Science Learning in the ICT Era: Toward an Ecosystem Model and Research Agenda

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Abstract
This chapter closes this edited volume on *Non-Formal and Informal Science Learning in the 21st Century*. Through an ecosystem perspective, we aim to understand and represent the interrelationships among the ecosystem elements that provide actors with avenues by which they may be introduced to and become knowledgeable about science and science learning. This is particularly relevant for non-formal and informal learning contexts, since actors engage in science learning activities outside the formal learning context, and therefore they are not (necessarily) learning and teaching professionals, and also science education is not (necessarily) their main objective (e.g., when in informal learning contexts). In addition, actors are different from one another, therefore it is necessary to take into consideration their attributes and beliefs to better understand their behavior, their capabilities, and their needs, which in turn will improve the efficiency, coherence, and performance of the ecosystem overall. The overarching goal of this chapter is to present a conceptualization of informal and non-formal science education through an ecosystem model and propose a research agenda for the future. By doing this, the chapter seeks to offer a broader foundation for paving the way toward a holistic understanding of *Non-Formal and Informal Science Learning in the 21st Century.*

Keywords: Informal Learning, Non-formal Learning, Science Education, Ecosystem Model

1. Introduction

The term "ecosystem" has been introduced to describe a system that includes living organisms, their non-living environment, and all their interrelationships in a particular unit of space (Tansley, 1935). The term has been applied to different fields such as biology, technology, and education. The concept of the ecosystem (i.e., interactions between organisms and their environment) has the capacity to employ representations that may be used in education research to conceptualize educational systems (Giannakos et al., 2016; Barron, 2006; National Research Council, 2014; Traphagen & Traill, 2014). The environment (context) may be physical or not, and includes activities, material resources, relationships, and the interactions that emerge from them (Barron, 2006). The concept of an ecosystem in the context of learning puts the learner at the center of the system and allows us to focus on activities and relationships across settings and time (Bell et al., 2009). The conceptualization of science (or science, technology, engineering, and mathematics; STEM) learning in the form of an ecosystem is not new (Traphagen & Traill, 2014; Corin et al., 2017), but it is arguable that it provides both the language to discuss an inclusive learner-centered system and the roadmap to develop collaborations between organizations and groups in the future (Corin et al., 2017).

Science learning can be seen as an ecosystem where the actors actively interact and collaborate with each other to create knowledge and new capacities while evolving their interrelations, leading to novel pedagogical frameworks and technological affordances. The advances in information and communications technology (ICT) as well as the inter- and multidisciplinary nature of science education offer diverse opportunities for non-formal and informal science learning. A comprehensive understanding of the science education ecosystem and its interdependencies will allow us to identify potential barriers as well as enable us to develop frameworks and technological affordances that will provide solutions that benefit the different actors within the ecosystem.

2. The Potential of the Science Education Ecosystem Approach in Non-formal and Informal Settings

As has been described in the literature, besides the main actors (organisms: teachers, parents, etc.), a science learning ecosystem might also include various organizations (e.g., schools, science centers, civil society; see, e.g., Traphagen & Traill, 2014; Corin et al., 2017). Through the learning ecosystem perspective, we aim to understand and represent the interrelationships among the ecosystem elements that provide actors with avenues by which they may be introduced to and become knowledgeable about science (Corin et al., 2017). This is particularly relevant for non-formal and informal learning contexts, since actors engage in science activities outside the formal learning context and the knowledge obtained is transferred and enriched between contexts (Barron, 2006; Traphagen & Traill, 2014). Another important element that posits the ecosystem perspective as a sound metaphor to describe non-formal and informal science education is the fact that it adopts the "porous" nature (Traphagen & Traill, 2014) of the boundaries between learning settings (compared to the relatively siloed nature of formal learning settings).

The representation of science education as an ecosystem highlights that each actor/organization complements and builds upon each other's efforts (Traphagen & Traill, 2014). Such a system working at full capacity has been envisioned to distribute responsibility for teaching and learning among all of the ecosystem's elements (National Research Council, 2014). To sustain collaborations over time, science learning ecosystems must be attentive to what Traphagen and Traill (2014) term the "enlightened self-interest" of their members; participating in the ecosystem must allow members to work toward their own organization's goals, objectives, and missions. Therefore, the alignment and co-existence of self-interests are critical and allow the various actors, as well as the ecosystem overall, to reach their own goals efficiently. In this chapter, we use the concept of the ecosystem in order to understand and represent the interrelationships among the various organisms (actors and organizations), the enablers, and the development of particular attitudes, values, and dispositions that young people as learners and as citizens may develop, in the context of informal and non-formal science education.

3. Conceptualizing Science Education and Its Ecosystem in Non-formal and Informal Settings

As already mentioned, in this work we adopt a perspective that recognizes the interconnectedness of an "ecosystem" and the aspects of learner agency within such a complex system, focusing on the ecosystem of science education. Previous works identify patterns of exclusion in science education, including contemporary forms of stereotypes, sexism, and other modes of inequality (e.g., Lord et al., 2019; Master et al., 2016). An educational ecosystem can be described as a set of complex self-organized communities that consist of actors that have different attributes, decision principles, and beliefs (Tsujimoto et al., 2018). Furthermore, an ecosystem consists of multiple hierarchical layers, cooperation, and collaboration; in addition, coopetition among its different actors is found to be of great importance, but difficult to achieve (Pappas et al., 2018). The relations among the different actors and organizations of an educational ecosystem cannot remain solely within the learning and teaching context; instead, they are likely to extend to different contexts, like personal, business, or procedural relations. Since the actors and organizations involved are different from one another, it is important to explore their attributes to better understand their behavior, expectations, capabilities, and needs, which in turn can be orchestrated to improve the efficiency and coherence of the ecosystem overall.

When referring to education and learning, the term ecosystem describes the environment created and supported by the numerous actors and organizations that comprise the ecosystem, as well as their interactions and interrelations. Gibson (1986) demonstrates how the understanding of the environment empowers potentialities for action (e.g., doors are openable). That work highlights the functional significance (affordances or enablers) that is visible to individuals (actors) with reciprocal skills (effectivities) and the intention to act (Gibson, 1986). While the environment provides such potentialities, their meaning can only be materialized through actor–environment interaction. Therefore, being an affordance or enabler is a property of an ecosystem. In other words, "The environment is a closed (but unbounded) set of affordances, or functionally defined goals, that identify the potential perceptions of the animal [individual actor] and that complement the effectivities" (Turvey & Shaw, 1979, p. 206). Educational ecosystems inherit the concept of a learning ecology; that is, "the set of contexts found in physical or virtual spaces that provide opportunities for learning. Each context is comprised of a unique configuration of activities, material resources, relationships and the interactions that emerge from them" (Barron, 2006, p. 195). Since our goal is to create sustainable ecosystems that promote science learning, we need to take into account the various actors and organizations, their capabilities, goals, and needs, as well as the potentialities of the environment.

Interactions among the various actors (e.g., teachers, policy makers) and the environment (e.g., government) are essential to creating the needed technological, institutional, and pedagogical conditions. Building on the above discussion, we posit that a science education ecosystem model comprises organisms, which can be individual actors (e.g., children, parents, instructors, curators) or organizations (e.g., schools, museums, universities, industry), who all have capabilities, goals, and needs. The actors and organizations need to utilize the various enablers that are available in their respective contexts, which will lead to the development and alternation of actors' motivations, beliefs, and self-efficacy, but also affect the society and business development. This is an iterative process based on which the organisms use available enablers to constantly achieve their goals, and in our case to promote science learning. Figure 1 presents the Science Education Ecosystem (SEE) model, which conceptualizes the organisms that need to cooperate, coordinate, and collaborate through the utilization and orchestration of the various enablers (e.g., means and activities), focusing on the potential for nurturing scientifically informed behaviors and improving attitudes, values, and dispositions that young people possess about science and science education.

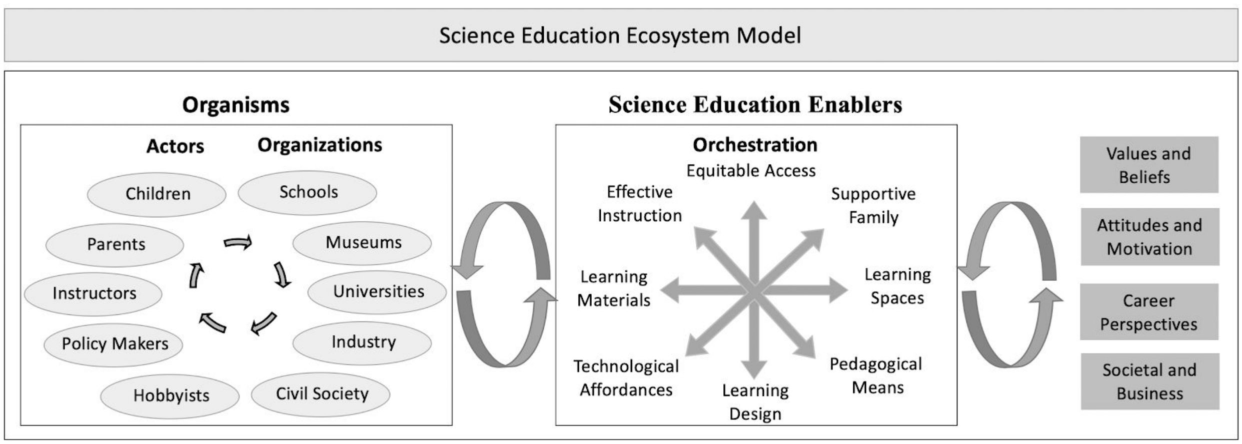

Figure 1: The Science Education Ecosystem (SEE) model

4. Conclusions and the Way Ahead

The importance of novel enablers such as digitalization and the utilization of emerging learning spaces is going to attract a lot of attention in science learning in the upcoming years. Novel technologies and spaces will enable and democratize science learning practices that can empower different actors (e.g., instructor, parent, hobbyist) to contribute to the ecosystem of science education. The proposed SEE model is an attempt to conceptualize these interrelationships and provide actors with avenues for facilitating learning and societal change, therefore generating knowledge that impacts both contemporary science learning practices and the society overall.

In this closing part of the volume, we would like to highlight two research avenues that are critical for the future development of non-formal and informal science learning in the twenty-first century.

The role of actors and organizations in utilizing and further developing science learning practices. How actively may the various actors (e.g., teachers, parents, policy makers) and organizations (e.g., schools, companies, universities) be involved in order to shape the development of novel science learning practices? These actors and most organizations are typically involved in bottom-up self-interested endeavors, through which they are introducing novel learning spaces and arenas, as well as a set of evidence-based practices that have been optimized through continuous planning, implementation, evaluation, and refinement. Therefore, the actors involved are furthering contemporary practices that benefit the ecosystem, as well as the particular contexts and learning settings (formal, non-formal, and informal) and science content areas (e.g., problem solving, manufacturing, coding).

Adoption and integration of new practices and affordances. Future research needs to examine how different actors (e.g., teachers, policy makers) and organizations (e.g., science centers, schools) can be empowered to adopt and integrate novel practices and affordances in their established processes. This is critical in order for the ecosystem to be able to utilize new knowledge. For such adoption and integration to succeed, various measures, such as personnel training and renewal of routines, need to be implemented.

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