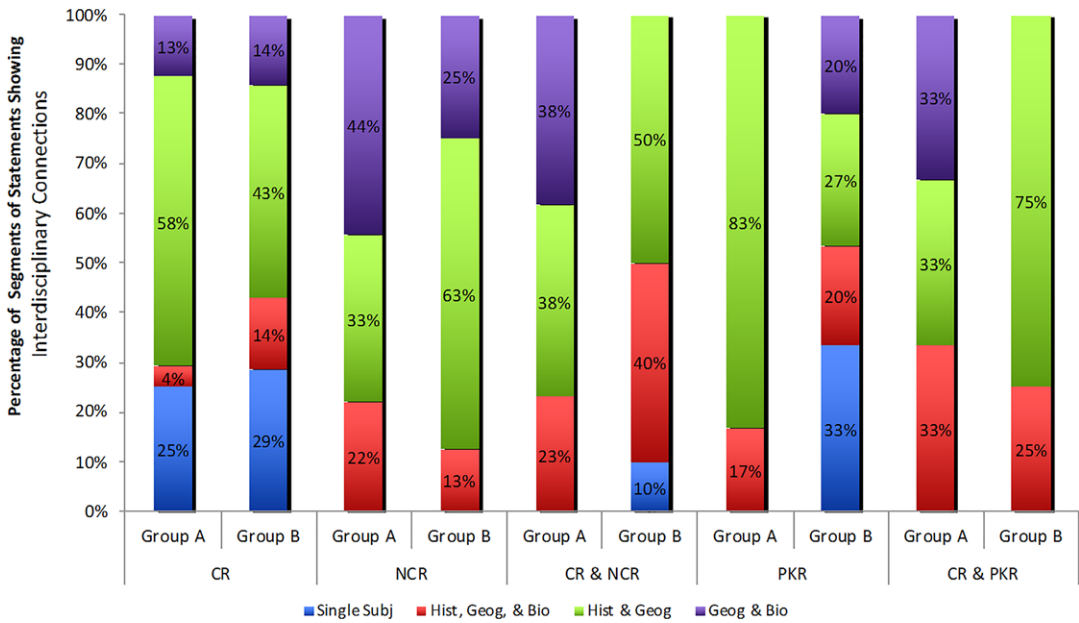


**Figure 4.** Frequency of interdisciplinary statements in group discourse.  
 Note: Geog = Geography, Bio = Biology, Hist = History, Single Subj = Single Subject.

two or more subjects. There were only 6 statements and 12 statements containing a single-subject idea in Group A and Group B respectively.

Next, we analyzed the group discourse for interdisciplinary thinking in the different types of knowledge resources used in the mean-making process. Figure 5 provides an overview of the interdisciplinary connections both Groups A and B made as they pursued their pre-trail inquiries. Overall, both groups of students demonstrated the ability to see relationships and draw interdisciplinary connections in the meaning-making process with almost 70% of the statements in each of the knowledge resource types containing two or more interdisciplinary ideas. Comparing the percentage of statements showing connections between two subject areas, both groups showed a higher percentage of statements with a combination of history and geography, as with geography and biology across the knowledge resource types in general. We believe that the integration of disciplines is contingent on the nature of their pre-trail inquiries. Noteworthy is also the integration of all three subjects (i.e., history, geography, and biology) in drawing relationships between contextual resources (CR) and new conceptual resources (NCR): the percentage of occurrences for integrating three subject areas seemed higher for both Group A (23%) and Group B (40%) in the use of CR & NCR as compared to integrating three subject areas in the use of contextual resources (CR) or new conceptual resources (NCR) or prior knowledge resources (PKR) alone. This was also true for the integration of all three subjects in drawing relationships between contextual resources (CR) and prior knowledge resource (PKR): Group A (33%) and Group B (25%).

Owing to space constraints, we provide here a discussion of an excerpt of the discourse that illustrates how students made interdisciplinary connections of two or three subjects in the use of these different resource types. Group B's pre-trail inquiry was to find out why the "Clean Singapore River Campaign" started in the late 1970s. They first began with contextual resources to identify the location of Singapore River and discussed the quality of water; here they demonstrated interdisciplinary thinking linking geography and biology (see Table 4, segment 1). Next, the students drew on the new conceptual resources connecting these two disciplines as they discussed marine life in relation to the location and water quality (see Table 4, segments 2 to 4). Consequentially, they harnessed both contextual resources and new conceptual resources (see Table 4, segment 5) showing interdisciplinary connections of history, geography and biology to identify one possible reason for the occurrence of the "Clean Singapore River Campaign" in 1977 for 10 years. The findings seem to show that environmental interaction plays a significant role



**Figure 5.** Interdisciplinary thinking in the different types of knowledge resources.  
 Note: CR=Contextual Resources, NCR=New Conceptual Resources, CR & NCR=Relations between Contextual Resources and New Conceptual Resources, PKR=Prior Knowledge Resources, CR & PKR=Relations between Contextual Resources & Prior Knowledge Resources, Single Subj=Single Subject refers to History or Geography or Biology, Geog=Geography, Bio=Biology, Hist=History.

**Table 4.** Group B discusses possible reasons for the clean river campaign.

Segment No	Student	Statement	Knowledge Resource Type	Interdisciplinary Thinking
1	Student E	Singapore river, Singapore river.	CR	Geography & Biology
	Student Y	Do you see the place?		
	Student T	Correct right, Gavin? Lower pH		
	Student G	More acidic.		
2	Student T	More acidic. Now dissolved oxygen. The dissolved oxygen...dissolved oxygen does what?	NCR	Geography & Biology
	Student E	Huh?		
	Student T	Other than promote marine life.		
	Student E	Dissolved oxygen...		
	Student T	Yea.		
3	Student E	Plants also?	NCR	Geography & Biology
	Student E	Wait, plants make dissolved oxygen.		
	Student G	No, the aquatic plants take in carbon dioxide and give out oxygen.		
4	Student E	I think when its aquatic and, aquatic life is there, //marine life is there, then you can.	NCR	History, Geography & Biology
	Student T	It will promote fishing all that. In the past times ... say that...		
5	Student E	I think it shows... it shows //how clean the how clean the country is.	CR & NCR	History, Geography & Biology
	Student T	Is it illegal to fish here?		
	Student G	It's illegal		
	Student T	It's illegal, right? Exactly. Then say last time...		
	Student Y	In the past?		
	Student T	Yea in the past. Other than that, // do we need to do any river, river water testing here?		

Note: CR=Contextual Resources, NCR=New Conceptual Resources, CR & NCR=Relations between Contextual Resources and New Conceptual Resources, PKR=Prior Knowledge Resources, CR & PKR=Relations between Contextual Resources & Prior Knowledge Resources.



in students' use of knowledge resource types, as well as in fostering interdisciplinary thinking to see the relationships.

## Discussion

This research study examined the effect of environmental interaction on interdisciplinary thinking and the use of the different types of knowledge resources. We posited that the affordances of the outdoor environment present authentic learning opportunities for students to experience and to explore the natural resources and natural phenomenon embedded in the real-world setting. In this study, students in the outdoor learning environment were able to concretize the abstract knowledge consumed within the confines of the classroom. Further, knowledge is no longer compartmentalized in neat separate disciplines, but assumes greater relevance when students saw for themselves the relationships between these disciplines, e.g., how physical geography is related to environmental biology in the outdoor environment.

The results indicate, first, students leveraged heavily on *contextual knowledge resources* to negotiate meanings and to co-construct knowledge. Both groups' discourse showed higher frequencies of statements made using contextual knowledge resources as compared to the other knowledge resource types. Here, environmental interaction plays a pivotal role in harnessing contextual knowledge resources. The content analysis showed that students drew connections between the different types of human activities and the specific areas in the environment. They were also able to explain why certain activities were discontinued and how the specific area was restored or demolished to make way for current activities. Also, students were able to concretize new conceptual resources and to apply prior knowledge resources due to their physical interaction with the environment. This is evident from their utterances where a particular place(s) and/or significant national event(s) forms their frames of reference in making inferences and drawing connections. They were able to obtain a holistic picture of why specific areas were set apart for specific activities along the Singapore River. Students were able to reconcretize knowledge and concepts owing to the immediacy and currentness of interaction with the rich physical affordances to re-contextualize and to reinterpret contextual and prior knowledge resource.

Second, students were able to see relations between contextual resources and new conceptual resources, as well as between contextual resources and prior knowledge resources. For instance, students made use of the contextual resources to re-concretize and to re-interpret theoretical concepts acquired in the three subject areas. This is apparent in Group B's discussion of marine life and human activities at the Singapore River, which they postulated were reasons for the clean Singapore River campaign. Likewise, for Group A, the location of buildings, shops, and the organization of human activities along the Singapore River enabled them to make sense of the reasons for the change that had taken place in the past three decades. Contextual resources in the physical and social outdoor environment were instrumental to activate prior knowledge and to advance knowledge.

Third, the naturally occurring opportunities of the outdoor environment enhance students' capacity to develop and to concretize interdisciplinary thinking. Content analysis showed that students across the two groups were able to link quality of water at the different points of the river to the environmental activities: they were engaged in discourse that required content knowledge in at least two or more disciplines. For instance, Group B's pre-trail inquiry on the clean Singapore River event initially contained only one subject area—history. However, as the students explored the different points of the Singapore River, they began to integrate new conceptual resources from biology and geography to substantiate their claims on the timing of the Clean River Campaign.

Although we witnessed some promising results in this research study, we acknowledge that there could be limitations. First, this study examined the discourse and interaction of two selected groups. The smallness of scale and the solitary nature of the research context need some caution for generalizing these findings to other contexts and research interventions. Second, this study examined history, biology, and geography as disciplinary areas and the findings might not be generalized to the integration of other disciplines whose cultural and social practices differ with changing learning contexts. Third, this study examined the students' environmental interaction within the unstructured learning activities. It will be

worthy to examine how the structured and unstructured learning experiences are interrelated and integrated to provide desired learning experiences. For future research directions, finding an optimal level of structure in outdoor activity design remains an important issue for researchers to further explore. In addition, although the framework on knowledge resources was employed in this study, the notion of “epistemic resources” (Hammer & Elby, 2003) may provide an alternative lens concerning how deep understandings emerge through epistemic sense-making. Lastly, this study was conducted from the perspective of qualitative research, which in its essence is interpretivist, rather than the perspective oriented toward post-ontology that emphasizes being rather than knowing (Lather & Pierre, 2013; MacLure, 2013). Methodologically, we acknowledge the limitation that this study was pursued through the quantitative content analysis method, and current post-quality research may generate descriptions and representations different from this study.

Despite these limitations, we are persuaded that we can equip our students with the necessary knowledge base for harnessing the affordances of outdoor learning to make interdisciplinary connections.

## Implications

Our findings carry four important implications on the value of outdoor learning in facilitating the acquisition of knowledge and skills and in fostering interdisciplinary thinking: (a) context; (b) content; (c) the integration of context and content; and (d) control and choice. First, knowledge is a “dynamic by-product” of an individual’s interaction with the environment where these individuals could immerse and engage in contexts of the authentic learning setting (Brown & Duguid, 1989). The situatedness of knowledge and being in “context” has greatly enhanced students’ meaning-making process. Places, objects, and human activities, where and why, began to assume concrete meaning. This enabled students to see a natural connection between different disciplines. Contextualized learning in outdoor can be enhanced with technological modalities. Although mobile technologies were not the main focus of analysis in this study, the mobile platform with various applications bridging the physical and digital/represented spaces helped students to build a sense of self-and-place in relation to the context of learning (Taylor, 2017).

Second, content plays an equally crucial role as the authenticity of the tasks has an effect on the learning process. As Choi and Hannafin (1995) put it, knowledge is “structured by the activity in which it is developed and deployed; not just learning, but knowledge itself is situated” (p. 57). By being in context, being in the most appropriate outdoor environment does not promise desired learning outcomes if the learning activities do not frame or engineer the desired interaction with the environmental affordances. Hence, to orchestrate the designed learning experiences, it is important for students to have relevant content-related knowledge, whether they gained it in formal or informal learning settings as knowledge resources. The design mechanism in this study was to embed the pre-trail lessons and the structured learning activities in the learning trails where students were able to gain relevant conceptual understanding through structured activities.

Third, context and content are intricately interwoven, and we need to harness the affordances of these two fundamental constructs in outdoor learning to facilitate the development of interdisciplinary thinking and connections. The staging of the learning continuum from pre-to-post trail was a pivotal measure to facilitate the execution of the unstructured learning activity and to provide learners with the contextual knowledge resources. *Sufficient* contextual resources are necessary for students to interact with the environment meaningfully to develop new knowledge and concepts. This study provides practical implications that the integration of context and content is critical for students to move beyond the state of inert knowledge. Prior knowledge resources and new conceptual knowledge resources that students gain from formal and informal learning experiences need to be activated in situ with relevant contextual resources.

Fourth, choice and control in the interaction with the outdoor environment is essential to recontextualize and to reconcretize meaning. We can promote a measure of “choice and control” by providing an unstructured learning space within a structured outdoor learning activity. Research has shown that learners learn more meaningfully if their learning experiences allow them a sense of agency over their own learning when they experience autonomy over choice of actions and having a sense of purpose for

taking those actions (Daniel, Bobilya, Kalisch, & McAvoy, 2014; Maulucci & Brotman, 2010). The unstructured learning activity not only helped students develop a “sense of situational intent,” but also “forced” them to exercise collaborative reflective thinking to make sound inferences as they affirmed relations between the different disciplines and drew conclusions, harnessing the different types of knowledge resources.

In sum, this study exemplifies the significance of environmental interaction in outdoor learning. The authenticity of the learning setting and the rich affordances of the physical environment fostered students’ use of different knowledge resource types as well as students’ interdisciplinary thinking. Of equal significance is the design of the different activity types (structured and unstructured) to equip and to empower students’ capacity to leverage the unique affordances of such a rich outdoor learning environment.

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