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EURASIA Journal of Mathematics Science and Technology Education  
ISSN: 1305-8223 (online) 1305-8215 (print)  
2017 13(8):5343-5363  
DOI: 10.12973/eurasia.2017.00833a



## Teaching and Learning Science Outdoors in Schools' Immediate Surroundings at K-12 Levels: A Meta-Synthesis

Jean-Philippe Ayotte-Beaudet  
Université du Québec à Montréal, CANADA

Patrice Potvin  
Université du Québec à Montréal, CANADA

Hugo G. Lapierre  
Université du Québec à Montréal, CANADA

Melissa Glackin  
King's College London, UNITED KINGDOM

Received 1 January 2017 • Revised 1 March 2017 • Accepted 1 April 2017

### ABSTRACT

This literature review synthesizes empirical data of 18 articles published between 2000 and 2015 about teaching and learning science outdoors from kindergarten to secondary levels (K-12). We asked four questions: (1) What are the general characteristics of the corpus of studies on teaching and learning science outdoors in schools' immediate surroundings at K-12 levels? (2) What are the authors' aims for conducting studies about teaching and learning science outdoors? (3) What are the main outcomes related to teaching and learning science outdoors in schools' immediate surroundings? (4) What further studies should, according to the selected articles, be conducted in the future? We identified three categories of authors' aims: environmental education, science education, and outdoor education. The main outcomes are classified into four categories: 1) learning, 2) student attitude or interest, 3) other students' perceptions, and 4) challenges to outdoor science teaching. Finally, in light of the review, we discuss how further studies should consider learning outcomes, students' attitudes, challenges, and methodological guidelines.

**Keywords:** environmental education, meta-synthesis, outdoor science, primary school, science education, secondary school

### INTRODUCTION

#### Science education and learning outdoors

In everyday life, scientific phenomena and scientific work do not necessarily happen indoors. For example, scientists need to go outside in order to study habitats, the effects of changing seasons on plants, or the effects of urban heat islands on human health. Paradoxically, science education at school generally happens indoors; it is only on rare occasions that it unfolds outside (Glackin, 2013, 2016; Rickinson et al., 2004). This might at least partly explain why many authors claim that more connections with real-life settings should be established to counterbalance the frequently reported and denounced lack of *authenticity* at school (Bencze & Hodson, 1999; Braund & Reiss, 2006; Fägerstam, 2014; Gafoor & Narayan, 2012; Krapp & Prenzel, 2011; Potvin, & Hasni 2014; Rivet & Krajcik, 2008; Smith, 2013; Tal, Alon, & Morag, 2014).

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**Correspondence:** Jean-Philippe Ayotte-Beaudet, *Département de didactique, Université du Québec à Montréal, Case postale 8888, succursale Centre-ville, Montréal (Québec) H3C 3P8, Canada. Tel: 1-514-999-6647.*

✉ [ayotte-beaudet.jean-philippe@uqam.ca](mailto:ayotte-beaudet.jean-philippe@uqam.ca)

#### State of the literature

- During the last decade, many studies showed that outdoor education could positively influence students' attitudinal/motivational constructs and contribute to their achievement. However, few articles synthesized findings in the context of science education.
- More is known about outdoor science in non-formal settings in the scientific literature than about outdoor science as part of a regular lesson at school.
- While there is a burgeoning literature on outdoor science appearing in science education journals, we did not find any clear portrayal of the situation in this field.

#### Contribution of this paper to the literature

- This article presents a specific systematic meta-synthesis of articles published between 2000 and 2015 in the field of outdoor science when practiced near the school grounds from kindergarten to secondary levels.
- Results indicate that there are still many challenges to teaching and learning science outdoors and that further studies should investigate the most effective ways to teach science outdoors.
- While this meta-synthesis identifies findings about outdoor science in schools' immediate surroundings, it also suggests further directions for further studies in the field.

In order to make school activities more authentic, it has been argued that teachers could consider the possibility of teaching science outdoors when this context shows potential. Indeed, such a rich environment often provides teachers with the opportunity to *contextualize* certain concepts (Braund & Reiss, 2006). Studies in the field of outdoor education also concluded that such learning environments could positively influence students' knowledge, attitude, interest, or motivation (Bogner, 2002; Braund & Reiss, 2006; Fägerstam, 2014; Fägerstam & Blom, 2013; Hovardas, 2016). For example, Fägerstam & Blom (2013) noted that students who learned outdoors showed better long-term knowledge retention. In another article, after conducting a longitudinal case study with teachers who frequently exploited the possibilities of school grounds, Fägerstam (2014, p. 78) concluded that "school-based outdoor learning increased student motivation and enjoyment." Many other research efforts have, in the same line of thought, reached the conclusion that outdoor environments can also favour contextualization in science lessons at K-12 levels, without compromising student achievement (Braund & Reiss, 2006; Fägerstam, 2014; Glackin, 2013; Uitto, Juuti, Lavonen, & Meisalo, 2006).

#### Research on learning science outdoors in schools' immediate surroundings

In 2004, the National Foundation for Educational Research and King's College London in England published a major influential review of outdoor learning (Rickinson et al., 2004). This research report "critically examined 150 pieces of research on outdoor learning published in English between 1993 and 2003" (p. 5). Their corpus covered three outdoor learning categories: 1) fieldwork and outdoor visits, 2) outdoor adventure education, and 3) school grounds/community projects. Without focusing on a particular subject matter such as science education, they reported that school grounds/community projects "have the capacity to link with most curriculum areas," that they might "include greater confidence, renewed pride in community, stronger motivation toward learning, and greater sense of belonging and responsibility," and that they might also "develop more positive relationships with each other [students], with their teachers and with the wider community" (p. 6). Furthermore, due to its close proximity and ease of access, one could argue that school grounds have great, yet underutilized, potential to help science teachers to achieve meaningful contextualization of learning. Undeniably, many other very rich contexts such as museums and field trips also allow interesting *real-life/school content* anchoring. However, they often require transportation and complex logistical organization that is not always easily compatible with schedules, especially at the secondary level (Glackin, 2013). Hence, given the potential of school grounds for learning, we chose to concentrate our synthetic efforts on this particular context.

Despite the alleged benefits, school-ground learning has been judged, at the turn of the century, to suffer from a supposed lack of "rigorous in-depth studies" (Rickinson et al., 2004, p. 41). A decade later, things did not

seem to have improved much. Indeed, Fägerstam & Blom concluded, in 2013 (p. 58), that there are still “few studies concerning outdoor learning as part of ordinary school work.” For their part, Tal, Alon, & Morag (2014, p. 431) suggested that outdoor education “is extensively studied, but not always in the science education literature.” Therefore, research might benefit from investigating outdoor teaching and learning science at school.

### Research questions

In response to these important and timely concerns, we felt the need to further systematically investigate the recent research literature in search of available and convincing results. Consequently, this article aims to identify and synthesize recent studies that were published in peer-reviewed journals in the field of learning science outdoors that happens in schools’ immediate surroundings, from kindergarten to secondary levels (K–12). The four research questions are as follows:

1. What are the general characteristics of the corpus of studies on teaching and learning science outdoors in schools’ immediate surroundings at K–12 levels?
2. What are the authors’ aims for conducting studies about teaching and learning science outdoors?
3. What are the main outcomes related to teaching and learning science outdoors in schools’ immediate surroundings?
4. What further studies should, according to the selected articles, be conducted in the future?

## METHODS

### Selection of the articles

We selected research articles with empirical results about teaching and learning science outdoors at K–12 levels published in peer-reviewed journals. Since we did not retrieve any specific synthesis about outdoor science since Rickinson et al.’s (2004) report, our main concern was to synthesize the most recent findings. This explains why we limited the meta-synthesis to articles published between 2000 and 2015. It also seemed important to choose peer-reviewed articles to uphold standards of quality. Because of these choices, we did not include comments or self-reported teaching experiences, books, research reports, theses, or unpublished materials. These materials often meet quality standards, but the most robust and innovative empirical data is usually published in peer-reviewed journals, despite the fact that we acknowledge that peer-reviewed is not the only criterion of quality.

To constitute the corpus, we queried the Education Resources Information Center (ERIC) database by EBSCOhost using the Boolean search mode. This choice is explained by the selection standard applied by the database, which is “related to one or more of the topics in the field of education,” and quality criteria: “completeness, integrity, substantive merit, utility/importance and educational research” (<https://eric.ed.gov/>). ERIC only considers materials written or translated into English, which excludes any materials not corresponding to these criteria. It is also the most commonly used in education.

We identified six expressions related to outdoors, which are *outdoor education*, *outdoor teaching*, *outdoor learning*, *outdoor activities*, *out-of-school*, and *outside learning*. In addition to *science education*, we searched for *environmental education*, because learning about the environment can sometimes be explicitly linked with science. To constrain the research to K–12 levels, we used the terms *kindergarten*, *primary*, *elementary*, *secondary*, and *high school*. Final criteria used to query ERIC anywhere in the abstracts, descriptors, titles, or texts were: (*outdoor education* OR *outdoor teaching* OR *outdoor learning* OR *outdoor activities* OR *out-of-school* OR *outside learning*) AND (*science education* OR *environmental education*)<sup>1</sup> AND (*kindergarten* OR *primary* OR *elementary science* OR *secondary* OR *high school*) AND (*peer reviewed*) AND (date published: 2000-01-01 to 2015-11-26) AND (*academic journals*).

<sup>1</sup> We also tried to include different disciplines such as ecology, biology, chemistry, and physics, but we did not retrieve additional articles.

On November 26, 2015, our final search led to 310 results. For the purposes of further selection, we considered six additional filter questions for which the answer should clearly be *yes*:

- Does the article present empirical results?
- Is the study focused on formal education?
- Is the considered teaching or learning situated between kindergarten and the end of secondary school (K-12)?
- Are the outcomes explicitly related to science education, partly or entirely?
- Do the results of the considered study relate to outdoor teaching or learning, partly or entirely?
- Is the outdoor area located on school grounds or in the surrounding areas?

After applying these 6 filter questions, we constituted a corpus of 18 peer-review articles obtained with an interrater agreement. These are listed in Appendix 1. We refer to them with this number in square brackets “[ ]” in the results section.

The low number of selected articles (18/310) highlights a considerable selection effort. Despite the fact that we expected to retrieve more articles, we did not change our criteria because we did not want to cut down the quality and strictness of the expected results.

### Analysis

To analyze the corpus, we developed a grid specifically for the purpose of this review. We adapted the grids used in Hasni, Bousadra, & Marcos's (2011) literature review on project-based approach and in Potvin & Hasni (2014) literature review about interest, motivation, and attitude. We then used four articles of the corpus to validate the grid and produce a final version (see Appendix 2). The analysis grid comprises five categories: article information (2 items), context and theoretical backgrounds (11 items), methodological information (5 items), results (3 items), and general remarks (3 items).

Initially, one member of our team applied the analysis grid to code the material and a second team member subsequently cross-checked the data. Items for which there was no initial interrater agreement were discussed until a consensus was reached. Needless to say, the analysis also necessitated many back and forth confirmations between the contents of the grid and the articles themselves.

## RESULTS AND INTERPRETATIONS

### **(Q1) What are the general characteristics of the corpus of studies on teaching and learning science outdoors in schools' immediate surroundings at K-12 levels?**

The general characteristics selected to describe the corpus (18 articles) were *authors, years of publication, geographic origin of data, school grades, type of data, research methodologies, instruments, participants, and investigated outcomes*. To avoid misinterpretation of this information, we prevented ourselves from going beyond what was explicitly reported by the authors except for *instruments* and *investigated outcomes*, which required synthetic and formatting efforts for the purposes of efficient and possibly comparative reporting. For example, a study used “two video cameras, three iPods, and two digital cameras” for classroom observation [7, p. 1349], so we reported these instruments under *observations*. In another article, the outcomes investigated by the authors were the “understanding of the water cycle” [1, p. 53] that we reduced to the general category of *science learning*.

In **Table 1**, the reader will find a synthetic presentation of the general characteristics of the selected articles.

The geographic origin of data was mostly North America (8) and Europe (6), while Asia (2) and Oceania (2) were also represented. It is worth noting that among the North American articles, 7 out of 8 were from the United States. Sarah J. Carrier published 4 of these 7 as first author in 2003, 2009, 2013, and 2014. Even though the corpus is composed of articles published between 2000 and 2015, two-thirds (12) of them were published in the last third of the considered time period (from 2011 to 2015). Two-thirds of the studies (12) were strictly about the primary level, 4 others were strictly about grades 7 to 12, and 2 considered both primary and secondary levels.

**Table 1.** Teaching and learning science outdoors at K–12 levels: general characteristics of the research articles

Authors (years of publication)	Geographic origin of data	School grades	Type of data	Research methodologies (as reported)	Instruments	Participants	Investigated outcomes
[1] Ben-Zvi Assaraf & Orion (2009)	Israel	Grades 7–8	Mixed	Design-based research	Questionnaires	At least 360 students [unclear]	Science learning
[2] Blatt & Patrick (2014)	U.S.A.	Grades 1–6	Qual.	Sociocultural	Written essay and interviews	148 pre-service elementary teachers	Pre-service teachers' experiences and intentions
[3] Carrier Martin (2003)	U.S.A.	Grades 4–5	Mixed	Quasi-experimental pre-/post-tests (Quant.) Inductive (Qual.)	Questionnaires and interviews	104 students	Environmental knowledge, attitudes, behaviours, and comfort levels
[4] Carrier (2009)	U.S.A.	Grades 4–5	Quant.	Quasi-experimental pre-/post-tests	Surveys	109 students	Environmental knowledge, attitudes, behaviours, and comfort levels
[5] Carrier, Tugurian, & Thomson (2013)	U.S.A.	Grade 5	Mixed	Pre-/post-tests (Quant.) [no distinct info for qual.]	Surveys, interviews, and observations	49 students, 2 teachers, and 1 principal	Science knowledge, environmental attitudes, outdoor comfort levels, and teachers' and students' perceptions
[6] Carrier, Thomson, Tugurian, & Stevenson (2014)	U.S.A.	Grade 5	Mixed	Pre-/post-tests (Quant.) [no distinct info for qual.]	Surveys, interviews, and observations	114 students (Quant.); 7 teachers, 30 students, 18 parents, and 2 principals (Qual.)	Science knowledge, environmental attitudes, outdoor comfort levels, and stakeholders' views
[7] Chen & Cowie (2013)	New Zealand	Grade 7	Mixed	Case study	Observations, interviews, and pre-/post-knowledge test	29 students and 4 teachers	Science learning and interest
[8] Christidou, Tseveni, Epitropou, & Kittas (2013)	Greece	Grades 1–6	Mixed	Case study, geographical and participatory design	Drawings, interviews, and observations	230 students	Children's views and experiences of the school ground
[9] Dhanapal & Lim (2013)	Malaysia	Grade 3	Mixed	Action research	Tests and survey	24 students	Students' perceptions and science learning
[10] Dymont (2005)	Canada	K–12	Mixed	Descriptive (Quant.) Case studies (Qual.)	Questionnaires and interviews	41 principals, 75 teachers, and 33 parents	Barriers and opportunities
[11] Eick (2012)	U.S.A.	Grade 3	Mixed	Narrative case study	Observations, interviews, and test	1 teacher and 16 students	Teachers' perceptions and science learning
[12] Fancovicová & Prokop (2011)	Slovakia	Grade 5	Quant.	Quasi-experimental pre-/post-/re-tests	Questionnaire	34 students	Students' attitudes and science learning
[13] Fisher-Maltese & Zimmerman (2015)	U.S.A.	Grade 2	Mixed	Pre-/post-tests (Quant.)	Tests, surveys, interviews, and conversations	66 students, 4 teachers, and 1 principal	Environmental attitudes
[14] Glackin & Jones (2012)	United Kingdom	Grades 7–11	Quant.	Descriptive	Survey	20 teachers	Barriers and opportunities
[15] Hyseni Spahiu, Korca, & Lindemann-Matthies (2014)	Kosovo	Grades 10–12	Mixed	<i>Not mentioned</i>	Questionnaire and interviews	244 teachers	Environmental education and teachers' perceptions

**Table 1 (continued).** Teaching and learning science outdoors at K–12 levels: general characteristics of the research articles

Authors (years of publication)	Geographic origin of data	School grades	Type of data	Research methodologies (as reported)	Instruments	Participants	Investigated outcomes
[16] Lindemann-Matthies et al. (2011)	Cyprus, England, Switzerland, and Germany	Grades 1–6	Quant.	Quasi-experimental, correlational	Questionnaire	680 pre-service teachers	Confidence and perceived competence
[17] Magntorn & Helldén (2007)	Sweden	Grades 3–4	Qual.	<i>Not mentioned</i>	Interviews	23 students	Science learning
[18] Skamp & Bergmann (2001)	Australia	Grades 1–12	Qual.	Interpretive	Interviews	6 primary teachers, 20 secondary teachers, and 2 principals	Teachers' perceptions

Thus, according to this corpus, most research on outdoor science education has focused on the primary school level. More than half of the authors used mixed data (11), whereas others used strictly quantitative (4) or strictly qualitative data (3). Research methodologies were diverse with pre-/post-tests (6) and case studies (4) prevailing. Participants in the 18 articles were students (12), teachers (9), principals (6), pre-service teachers (2), and parents (2); some articles were exclusively about one category of participants, while others included more than one. Finally, the corpus investigated various outcomes, which could be summarized as *students' learning*, *students' perceptions* and *teachers' perceptions*. These results are presented further below (Q3).

**(Q2) What are the authors' aims for conducting studies about teaching and learning science outdoors?**

We have recorded different aims that motivate research efforts in outdoor education in schools' immediate surroundings.

A total of eight articles justified the relevance of conducting studies about outdoor science with environmental concerns. One study, addressing the water cycle, "aimed at developing a meaningful learning experience that would lead to the development of environmental insight among junior high school students" [1, p. 60]. The author of a second article stated that her "study was designed to examine the effects of participation in regular outdoor schoolyard environmental education activities on environmental knowledge, attitudes, behaviors, and comfort levels" [3, p. 53]. The same researcher also conducted another "study [in order] to assess the effectiveness of outdoor activities for teaching environmental science to elementary students" [4, p. 4]. A garden-based approach was also used to measure and track "shifts in students' attitudes toward the environment" [13, p. 51]. Other researchers were interested in investigating "whether outdoor environmental programme influences Slovakian pupils' attitudes towards and knowledge of plants" [12, p. 539]. Three other articles focused on teachers rather than students. Their authors investigated teachers' perceptions about "environmental education development and especially as it relates to formal curricula" [18, pp. 336-337]. In another study, pre-service primary school teachers were questioned "to assess the importance given to biodiversity education" [16, p. 2250]. Finally, in an educational system where the "integration of education for sustainable development" [15, p. 2750] was a priority, teachers were questioned about "their experiences with [environmental education]" [p. 2753]. After reflecting on this enumeration, we came to the conclusion that many authors consider outdoor science essentially for **environmental education** goals. This suggests that science education learning is widely considered as a vehicle for achieving environmental aims.

A second aim for conducting studies about outdoor science teaching and learning was to focus on science learning objectives during a studied intervention. Seven studies were categorized as sharing this kind of goal. Interested in primary education, the authors of one study aimed "to understand students' knowledge and attitudes about the outdoors and environment" [5, p. 2064]. The same team of authors presented an article examining "two

elementary schools' science programs with a focus on each school's efforts to include outdoor learning experiences" [6, p. 2199]. In both cases, they measured environmental attitudes, but their main focus was the development of scientific knowledge. Two other studies were conducted with primary school students from the third grade. One of the studies targeted "enhancing the learning of science significantly" [9, p. 3], while a narrative study documented the case of "an experienced third grade teacher [...] in how she takes her children outdoors and into the woods to enhance their science and language literacy through awareness of nature and the environment" [11, p. 790]. A final study with primary students wanted "to characterise students' sophistication and ability to read nature [...] via an initial focus on one species" [17, p. 69]. At the secondary school level, authors used context-based science education "to frame the description of a unit on New Zealand birds" and explore "[t]he impacts on students of making science relevant and coherent" [7, pp. 1346-1347]. Finally, two researchers conducted a study aiming "to support teachers in identifying possible context-specific barriers to working outside, with an offer of possible 'solutions'" [14, p. 105]. A synthesis of these seven articles exposes a common aim to use outdoor contexts to enhance **science education**.

Across the 18 articles, 3 did not focus primarily on environmental education or on science education. Instead, they considered science education as a pretext to use the school's immediate surroundings. In an article reporting results obtained with 45 school-ground greening initiatives, an author wanted to understand "if and how" these schools "might be particularly well suited locations to facilitate outdoor learning" [10, p. 29]. The authors of a second study explained that they "were interested in exploring how pre-service teachers' past interactions with 'place' in outdoor settings contribute to their current perceptions of the importance of taking their own students into the outdoors" [2, p. 2245]. Similarly, this time with primary students, an article focused "on the exploration of the use of the school ground" and on "children's experiences and views about their school ground" [8, p. 62]. The aforementioned results let us conclude that the foreground aim of a few available articles is to encourage **outdoor education** at school.

### (Q3) What are the main outcomes related to teaching and learning science outdoors in schools' immediate surroundings?

The recorded outcomes of the research in our corpus were differentiated and classified into four categories: 1) learning, 2) students' attitude or interest, 3) other students' perceptions, and 4) challenges to outdoor science teaching.

#### *Learning*

A large majority (14) of the articles reported on *learning outcomes* in outdoor settings. First, it is interesting to note that most of the targeted knowledge elements were partly or entirely related to *ecology* [1, 3, 4, 5, 6, 7, 11, 12, 13, 16, and 17] or *environmental issues* [3, 4, 15, and 18]. A succinct list of ecology topics includes *adaptation, biodiversity, ecosystems, food webs, interdependence, life cycles, plants and animals, species conservation, and water systems*. For environmental issues, topics were related to *environmental protection, global change, habitat depletion, human impact, pollution, and society and environment*. Other targeted notions that were not about ecology or environmental issues were inventoried: *force and motion* [5, 6], *lands* [5, 6], *man-made structures and their materials* [9], *scientific activities* [5], or *weather* [5, 6]. Two articles were not explicit about targeted knowledge [10, 14] and only two did not show any particular interest in learning outcomes [2, 8]. A preliminary finding that we can draw from our analysis of this corpus is that **when teachers go outside, science learning is mostly about ecology or environmental issues**.

A total of nine articles (out of the previous 14) recorded measures of learning. Most used questionnaires for assessment [1, 3, 4, 5, 6, 9, and 12] and another interpreted interviews with the SOLO taxonomy, "a model for characterising the levels of sophistication of children's developing explanations" [17, p. 70]. Four of them compared outdoor learning with learning that happens indoors [3, 5, 9, and 12].

A first study (n=34) recorded that "outdoor educational programmes significantly improved pupils' knowledge of plants" [12, p. 546]. Similarly, another one (n=24) judged that "outdoor learning provides more effective and influential impacts on students' academic performance in understanding science" [9, p. 20]. A third

one (n=104) noted that a “fifth-grade treatment group showed statistically significant differences in the measures of environmental knowledge [...] when compared to the control group”; however “[t]here were no significant differences between the fourth-grade treatment and control groups,” though not all differences between control and experimental groups were recorded [3, p. 57]. Authors suggested that students’ “maturity level” and “teacher’s effect” contributed to these contrasting results. The authors of a fourth article (n=109) concluded that “[b]ecause [they] were able to document very limited use of the outdoors for science instruction, the attitudinal and learning impact of the outdoor school experiences remains in question” [5, p. 2076]. Not all of the surveyed articles produced positive results, but none produced negative ones. Our findings suggest, although the studied populations were rather small, that **learning science outdoors appears to show a greater impact than indoor learning for a particular kind of knowledge.**

Many authors were also interested in the relationship between outdoor learning and indoor learning [1, 4, 6, 7, 9, and 17]. Among other conclusions, researchers argued that outdoor settings could help students to better “understand their natural environment as a system” [1, p. 55] or provide “more active learning environments” [4, p. 9]. A study about New Zealand birds considered that “students had learnt more than usual” in a relevant context outside the classroom [7, p. 1360]. In another study, an interpretation of results obtained with the Wilcoxon test suggested that “both indoor and outdoor learning complement each other to improve students’ academic performance in science” [9, p. 20]. But some primary teachers also “failed to link outdoor experiences directly with [indoor] science instruction” [6, p. 2213]. We found no study that suggested that outdoor learning could replace indoor learning, partly or entirely, for certain topics. These results lead us to the conclusion that **learning science outdoors could be a good complement to indoor learning**, but that this linkage is not necessarily automatic. Although this conclusion seems self-evident, many authors believed it was necessary to state it.

### *Students’ attitude or interest*

A total of seven studies questioned students’ attitudinal/motivational constructs: environmental attitudes [3, 4, 5, 6, and 13], students’ interest [7], and even students’ attitudes toward plants [12]. The six articles about attitudes collected quantitative data with questionnaires, while the one on interest analyzed qualitative data from interviews. Participants of the seven studies were first- to seventh-graders.

In a first article, data revealed that students’ “interest in and knowledge of science had been increased” at the end of a unit on New Zealand birds [7, p. 1357]. Concerning attitudes, researchers found support for the hypothesis stating that “[o]utdoor education programmes will positively influence pupils’ attitudes towards plants” [12, p. 545]. They obtained such results with a randomly divided experimental group (n=17) and control group (n=17). Carrier, who is the first author of four articles [3, 4, 5, and 6] about environmental attitude (out of the five), also noted with her colleagues that the “attitudes of students to the environment [...] significantly improved over the course of [their] study” [5, p. 2076]. In another study, results “indicated significant changes in students’ environmental attitudes from pre- to posttest” [6, p. 2201]. A third one with two experimental groups (fourth- and fifth-grade classes) and two control groups (fourth- and fifth-grade classes) showed that “[b]oys increased their environmental attitudes [...], [but] respective differences for girls were not statistically significant” [4, p. 7]. A fourth study led by Carrier with the same experimental/control groups design did not record any positive shift, because “[t]here were no significant differences in the fifth-grade treatment and control group posttest scores in the measure of environmental attitudes” [3, p. 56]. Other authors described contrasted results, given that “data from the pre/post test, interviews, and student conversations suggest an improvement in students’ attitudes toward a more empathic view of nature, specifically insects,” although quantitative data “show[ed] no statistically significant shifts in attitudes” [13, p. 61]. There were no results that concluded that learning science outdoors could have a negative effect on students’ attitude toward science or the environment. Therefore, the results suggest that **learning science outdoors is likely to enhance attitude or interest toward the environment or science**, but that further confirmation may be needed.

### *Other students' perceptions*

Among the 18 articles, a third (6) was interested in non-attitudinal perceptions of K–6-level students; no studies investigated 7–12 levels. Five studies collected quantitative data [3, 4, 5, 6, and 9], while one used a qualitative analysis [8].

Four articles investigated students' outdoor comfort level [3, 4, 5, and 6]. The authors did not define the concept, but they all used the same instrument first described in 2003 [3]. The Comfort Level Scale instrument "consists of 11 open-ended questions" [6, p. 2200]. For instance, one of the items was: "Do you feel comfortable with lots of trees around you?" [5, p. 2066]. "The responses were coded with a 0, 1, or 2, with 0 indicating fears or discomfort, 1 indicating minimal discomfort or indifference, and 2 indicating clear comfort or enjoyment for each of the outdoor experiences described in the question" [5, p. 2065]. In a first study with 104 participants, "[t]he fifth-grade treatment group showed statistically significant differences in [...] comfort levels, [while] [t]here were no significant differences between the fourth-grade treatment and control groups" [3, p. 57]. With another population of 109 fourth- and fifth-graders, data showed a lower comfort level for boys "in the traditional classroom"; however, "in the outdoor treatment condition, boys and girls expressed comfort levels that were similar to each other" [4, p. 10]. A different study reported "a teacher effect on students' [...] comfort levels in the outdoors" [5, p. 2075]. However, in a last article, "outdoor experiences [...] have failed to influence outdoor comfort levels" [6, p. 2213]. Other researchers who did not use the concept of outdoor comfort level found that "students [were] more zealous to participate in the outdoors than staying indoors" [9, p. 20]. The reviewed studies, however, have not identified factors that could possibly influence outdoor comfort levels. In summarizing the results of outdoor comfort levels, it appears that **students are able to feel just as comfortable outdoors as indoors**.

In two studies [5, 6], students went outdoors with their teacher, who included outdoor learning experiences that spanned an entire academic year. At the end of the school year, while teachers generally felt they succeeded in connecting science learning that occurred indoors and with science learning that occurred outdoors, one study concluded "that students did not identify the outdoor activities that did occur as science" [5, p. 2077], and another that "students saw science as occurring in school and failed to make connections beyond the classroom" [6, p. 2211]. A final article interested in *views and experiences of the school ground* suggested that "the children neither viewed their school ground as a space for coming in contact with and exploring nature" [8, p. 78]. These three interpretations lead us to believe that **primary students do not necessarily perceive a clear connection between the outdoor learning they perform and its scientific value**. We suggest that primary teachers have a role to play in helping students to establish such a connection and to see the relevancy of what they do outside for their scientific understanding or achievement.

### *Challenges to outdoor science teaching*

Ten articles reported challenges about teaching science outdoors according to teachers [1, 2, 5, 6, 10, 11, 14, 15, 16, and 18]. They referred to both primary and secondary levels; six of them used mixed data.

The 10 articles all reported challenges concerning the teachers' role in using the outdoors. One article judged that an important barrier "was the lack of teachers' willingness to get out and teach in an outdoor learning environment" [1, p. 60]. This analysis is in concordance with researchers who noted that some participants "clearly expressed [...] planning concerns as barriers which need to be addressed" [18, p. 351]. Another study with Grade 5 teachers observed that "there was no clear evidence of the teachers' ability to effectively incorporate the outdoors for instruction" [6, p. 2215]. Likewise, 3 other articles reported a "lack of teacher preparation or professional development" [5, p. 2076], referring to primary teachers, and "insufficient teacher preparation" [15, p. 2758] and "limited staff expertise" [14, p. 107], this time at the secondary level. In addition to in-service teachers, research has been interested in pre-service teachers. It seems that "preservice teachers, who believe that they have the abilities to succeed in outdoor activities, may be more willing to engage in these activities as practising teachers" [16, p. 2265]. Beliefs could be rooted in "vivid memories of the interactions that occurred in outdoor 'places' during their childhood" [2, p. 2260], which could explain why an in-service teacher has "the dispositions (life experiences and beliefs) that are also needed to support a teacher" to teach science outdoors [11, p. 801]. Finally, a researcher

who conducted a study with 41 principals and 75 primary and secondary school level teachers concluded that to maximize the full potential of school grounds, “teacher training courses must recognize that outdoor learning is an important part of core competencies” [10, p. 41]. These results show that a major challenge is a lack of **teachers’ expertise in teaching outdoors**.

A total of four articles highlighted problems related to the curriculum. In many educational systems, since “the mandated curriculum does not explicitly endorse or support the use of school grounds for curriculum delivery” [10, p. 38], teachers are not formally encouraged to use real-life contexts for deep comprehension in science. In addition, in a study with 148 primary pre-service teachers, 24.3% of them declared that educators would be more inclined to expose students to nature if schools “stop focusing so much on test taking” [2, p. 2255]. Indeed, evaluation procedures, like national testing, tend to constrain and regulate teachers’ conduct and make them more inclined to use methods that help a rapid convergence toward correct answers, therefore reinforcing “traditional teaching strategies” [5, p. 2076]. Speaking of this issue, one article referred to “the testing dilemma” [6, p. 2209]. Authors also suggested that it is easier to include “some outdoor experiences in untested grades” [5, p. 2076]. Our corpus teaches us that, in certain cases, an absence of reference to a school’s immediate surroundings in the curriculum when combined with standardized testing pressures can give the impression that teaching science outdoors is not an efficient enough way to teach the curriculum. Therefore, a second challenge is the constraints that **national curricula and testing** impose.

In four other studies, available time appears to be a considerable challenge. For instance, “limited time in the school day” affected experiential outdoor science education in a study at the primary level [5, p. 2076]. The same research team concluded in a subsequent article that limited “time to teach science” is a problem for school science [6, p. 2205]. In a study involving secondary level teachers, 20.5% of them (n=244) declared that “lack of time for outdoor teaching” was an obstacle to environmental education [15, p. 2758]. In another article, a teacher explained that there was “a war between the teachers and the Board of Education and the Government. And when you’re in a state of war there isn’t room for extras” [10, p. 39]. This excerpt suggests that teaching outdoors can be considered as extra effort to be provided; consequently, it is also considered time-consuming. These results at the primary and secondary levels let us conclude that **available time** is a third challenge.

While classroom management is a part of teachers’ responsibilities, according to four articles, it appears to be a concern for teachers regarding outdoors initiatives. In the first study, 18 secondary teachers were questioned about outdoor teaching. “Seven interviewees did not conduct outdoor teaching or field work. All of them mentioned [...] too many students in class” [15, p. 2764]. Other secondary teachers identified “adequate staff supervision” and “student behaviour issues” as barriers for taking students outside [14, p. 107]. In a study interested in biodiversity education implementation in primary schools, the authors judged that “a person’s enthusiasm and commitment to the implementation of biodiversity education might be diminished by other factors such as classroom management, discipline problems” [16, p. 2267]. Finally, identifying the perceptions and self-reported practices of primary and secondary teachers, a fourth article noted that some of them “clearly expressed management [...] concerns as barriers” [18, p. 351]. These worries add **classroom management issues** to the challenges exposed by the corpus.

Four articles revealed problems related to the educational potential of school grounds. In the first study, four teachers (out of 20) expressed that “limited benefits/no [National Curriculum] links” was a barrier to more fieldwork [14, p. 107]. Authors of another article noticed a “perceived lack of applicability” of outdoor possibilities [18, p. 352]. A more complex problem for outdoor science, according to them, is that “some teachers do not believe that teaching outdoors is ‘real teaching’” [p. 352], possibly because they are unable to perceive its pedagogical potential. A survey conducted with 244 upper-secondary education teachers also indicated that “few [teachers] regarded their school ground unsuitable (too noisy, too small, not enough green space)” [15, p. 2767]. In another, it appeared that “the potential to use school grounds as an outdoor classroom remains largely unrecognized and untapped” [10, p. 39]. These considerations reveal that the **perception of the educational potential of nearby school grounds** is a fifth challenge to be considered.

An infrequently identified challenge, which has nevertheless come up in two articles, is **weather variation**. Because of sub-zero temperatures, a questionnaire respondent wrote that “the Canadian climate makes it difficult to use the outdoor classroom in some seasons” [10, p. 40]. In a second research study, conducted in the United Kingdom, one teacher (out of 20) responding to a multiple-choice question indicated that weather necessarily has to be taken into account “when taking a class out of school” [14, p. 107]. Currently, there is not strong evidence to argue that weather is a major challenge to outdoor science. However, because secondary teachers generally have less flexible schedules than primary teachers, we considered it important to mention it in this review.

#### **(Q4) What further studies should, according to the selected articles, be conducted in the future?**

In the field of outdoor science education, according to the corpus, further studies should consider learning outcomes, students’ attitudes, challenges, and methodological guidelines. Although some recommendations were implicit, only authors’ explicit recommendations are reported here.

A first direction for possible future study was *learning outcomes*. Differences between indoor and outdoor learning environment characteristics explain why further studies should better understand “the way students learn from direct and concrete experiences, in a real and relevant environment” [1, p. 60]. If it was suggested to investigate the effect of outdoor environments on learning, “the effectiveness of learning science through the indoors and the outdoors” should also be addressed [9, p. 21]. Then, in a study that divided 34 students into quasi-experimental and control groups, it was found that the tested outdoor educational programme could favour knowledge retention, but the authors considered that further research would be “necessary to allow generalization of these preliminary results” [12, p. 547]. In line with the previous recommendations, **we suggest conducting more studies that would identify the most effective outdoor teaching strategies to find out how outdoor learning could best complement indoor learning and to determine if learning outdoors favours knowledge retention.**

Two studies that concentrated on students’ attitude reveal prescriptions for further studies. At the end of their study, which measured students’ attitude toward plants (quasi-experimental and control groups; n=34), two authors concluded that despite “increased attitudes [...] scores,” the construct of *attitude* should be further investigated “to allow generalization” [12, p. 547]. Likewise, other researchers judged that “the field should proceed with better measures” of attitude toward the environment [13, p. 63]. This recommendation came after they collected quantitative and qualitative data that led to divergent conclusions. According to these authors, it appears that more research is required about **the effect of outdoor science education on students’ attitude toward the environment and that the validity of the results should be stronger**. One way to “yield more reliable results” would be using “surveys that are age-appropriate and specifically match curriculum content” [13, p. 63].

Five authors recommended conducting studies to address the challenges previously identified (Q3). In fact, it was suggested that research should further investigate “the opportunities and obstacles” [5, p. 2079] of learning science outdoors, because “not addressing them may be even more damaging” [10, p. 42]. To improve teachers’ expertise in teaching outdoors, it was suggested to follow pre-service teachers and collect “data regarding whether or not these teachers take students outdoors and obstacles encountered in attempting to do so” [2, p. 2260]. Another article justified the importance of further research “to analyse effective teaching strategies” outdoors, because their results indicated that this learning context “may improve boys’ interest and performance in school” [4, p. 10]. It was also pinpointed that teachers manifested planning concerns “which need to be addressed” [18, p. 351]. The same authors also exposed teachers’ preoccupations with classroom management. Other researchers also think that “the perception that science is best and most efficiently learned only inside the classroom” should be kept in mind [5, p. 2079]. Studying these perceptions could help teachers to use the outdoors with “teaching approaches [that are] congruent with their values” [18, p. 351]. Another article concluded that such a research agenda should take place “in a variety of locations and a range of cultural and socioeconomic backgrounds” [2, p. 2262]. Recommendations to conduct studies about *national curricula and testing, available time, and weather variation* were not identified in the corpus. This did not surprise us, considering that teachers generally have less control over these three challenges than the three mentioned above. It then follows that further research might need to **address challenges that limit the outdoor learning provisions over which teachers have the most control:**

teachers' expertise in teaching outdoors, classroom management issues, and the perception of the educational potential of nearby school grounds.

From a methodological point of view, some recommendations stand out. Authors who conducted a study on pre-service teachers would have preferred to "follow teachers from the early part of their initial certification [...] through their induction years and on the early phases of their careers" [16, p. 2267]. In the same way, researchers judged that a "longitudinal study in which pre-service teachers are followed from the university to the classroom" would be relevant to better understand their investigated construct [2, p. 2260]. Another source considered that "[l]ongitudinal studies might allow researchers to disentangle the messiness of data" [13, p. 63]. Even though they are a legitimate educational ambition, long-term training or learning effects have almost never been recorded. Therefore, the first methodological guideline that emerges from our synthesis is to **carry out more longitudinal studies to better understand teaching and learning science in the outdoors over time.**

Eleven of the eighteen selected articles used mixed data (see Q1). Within the conclusion of one of these articles, the authors underlined that "positive shifts in attitude [...] would have been missed if quantitative methods were used in the exclusion" [13, p. 63], and hence "recommend[ed] the use of mixed methods [to] reveal possible drawbacks associated with a single method approach" [p. 62]. We did not find any other explicit recommendations related to methods. Therefore, as a second guideline, contrasted results let us believe that authors think that **the use of mixed data should allow a more comprehensive view of the effects of different constructs.** As another study limitation, it is important to draw attention to the frequent explicit mention that interpretations are usually restricted to the investigated populations [3, 5, 6, 7, 12, 13, 15, and 16]. For instance, the author of a study with 104 students in the United States explained that "results [...] are limited to the generalizations with this population only" [3, p. 60]. This is why **more generalizable results, obtained with more representative samples, are deeply needed in order to suggest more potentially effective prescriptions for teachers.**

## DISCUSSION

In the discussion, we reflect on the main outcomes of our synthesis. In certain cases, and in light of our findings, some propositions for directing further research efforts will be formulated. Finally, we will discuss the limitations of our meta-synthesis.

### Comments on the results

The synthesis of the general characteristics of the 18 studies on learning science outdoors in schools' immediate surroundings at K-12 levels are (a) that two-thirds of the articles were published very recently (between 2011 and 2015), which suggests an acceleration in the field, (b) that they were mainly conducted in North America and Europe, (c) that most were focused on the primary level, and (d) that mixed data methods were often used.

Before conducting our meta-synthesis, we had anticipated finding more articles corresponding to our search criteria in order to understand the research field. We suggest that the small number of selected articles may be partly explained by the nature of some publications conducted outside academia (e.g. the seminal piece of work of Rickinson et al., 2004). However, the increased number of articles published between 2011 and 2015 (n=12), compared to between 2000 and 2010 (n=6), indicates the more recent emergence of and growth in the research area.

We had also presumed that we would find more studies that deal with the secondary level (high school). We suspect that the low number of studies reflects the limited use of outdoor science teaching at these levels. This finding requires further investigation if authenticity in science education is to be better understood and embedded in secondary science practice (Ajiboye & Olatundun, 2010; Ballantyne & Packer, 2009; Braund & Reiss, 2006; Fägerstam & Blom, 2013; Ghafouri, 2014; Rennie, Feher, Dierking, & Falk, 2003; Waite, 2011).

Our synthesis also suggests a certain variety in research methodologies and instruments, and therefore in the type of analyzed data, which did not really surprise us, considering the important heterogeneity of outdoor environmental settings compared to usual classroom or laboratory settings. Indeed, research may better grasp the complexity of outdoor learning environments by using varied, rich, and comprehensive – as well as standardized –

research methods. Nevertheless, we would have appreciated finding more information about the instruments used for data collection in several articles, especially the ones that use quantitative methods. We recorded some articles in which there was no description of the instrument used or no knowledge if the instrument had been previously used and validated. A richer description would have enabled better comparisons between published results, which we believe could be crucial to the development of the field.

Despite the converging keywords we used to find the articles of our corpus, we were nonetheless able to identify three distinct categories of authors' objectives: studies that targeted environmental education, science education, and outdoor education. While they might appear to be obvious, these results are interesting, as they highlight significant differences in authors' intentions and backgrounds. That is to say, it is not unreasonable to believe that reasons for going outdoors also often diverge in essential ways. Realizing this, we encourage further research initiatives to explicitly refer to them for the purposes of better understanding the nature of the various contributions to the field.

Our third research question focused on outcomes related to outdoor science education. First, we identified *ecology* and *environmental issues* as the most frequent elements of knowledge addressed outdoors. Therefore, the prime motivation for going outdoors in the articles of our corpus is mostly to better understand the living world. Although biology should remain a legitimate learning objective, we are surprised that teachers taking part in the studies rarely targeted knowledge elements in other science disciplines, such as astronomy (for example, the cycle of seasons or the solar system), chemistry (for example, the chemical properties of a watercourse or chemical reactions), geology (for example, rocks and stones or the geological development of lands), or physics (for example, gravity or simple machines). The lack of attention to such scientific knowledge could be a manifestation of the difficulty of perceiving the educational potential of nearby school grounds, a challenge previously identified in our results (Q3). We suggest there could be benefits from more studies considering non-biological outdoor science initiatives. Such studies would provide a broader understanding of how science teachers might use school grounds across scientific disciplines, and, in turn, convince teachers that school grounds might have more teaching and learning potential than initially expected.

We believe that our results also suggest that when outdoor teaching and indoor teaching are coordinated to complement one another, a more positive effect on learning can be expected than when compared to indoor teaching alone. This finding supports one of Rickinson et al.'s (2004, p. 7) conclusions, which underlines the positive effects of programs that "use a range of carefully-structured [outdoor] learning activities and assessments linked to the school curriculum," that "incorporate well-designed preparatory and follow-up work," and that "develop close links between programme aims and programme practices." Rickinson et al.'s conclusions (2004) and our own synthesis convinced us of the necessity of planning outdoor activities in line with prescribed national curricula and of reinforcing usual indoor science education to maximize its impact on student learning. Further studies might investigate the most effective ways to do such complementary planning.

Previous research findings also suggest that learning science outdoors can enhance students' attitude or interest toward the environment or/and science. However, these claims were based on limited control group comparisons, and this current research synthesis does not allow us to argue strongly that other pedagogical interventions could not have obtained similar results. Also, since there was limited research that clearly described the control treatments, it is possible that positive outcomes could be the result of mere novelty effects. We therefore demand more studies about attitudinal/motivational constructs that would use convincing research designs.

We believe it is noteworthy that three (out of 6) of our identified *challenges to teaching and learning science outdoors* also appear in Rickinson et al.'s (2004, p. 6) list of barriers for "the provision of outdoor learning in schools and universities":

1. *teachers' expertise in teaching outdoors*, which can be associated with "teachers' lack of confidence in teaching outdoors"
2. *national curricula and testing*, which conforms to "school and university curriculum requirements"
3. *available time*, which is similar to "shortages of time, resources and support"

From our viewpoint, beyond contextual or local validity, the similarities between our studies suggest that some challenges are common to many educational systems. However, our analysis allowed us to find three additional challenges:

4. *classroom management issues*
5. *perception of the educational potential of nearby school grounds*
6. *weather variation*

In contrast with Rickinson et al. (2004), our meta-synthesis did not allow us to identify *fear and concern about health and safety* or *wider changes within and beyond the education sector* as noteworthy challenges. These differences could, however, be explained by the fact that Rickinson et al.'s (2004) review was not restricted to science (i.e., art, language, and mathematics) and that it considered the wider "fieldwork and outdoor visits and outdoor adventure education" context in addition to the "school grounds/community projects" subfield. While recognizing the major contribution of Rickinson et al. (2004), our results confirm the importance of deepening our understanding of the challenges of outdoor learning contexts for specific school subjects in order to get a clearer picture of the possibilities for and obstacles to outdoor education in schools' immediate surroundings at K-12 levels.

We believe that the six challenges to outdoor science teaching synthesized in this literature review could be considered for the development of practice, policies, and research.

First, the lack of *teachers' expertise in teaching outdoors* was a dominant concern. We believe that pre-service teachers who have previously been exposed to professional development in teaching science outdoors will demonstrate more willingness to take their students outdoors. In an article published after our final search on ERIC on November 26, 2015, Glackin (2016, p. 430) addressed this issue, arguing that "it is critical that professional development programmes are developed" to help teachers to perceive how outdoor science could offer "authentic opportunities for science learning." Without this kind of development, most teachers may not be confident enough to risk a first outing. To address this challenge, we require more studies and initiatives that explore 'effective' professional development that enhances pre-service and in-service teachers' confidence and expertise in teaching science outdoors.

Furthermore, the combined effect of an over-emphasis on *national curricula and testing* should fuel debates about the relative focus we should put on quantity *versus* quality of learning. In our synthesis, we found that curricula and testing requirements shifted teachers' pedagogical decisions, often constraining their practice to prioritizing quantity over quality. Conversely, outdoor learning contexts appear to be proficient in developing many competencies and attitudes that remain hard to assess with traditional paper-and-pencil methods. We believe that as long as the educational system focuses exclusively on easy-to-quantify correct answers, most teachers might consider outdoor science education as an ambition that is admirable yet difficult to materialize.

Since time is limited for any pedagogical innovation, *available time* appears to somehow be a trivial and commonplace preoccupation. It was nevertheless recorded in teachers' testimonies, though not necessarily presented as exclusive to learning outdoors.

It is not particularly surprising to find *classroom management issues* in the challenges since the outdoors is necessarily unusual and innovative for most teachers as well as usually entertaining, new, and therefore distracting for students. It is also unfamiliar to them (as a formal context for learning), and so they are subject to possible misbehaviour. Teachers have to be rather confident in their ability to compensate for such possible difficulties and take responsibility in an unfamiliar and potentially challenging setting.

We also believe that the problem generated by a weak *perception of the educational potential of nearby school grounds* might explain the limited corpus of articles concerning outdoor science education. The scarcity of outdoor initiatives could also limit the possibilities of studying them merely because they are hard to capture.

Finally, though not widely reported, *weather variation* remains relevant to us. We believe that the unpredictability of weather could make it difficult for teachers to plan an outdoor lesson without being sure that

meteorological conditions will be absolutely favourable, especially in countries where weather variations can be abrupt. This problem could be reinforced at the secondary level, where schedules are generally inflexible. Because no studies interpreted their results in this way, this is, for the moment, a mere presumption that should be investigated.

In accordance with Rickinson et al.'s (2004) and Dymont's (2005) invitations, we encourage practitioners, policy-makers, and researchers who believe in the potential of outdoor science education to address these challenges head-on. The educational community would certainly benefit from understanding how teachers who carry out outdoor science with minimal success might overcome these challenges. We believe this would be an essential contribution to the development of the field.

Reflecting on the reviewed articles, exploring our fourth research question also allowed us to identify possible recommendations for further studies about learning outcomes, students' attitudes, and challenges. As for methodological considerations, Rickinson et al. (2004, p. 56) already concluded that their corpus contained studies with "poor conceptualisation and research design; broad generalisations being made from small samples; too much description without any critical analysis; and little or no follow-up in the medium to long term." In our own analysis, we unfortunately were unable to come to dissimilar conclusions. Indeed, we felt the need for clearer instrument descriptions, more longitudinal studies, the use of mixed data methods that are sensitive to the complexity of outdoor environments, and more results with a better range of applications or greater generalizability.

### Limitations

In our opinion, one of the most important limitations of our study is the strictness of our selection criteria. We deliberately decided to select journal articles only, excluding books, research reports, theses, and unpublished materials. We have also left out critical commentaries, self-reported teaching experiences, and theoretical articles in order to remain focused on empirical results. Although ERIC is a popular database, articles that were not indexed on November 26, 2015, were not taken into account. Another previously mentioned limitation about the choice to use the ERIC database is the consideration of materials that are strictly written in—or translated into—English. Finally, when we selected the articles out of the 310 results, we picked only the ones referring explicitly to our six filter questions. Consequently, if some studies' pedagogical interventions were related to science with no mention, for example, of the outdoors, these articles were unfortunately excluded. These strict selection criteria probably unfortunately deprived us from some pieces of relevant material, but they also probably reinforced the objective value of our results. Indeed, if we keep these limitations in mind, we believe that this strictness possibly provided us with a corpus of a higher objective value (considering our specific research questions), which in turn makes our research a stronger—however more specific—contribution.

### CONCLUSION

In this meta-synthesis, we identified and attempted to synthesize studies that were published between 2000 and 2015 in peer-reviewed journals that were concerned with learning science outdoors when it happens in schools' immediate surroundings from kindergarten to secondary levels (K-12). With the intention of ensuring the reliability of our results, we described a systematic method of selecting the articles. We retrieved a corpus of 18 relevant articles that reported studies that were mainly conducted in North America and Europe, mostly focusing on primary-level schooling, and commonly using mixed data methodologies, as summarized in Table 1.

Since the fact that few studies were focused on the secondary school level, we believe that future efforts should concentrate on this age range, despite the specific difficulties it might pose. Numerous challenges to outdoor science teaching were indeed identified as specific to these levels, but ways to overcome them unfortunately remain largely unclear. As Glackin (2016) suggested, such research studies might be crucial in the development of effective training programs for pre-service and in-service teachers.

In the future, we also hope to find more results describing effective pedagogies and how they should complement indoor science teaching and learning. The scientific literature pointed out numerous challenges to

outdoor science, which is an important step. However, we believe that the community of researchers interested in the topic has reached the point where they could prioritize investigating the means by which teachers could address the identified challenges and succeed – and be confident – in their attempts to teach science outside. Moreover, we hope that such efforts will result in going beyond contextual or local validity. Obviously, we acknowledge, along with Sandell & Öhman (2013), that outdoor learning environments are context dependent. Therefore, available results are often harder to transfer to other learning environments and other teaching settings and cultures. However, we still believe that it should be possible to find interesting invariants that could help teachers and researchers to get a better picture of the general possibilities, constraints, and opportunities of outdoor science teaching.

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## APPENDICES

### Appendix 1

#### *List of the 18 selected articles*

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## Appendix 2

### *Analysis grid*

#### *A. Article information*

- (1) Reference
- (2) Summary

#### *B. Context and theoretical backgrounds*

- (3) Geographic origin of the data
- (4) Education level [one or more]
  - (a) Primary school
  - (b) Secondary school
  - (c) College
  - (d) University

- (e) Initial teacher training
  - (f) Continuous teacher training
  - (g) Other (specify)
- (5) Type of education [one or more]
- (a) Formal
  - (b) Non-formal at school
  - (c) Non-formal elsewhere than school
  - (d) Other (specify)
- (6) Scientific subject [one or more]
- (a) Astronomy
  - (b) Biology
  - (c) Chemistry
  - (d) Physics
  - (e) Science
  - (f) Science & technology
  - (g) Other (specify)
- (7) Learning environment [one or more]
- (a) School grounds
  - (b) Park
  - (c) Forest or clearing
  - (d) Watercourse
  - (e) Other (specify)
  - (f) Not specified
- (8) Dominant field of study
- (a) Environmental education
  - (b) Outdoor education
  - (c) Science education
- (9) Research question(s) (if applicable)
- (10) Research objective(s) (if applicable)
- (11) Hypothesis (if applicable)
- (12) Dependent variable(s) (if applicable) [one or more]
- (a) Learning
  - (b) Attitude
  - (c) Interest
  - (d) Motivation
  - (e) Other (specify)
- (13) Independent variable(s) (if applicable) [one or more]
- (a) Weather conditions
  - (b) Duration of the pedagogical intervention
  - (c) Teacher
  - (d) Teaching experience

- (e) Classroom management
- (f) Pedagogical method
- (g) Learning environment
- (h) Knowledge
- (i) Program of study
- (j) Financial resources
- (k) Pedagogical resources
- (l) Other (specify)

**C. Methodological information**

(14) Type of data

- (a) Qualitative
- (b) Quantitative
- (c) Mixed

(15) Research methodology [one or more]

- (a) Case study
- (b) Multiple case studies
- (c) Action research
- (d) Correlational research
- (e) Descriptive research
- (f) Research and development
- (g) Exploratory research
- (h) Evaluative research
- (i) Quasi-experimental research
- (j) Longitudinal research

(16) Studied population

- (a) Teachers
- (b) Pre-service teachers
- (c) Students
- (d) Principals
- (e) Parents
- (f) Other (specify)

(17) Number of participants

(18) Instruments

- (a) Questionnaire (quant.)
- (b) Questionnaire (qual.)
- (c) Individual interviews
- (d) Group interview
- (e) Observations
- (f) Direct observation
- (g) Video recording
- (h) Audio recording
- (i) Document
- (j) Other (specify)

*D. Results*

- (19) Main results: \_\_\_\_\_
- (20) Implications for education: \_\_\_\_\_
- (21) Implications for research: \_\_\_\_\_

*E. General remarks*

- (22) Objective/methodology linkage
- (a) Strong consistency
  - (b) Minor weaknesses
  - (c) Major weaknesses

Reviewer's explanations: \_\_\_\_\_

- (23) Strength of the results
- (a) Strong consistency
  - (b) Minor weaknesses
  - (c) Major weaknesses

Reviewer's explanations: \_\_\_\_\_

- (24) Critical comments: \_\_\_\_\_

The Social Sciences and Humanities Research Council under the Vanier Canada Graduate Scholarship supported this work.

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