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Innovation in STEM learning

Taking constructionism outside: combining outdoor education, maker pedagogy, and constructionist learning

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Introduction

The COVID-19 pandemic has required educators to reimagine education in an effort to facilitate high quality learning while adhering to a myriad of health and safety protocols. Within the several new and creative combinations of educational activities, we have considered two pedagogical approaches that have been widely studied, but rarely imagined together: outdoor education and constructionism. By combining their principles and practices, we propose a new approach that may benefit educators both during and after the pandemic. Outdoor education yields many advantages to the school community (Wattchow & Brown, 2011), and the COVID-19 emergency brings it to the foreground, as outdoor spaces provide a decreased risk of contagion (Quay et al., 2020). Constructionism, and its newest instantiation, maker education, has played a crucial role in the process of revamping STEAM subjects in the last ten years. The new practices and learning environments that resulted have been shown to be effective in teaching students how to approach new problems, create and debug solutions, and employ critical thinking so as to understand complex phenomena. These new learning environments have also been shown to have a deep effect on students' identity, self-efficacy, and sense of belonging.

1. A short overview of outdoor education

The value of outdoor education has been studied, especially in northern European countries, for at least 50 years, yielding many publications showing its positive impact and validity (see, for example, Donaldson & Donaldson, 1958; Ford, 1986; Mannion et al., 2011). Mutz and Müller (2016), for example, determined several benefits for students following outdoor learning activities, such as lower levels of stress, higher levels of self-efficacy, mindfulness, and life satisfaction. Such findings are also supported by White and collaborators (2019): in their study, compared to individuals with no exposure to nature, participants that spent at least 120 minutes a week in nature had consistently higher levels of both health and well-being. In addition to aspects related to the health of body and mind, outdoor pedagogy lends itself to many trans- and interdisciplinary applications. A study conducted in Scotland (Mannion et al., 2011) – a nation that has been promoting this practice for many years – with primary teachers showed that they appreciated the opportunity to work in nature and that outdoor education made it possible to connect many areas of their curriculum. Furthermore, students stated that learning was more meaningful because of the interdisciplinary connections. Further literature and reports have been providing evidence and advocacy for outdoor education, such as Simone Beanes' "Learning Outside the Classroom" (2012) and a widely known national report in Scotland (Education Scotland, 2012) which summarized the principles of outdoor pedagogy as follows:

- Connections are made experientially with the world outside the classroom, helping develop skills and knowledge in a meaningful context.
- Outdoor environments and surroundings act as a rich stimulus for creative thinking and learning. This affords opportunities for inquiry, critical thinking, and reflection
- Children and young people find that not everything outside of the classroom matches the models discussed in textbooks. But this does not mean that what they have found is incorrect – instead, they develop awareness of the complexities of the real world.
- Students are able to understand the relevance of school subjects and their connection to everyday life.
- Children and young people can sometimes behave differently outdoors, sometimes positively changing their behavior. The quieter student may speak more, others become calmer or more focused.
- The multi-sensory experience in the outdoors can help retain knowledge more effectively. There are opportunities to learn with their whole bodies on a larger scale.
- Learning in a less structured environment can provide a different experience from that of the classroom.

The report also states that children who attended a week-long residential outdoor education program increased their test scores compared with children who did not have this experience. There was a 27% increase in measured mastery of science concepts, enhanced cooperation and conflict resolution skills, gains in self-esteem, environmental appreciation, problem-solving, motivation to learn, and classroom behaviour.

However, a common criticism that emerges when we discuss outdoor education, one that prevents many teachers from integrating this practice into their daily work, is the belief that doing outdoor activities is more risky than being in the classroom, and that parents therefore will not approve of this type of initiative.

Even though we acknowledge that the response to this issue is multifaceted, there are some indications in the research that teachers (and also parents) should have a more positive approach to risk. Students, even young children, need to learn about and know the real risks involved in moving outdoors because this will give them appropriate skills to assess the risk and avoid dangerous actions (Stan & Humberstone, 2011). Another productive point of reflection is the apparent contradiction between the fact that parents and students accept the risks in sports and recreational activities, and yet believe that the school should be an absolutely risk-free environment (Dickson et al., 2000). Risk is accepted as part of normal physical activity, and the controlled environment of sport practice gives children ways to gradually understand and assess it. Learning activities outdoors could have the same role. Stephenson (2003) also suggests that children have a natural tendency to search for challenging experiences and take part in risky activities as part of their development in order to expand their world view, their understanding of themselves and others, and how to become competent in a variety of life skills. Thus, although we recognize the complexity of the issue, we believe that a more balanced approach to the assessment of risk would make outdoor learning much more approachable for teachers and students.

2. Constructionism and maker education

Educators have been proposing student-centered, experiential education for decades (Dewey, 1902; Freudenthal, 1973; Montessori, 1965). Scholars such as Freire (1974) and Moll (1992) stress the importance of also designing educational systems and materials that respect and speak to students' cultures and lived experiences. Papert (1980) amplified the conversation to include a theory of how different types of tools, media, and materials could shape our cognition, considering learning as a process of building and debugging theories in close connection with constructions in the world. Papert and collaborators offered one of the first theorization about how learning could happen in such a way, and the first powerful examples of this process, first with the Logo programming language, then with the invention of Lego robotics, and in the following 30 years with all sorts of technologies, toolkits, and software for students to build and create. Their theory, called "Constructionism," was an attempt to understand what students learn when they are immersed in learning environments with such materials and toolkits in which they can build objects, share them with peers and teachers, and refine their understandings of the world based on multiple cycles of construction and debugging. Much of what we consider as "experiential learning," "learning by doing," or "hands-on learning," are in fact different names for Constructionist-inspired learning. Maker education, in a sense, is the ultimate realization of the constructionist "utopia." In makerspaces, students have access to incredibly expressive and flexible tools such as 3D printers and laser cutters, and considerable freedom to build objects and inventions. Even though it might seem like maker education is a very recent phenomenon, in fact it is just the newest chapter in a long story of educational transformation.

3. What happens if we combine outdoor education and pedagogy maker?

The idea of having students explore topics in mathematics, science, and engineering by working on projects of their own interest is not new, but maker education brought new tools, novel materials, a renewed public interest, and achieved something quite remarkable: a new type of space in schools – the "makerspaces." These spaces have some very special characteristics: first, they look very different from regular classrooms and are incredibly flexible, so what happens in a makerspaces can be quite different from the traditional activities and classes that happen in the rest of the school. Second, they have a permanent physical presence in the school, which is essential for the sustainability of any kind of educational reform. Third, maker education typically requires schools to hire a new kind of teacher, often with a lot more freedom not only to create new activities, but also to help other teachers around the school to redesign what they already do.

Therefore, makerspaces should not be regarded as just one new type of space in schools, but as an incubator of new ideas, curricula, and activities, even beyond its walls. In many of those places, actually, we see teachers creating toolkits that students can take outside of the classroom or the school to collect data about the environment, build objects to solve everyday problems, or simply go deeper in a topic in mathematics or science. With the COVID-19 pandemic, makerspaces are struggling to regain their prominence in schools, given that there are considerable challenges to continue operating these spaces with social distancing and safety. Nevertheless, we believe that there is a momentous opportunity to extend constructionist learning and maker education to outside of the school walls, especially if we consider outdoor education.

Constructionist learning and outdoor education are not often considered together because of their different theoretical roots, and roles in our school systems. Also, constructionist learning and maker education are exceedingly identified with computers, robotics, 3D printers, laser cutters, all installed in an enclosed space quite far from anything that reminds of the outdoors. However, maker education does not have to be like that, and the fact that we were obliged, due to the COVID-19 emergency, to explore options outside of the school made many of the missed opportunities more evident.

We are aware that many teachers are looking for immediate ways to offer different types of educational activities to students, given the disruption of COVID-19.

In what follows, we will explore some examples of possible combinations of constructionist learning, maker education, and outdoor learning, trying to bring together their benefits and potential. Counterintuitively, many activities that would otherwise happen in a makerspace can happen in nature; and many outdoors activities can benefit from the pedagogies, materials, and methods of constructionist learning.

The purpose of this reflection paper is to provide suggestions as to what activities teachers may create when combining Constructionism and outdoor education. Our goal, however, is not to provide ready-to-use units but suggestions to inspire teachers, curriculum designers, and researchers to develop their own lessons and units. It is important to note that taking this combined approach need not disrupt a school's existing curriculum. Constructionism and outdoor education can address traditional classroom topics, and do not require teachers to travel far from the school building. Any outdoor space, even sometimes nearby the school, can offer space and materials to enable students to engage in inquiry and investigation. Under normal circumstances, we would likely encourage more radical pedagogical experiments, such as venturing far from the school/house or imagining novel content areas to investigate. Given the immediacy of the pandemic crisis, however, we believe it is important to discuss examples with more immediate applicability.

4. Two Examples of Constructionist Outdoor Activities

4.1. First example: Outdoor Physics and Measurement

Outdoor spaces lend themselves well to content involving the measurement of length, angle, and mass. As students become more experienced, they will be able to combine these concepts in order to perform more complex activities, including role-playing games, orientation games, and treasure hunts (Keith, 2017; Kohen-Vacs et al., 2013).

An outdoor activity based on these ideas might start with learning how to measure a simple quality of objects: *length*. Students may begin by creating their own unit of measurement, using an ordinary object: perhaps a small tree branch found outdoors, or their own hands, fingers or feet. Once the unit of measurement is defined, students explore the principles of measurement by recording distances and sizes. As the activity progresses, we can start to add layers of complexity: what units of measurement are more adequate for small versus large distances? How to consider units that allow for regular subdivisions or multiples (metres, centimetres, and kilometres)? How to define a "stable" unit of measurement that will not change overtime? If the unit is based on a piece of wood, how would it behave in hot versus cold weather? Here, the principles of Constructionism and student-centered learning are at play: instead of giving a ready-made unit of measurement to students, we ask them to create their own; instead of telling students how measurement works, we insert them in a rich context in which they will understand it by creating and debugging solutions.

A second step in the activity could be to construct a device to learn how to measure angles, which will entail discussions about how to discretize the angular space, how many divisions it should have, and eventually the connection with our accepted methods of measuring angles in 1/360 increment. Next, they could apply this knowledge to construct a compass by gluing a magnetized metal pin to a small piece of floating cork, and let it float in a small bowl of water (Challoner, 2018). Using the compass, students may then experiment with finding the magnetic north pole as a reference point.

Since they would have developed their ability to measure length and angles, they could then use the compass to orient themselves and find a place, in activities such as a treasure hunt, which could include directions to the hidden item utilizing distance and orientation. At this point, many variations are possible, such as splitting into two teams (with each team writing directions that the other will follow), or creating ways for different students to discuss and negotiate their own units of measurement and angle, coming up with classroom-wide units or methods. Rich integrations are possible with computational media and mobile platforms as well, if those are available.

As educators become more comfortable with planning maker-based outdoor lessons with simple tools, many more areas of knowledge become accessible. Students may for example experiment with the relationship between linear and square units using units of measurement that are found in nature, or measure the weight of an object with an elastic band or water displacement. Many concepts even lend themselves well to games; for example, a stone-stacking competition allows students to explore the concept of the barycentre and centre of mass. More advanced students may explore the rectilinear and accelerated motion at play in the trajectory of a launched object using simple, nature- or home-based measuring instruments (Brondo & Chirico, 2019). Many of those instruments can be designed in makerspaces, produced in large quantities at low cost, and given to students as kits for exploration in nature. The raw material for making those kids can actually be reclaimed wood, bark, or other organic materials found in nature and brought back to the makerspaces for being shaped into new tools and gain a new life.

4.2. Second example: Art and the outdoors

An initial examination of outdoor education and the principles of maker education may suggest that STEM subjects, in particular ecology and sustainable development, could be very well suited to these pedagogical approaches. However, there are also many opportunities to include Art in arenas that are typically utilized for STEM learning.

It is not hard to imagine that outdoor environments allow students to find inspiration for an artistic artefact, and such a learning experience may have great pedagogical value. As Wattchow and Brown (2011) state,

> Outdoor educators may then find strong allies in the creative arts (such as dance, drama, art), which also rely very much upon the body as a medium of expression and learning. Strong similarities could also be drawn with the humanities where, as we have seen with cultural geography, historical fieldwork and creative writing for example, it is possible to commit to exploring and experiencing the richness and potential of a topic and/or place as much as is humanly possible.

In bringing together outdoor education and maker pedagogy, we have one powerful source of inspiration: the natural environment around us. From forests to urban gardens, we are faced with a heterogeneous and resource-rich scenario that we can carefully observe (with the naked eye, or using specific investigation tools such as macrophotography, short films, etc.) to create our artistic expression. Also, any raw material found in the environment can be a useful element for the construction of artwork: sculptures (Payne et al., 2009), musical instruments (Eaton, 2000), or even a theatre play (Martin et al., 2001).

In this second example, we propose a scenario divided into three phases. In the first phase, the teacher takes on the role of tutor and guides students in the in-depth observation of an aspect of nature in order to understand the relationship between oneself and the surrounding space, suggesting finding a strong connection with nature (Lumini, 2014). For example, students may closely observe leaves and their veins, the shape of tree branches, or the patterns of mould and moisture on the walls. In-depth observation gives students the ability to assimilate that shape or dynamic form and allows them to acquire the tools they need to start thinking about how they want to express themselves artistically. The teacher will also prepare the class by asking students to observe the world around them, or to watch videos on a concept related to the theme they wish to develop and deepen through an artistic product.

In the second phase, students are invited to design and realize the artistic product. They will carry out activities outside the classroom in any available and appropriate space during their typical class time. Students should use only objects found in nature or design actions in which they interact directly with nature and their own body. To express themselves, students will have to refer to the elements of nature that they have previously observed and studied by adding the concepts, emotions, and moods that arose from the reflection during phase one. In this phase, there are many possible integrations with maker education and tools. For example, organic materials can be brought back to the makerspaces for all types of transformations, from changing their shape to making copies of them, or to change their colours, textures, and flexibility. Textiles can be shaped and turned into costumes or other artistic objects. Again, the interaction could work both ways: teachers can also create kits of materials and tools in the makerspace to enhance explorations in nature and artistic expression.

The third and final phase consists in the restitution and representation of all the artistic products made. Often the best solution is to create an outdoor moment of sharing, a sort of exhibition mixed with a performance. What has been put into practice at the Reggio Children Foundation is an interesting example, because thanks to the work of the architect and maker Francesco Bombardi (2020), even the place where the artistic work is shown was built with natural and eco-sustainable materials that integrate perfectly with the surrounding nature.

Conclusion

Our first goal in this article was to show that the principles of constructionist education could be a great fit to contexts in which students go outside of the school walls and into nature. We discussed how, traditionally, constructionist learning and maker education have happened inside schools, because of their reliance on computers, 3D printers, and other types of similar equipment. Fifteen years ago, it would be unimaginable to take a laptop computer, a set of scientific sensors, or any digital fabrication equipment into nature, but as those technologies became cheaper and more personal, many new possibilities arose. Another possibility, which is becoming very common in many makerspaces, is for maker teachers to create custom toolkits for students to explore topics in science and mathematics. Previously, those toolkits or sets of manipulatives had to be produced by a commercial company in large numbers. Now, with digital fabrication equipment, materials can be produced in small scale for very specific contexts or groups of students, opening up many new possibilities.

Because of the pandemic, many schools are rethinking how much time students spend indoors, both during the epidemic and after its end. Many ideas which were unthinkable before, such as taking students more often to nature, are being revisited and their relative risk is being reassessed. We know from recent research that teaching outdoors is useful and effective, and we hypothesize here that it would be especially successful if combined with the principles of Constructionism and maker pedagogy. In addition to the outdoor environment (which is, by itself, very stimulating), activities could be designed in which students have to solve real problems either by creating or using all types of inventions and objects. Moreover, the very nature of the outdoors is interdisciplinary – much more than in the artificial environment of the classroom. Whereas in traditional curricula combining different disciplines requires extra effort, in nature all domains of knowledge are naturally combined: chemistry, biology, and mathematics are all instantiated at the same time, in the same place – even combined with our own aesthetic and artistic sense. We believe that this design space offers transformative and rich opportunities for students and teachers to redesign what they want education to be in the post pandemic era.

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