# An Introduction to Non-formal and Informal Science Learning in the ICT Era

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## Abstract

This chapter provides an overview of this edited volume on *Non-Formal and Informal Science Learning in the 21st Century*. The goal of this volume is to introduce the reader to evidence-based non-formal and informal science learning considerations (including technological and pedagogical innovations) that have emerged in and empowered the information and communications technology (ICT) era. The contributions come from diverse countries and contexts (e.g., hackerspaces, museums, makerspaces, after-school activities) to support a wide range of educators, practitioners, and researchers (e.g., K-12 teachers, learning scientists, museum curators, librarians, parents, hobbyists). The documented considerations, lessons learned, and concepts have been extracted using diverse methods, ranging from experience reports and conceptual methods to quantitative studies and field observation using qualitative methods. This volume attempts to support the preparation, set-up, implementation, but also evaluation of informal learning activities to enhance science education. In this first chapter, we introduce the reader to the volume, present the contributions, and conclude by highlighting the potential emerging technologies and practices connected with constructionism (e.g., the maker movement), coding, and joyful activities that are currently taking place under different spaces such as hackerspaces, makerspaces, TechShops, FabLabs, museums, libraries, and so on.

**Keywords:** Informal learning, non-formal learning, science education.

## 1. Introduction

According to the established definitions coming from the European guidelines (CEDEFOP, 2009), formal learning occurs in an organized and structured environment (e.g., in an education or training institution or on the job) and is explicitly designated as learning (in terms of objectives, time, or resources). Formal learning is also intentional from the learner's point of view, and typically leads to validation and certification. This in the world of *science, technology, engineering, and mathematics (STEM) education* largely coincides with science classes in schools and tertiary education, although we agree that formal science learning plays an important direct and indirect role in non-formal and informal learning as well. The focus of this volume is on non-formal and informal science learning that takes place outside the classroom, and formal science learning is mentioned in cases where its contribution influences non-formal and informal science learning.

There is substantial broad knowledge already about informal science learning and science education outside the classroom (e.g., Lloyd et al., 2012; Falk et al., 2012; Robelen et al., 2011). What is still needed, especially at the European level, is much deeper insights into the nature and multifaceted impact of this type of learning. Gaining such deeply probing insights requires a focus on specific areas of the wider field, considering contemporary developments such as technological and pedagogical innovations, which will yield results that can then both be extrapolated and guide further research in other neighboring areas.

In non-formal science learning we consider learning that is embedded in planned activities not always explicitly designated as learning (in terms of learning objectives, learning time, or learning support), but that contain an important learning element; non-formal science learning is, most of the time, intentional from the learner's point of view, and can take place in museums, science camps/clubs, and so on. In informal science learning, learning results from daily activities related to work, family, or leisure, which is not organized or structured in terms of objectives, time, or learning support, and is mostly unintentional from the learner's perspective. Therefore, the level of intentionality plays an important role in both non-formal and informal science learning.

During the last few years, we have seen new ways in which non-formal and informal science learning is taking place through various activities (e.g., coding, making, play). Those activities are nowadays taking place outside K-12 school and higher education science classrooms, beyond the formal boundaries of science education. The increased interest in and implementation of those activities have led to the development and practice of different tools, affordances, and methods that support a wide range of educators and practitioners (e.g., K-12 teachers, museum curators, librarians, parents, hobbyists). This chapter initiates a discussion on the role and potential of those activities to support non-formal and informal science learning, as well as on their impact on current practices and society.

## 2. Coding, Making, and Playing as Enablers of Out-of-Classroom Science Learning

Among the various informal science learning spaces and practices, much attention has been given to experiences and activities characteristically (one could also say, traditionally) associated with science museums and centers, zoos, exhibitions, competitions, field visits, and so on. However, the increasing emergence and proliferation of learning materials and practices emphasizing the joyful and creative element of informal science learning, as these are characteristically exemplified in coding, making, and joyful/play-based activities, have not yet drawn enough focus to them, while appearing to be one of the most important enablers in the field.

The links and contributions of coding- and making-based creative learning activities to science education are strong and intuitively obvious, albeit still only little explored and understood in depth. To a conservative approach to science education, coding and making may appear to lie beyond the boundaries of science classrooms, pertaining only to the fact that technology, engineering, and the arts are nowadays acknowledged partners of science and mathematics in the landscape of STEAM. However, the relation between these activities and science education, and especially informal science learning, is far deeper and very critical. Through computational thinking, design thinking, problem setting and solving, using their curiosity, imagination, creativity, critical thinking, and knowledge to understand and change the world, young coders and makers are at the same time deeply engaged science learners gaining insights into systems, data, and information, exploring patterns, getting involved in inquiry, collaborating and communicating, and understanding the role of science and technology in today's and tomorrow's societies and world.

### 2.1. Coding

Teaching coding to turn youngsters into confident and creative developers of digital solutions is currently gaining momentum in classrooms and informal learning spaces (coding fairs, labs, challenges, etc.) across the world. In 2013, the UK introduced a coding curriculum for all school students (Department for Education, 2013); since then, several other European countries have been moving in the same direction. In particular, coding has, in recent years, become an integral part of school curricula in countries such as Estonia, Israel, Finland, and Korea. In the USA, a number of organizations (e.g., the acclaimed Code.org initiative) support computer programs in schools and offer coding lessons for everyone. Such new curricula and out-of-classroom initiatives are aiming far beyond just creating a new generation of computer programmers as a response to changing global demands for workplace skills. The purpose is to provide young people with the tools to navigate digital landscapes effectively, by developing their technological fluency and deeper understanding of how the digital world is created, how it might be used to meet our needs, and how we might repair or modify it. These growing efforts of governments to integrate coding as a new literacy and to support students in creative problem-solving tasks (Hubwieser et al., 2015) posit coding as a new and emerging affordance that has the potential to update and enable new non-formal and informal science learning practices.

### 2.2. Making

The maker movement of independent innovators, designers, and tinkerers has also dynamically entered the landscape of innovative education and informal learning (Papavlasopoulou et al., 2017). In makerspaces that are mushrooming in schools as well as in science centers, libraries, museums, and other informal learning spaces, more and more young makers are developing projects focused on prototyping innovations and repurposing objects. Maker education is emerging as a topical approach to interdisciplinary problem-based and project-based learning, entailing hands-on, often collaborative, learning experiences, and making in learning spaces and the positive social movement around it are seen as an unprecedented opportunity for educators to advance a progressive educational agenda. In the USA, the Obama administration strongly supported the growing maker movement as an integral part of STEM education, hoping to increase American students' ability to compete globally in the areas of science, engineering, and mathematics.

The confluence of the two movements, "coding" and "making," around the notion of digital making and fabrication is often linked to other technology-related learning activities such as those pertaining to robotics and the Internet of Things (IoT). Digital fabrication has dynamically entered the worlds of education and informal learning, boosted by world-wide FabLab initiatives (e.g., Stanford's FabLearn Labs, formerly FabLab@School). These educational digital spaces for invention, creation, inquiry, discovery, and sharing put cutting-edge technology for design and construction into the hands of young people so that they can "make almost anything," thus supporting project-based student-centered learning integrated into personal interests and daily life.

### 2.3. Playful/Joyful Activities

Across the spectrum of these emerging creative learning spaces, the elements of fun, joy, and playfulness are dominant. Especially outside classrooms, in the inviting and open-ended informal learning atmosphere of science centers, museums, libraries, zoos, community labs, outreach centers, fairs, contests, and so on, playful learning is the norm. There, fun and creative learning activities harness children's sense of joy, wonder, and natural curiosity, achieving high levels of engagement and learners' personal investment in learning. In a sense, in these informal learning spaces young people discover or reinvent their true selves as natural scientists, mathematicians, or artists, constantly seeking to construct new meaning and make sense of the world around them. Thus next to and far beyond game-based learning in science education (Li & Tsai, 2013), whereby learning content and processes are incorporated into gameplay, in coding and making activities pure learning through play finds very fertile ground; as the seminal work by the LEGO Foundation (2017) puts it, "learning through play happens when the activity (1) is experienced as joyful, (2) helps children find meaning in what they are doing or learning, (3) involves active, engaged, minds-on thinking, (4) as well as iterative thinking (experimentation, hypothesis testing, etc.), and (5) social interaction." This is exactly what is happening when young people code and make in the context of playful informal science learning experiences.

## 3. Contributions and Themes of This Volume

### 3.1. The Lens of Science Capital to Understand Learner Engagement in Informal Makerspaces

Opportunities for young people to participate in making activities have increased dramatically in recent years. In describing informal learning spaces (e.g., science museums, makerspaces, FabLabs), many have argued that such spaces provide an inclusive approach to youth engagement in STEM education. The potential for enabling inclusive engagement is particularly significant given wider research findings that document the under-representation of some groups within the STEM workforce and engaged in STEM study, such as women and ethnic minority groups. Although the potential of making and makerspaces for empowering young people has been acknowledged, the ability of makerspaces to support equitable engagement is under-explored.

King and Rusthon (this volume) draw on an underpinning framework that builds on the concept of science capital and the principles of the science capital teaching approach. In their contribution they consider the ways in which makerspaces can be sites of equitable participation in informal science learning. They exemplify those ways through data from observations and interviews conducted in a UK-based makerspace, and argue that science capital pedagogic principles are evident in makerspaces and, when enacted, help to create an environment where young people feel valued and better able to participate in making and coding activities. King and Rusthon (this volume) showcase how science capital pedagogical principles are utilized in makerspaces, and argue that small changes to practice in the design and facilitation of makerspaces could result in such spaces being more equitable and socially just. Therefore, it is important for facilitators to empower children, as well as recognize and value the previous experiences children bring to the space and how these are incorporated into activities.

### 3.2. Digital Games as an Enabler for Science Learning

Digital games, online gamified labs, and virtual simulations (De Jong et al., 2014) present great potential for science learning, scientific literacy, and motivating interest in science. Such, mostly online, resources (e.g., https://www.golabz.eu; http://onlinelabs.in) are most of the time free, and enable children to experience science and math without having to set foot in an expensive, physical environment. There are resources in almost every science discipline that enable children to perform scientific experiments. Previous works have examined the effectiveness of such technological innovations in attaining learning objectives such as content knowledge, conceptual understanding, and problem-solving skills, usually in formal education settings.

Voulgari (this volume) examines the potential of digital games to support science learning and scientific literacy by looking at trends identified by previous meta-reviews over the past decade. Her work identified that there are games appropriate for most school subjects, including history and literature; however, research has focused on STEM-related games and learning objectives (e.g., physics, biology, chemistry, and the environment). During the last few years there has been a shift to learning objectives and research that focus not only on content knowledge, but also on the understanding of scientific processes and practices, attitudes toward science, and higher-order thinking skills. Factors involved in science learning through games have been identified such as the appropriate design of the game, individual characteristics such as previous science knowledge and interest, and the impact of the setting (e.g., a classroom environment).

### 3.3. Web-Based Science Learning: The Case of Computer Science MOOCs

Another opportunity that emerged during the last few years in science learning and non-formal learning is the rise of Massive Open Online Courses (MOOCs). MOOCs allow people to participate in a series of online learning materials, targeting specific content knowledge. There is research on the effect of MOOCs on learners' motivation, interest, and learning, as well as reasons for dropping out and disengaging. However, our knowledge about learners' preferences in the area of computer science and programming MOOCs is rather limited.

In their work, Krugel and Hubwieser (this volume) put into practice a MOOC in programming and investigate learners' experience by identifying aspects that improve or hinder that experience. In addition, they identify detailed reasons for dropping out of the MOOC in programming education. Overall, it is arguable that the design of the MOOC needs to be learner centered and take into consideration the various particularities of the learners (e.g., timewise flexibility, interactive exercises). Such barriers seem to be of particular importance in the non-formal learning context, and further work needs to quantify their effect on learners' experience and adoption, as well as providing systematic ways of considering such aspects in the design phase.

### 3.4. Music and Coding as the Intersection of Literacies

Computational literacy has been defined by scholars such as diSessa (2018) and Vee (2017) and is currently gaining increasing attention and adoption in the science education field. This is also supported by the fact that computational tools and methods have become pervasive in modern scientific research across almost all fields of inquiry. What is less clear, however, is how to integrate computational literacy into formal, informal, and non-formal learning, as well as how to develop the next generation of computationally literate researchers.

Horn et al. (this volume) consider interviews, music, and computational artifacts produced by middle-school students in a summer camp setting using a learning platform called TunePad (https://tunepad.live). Their work furthers our understanding of the development of computational literacy through more informal learning experiences, with a focus on middle-school learners at the intersection of music and coding.

### 3.5. Non-formal Learning in Primary School: Programming Robotics

Besides the adoption of computational literacy in middle-school learners, during the last few years there has also been an ongoing and growing discussion about the necessity of such skills in primary education. The early development of key understanding, skills, and thinking approaches emerging from computational literacy and programming seems to have several positive effects on children. Programming plays a role in the context of formal, informal, and non-formal education, and more and more countries are including coding in their formal education (i.e., the curriculum), but also are developing various after-school activities and non-school organizations are developing concepts, methods, and activities. Despite the potential, it is still unclear to what extent and in what form computational literacy and programming can and should be introduced in primary education in the longer term, and the role that informal and non-formal learning activities can play in the transition and adoption period.

Geldreich and Hubwieser (this volume) investigate this further by conducting a series of interviews of Bavarian primary school teachers who put into practice programming activities with their entire class and in the non-formal setting of a programming club. Their work focuses on efficient practices and the challenges they encountered in these particular settings. A useful implication of their work is the view of teachers, who agree that all students should have the opportunity to learn programming – but that this has to be properly scaffolded and anchored to curriculum activities and learning materials.

### 3.6. Games for Artificial Intelligence and Machine Learning Literacy

Artificial Intelligence (AI) and Machine Learning (ML) education is also an interesting and rapidly developing field, attracting an increasing number of learners and instructors in the past few years. In response to this need, efforts in the USA, China, and other countries have resulted in AI/ML curricular activities for K-12 students (Touretzky et al., 2019). In addition, during the last few years new online resources have been developed focusing on pre-college students, as well as professional development for teachers to learn the basics of AI (Touretzky et al., 2019). Recently, the Association for the Advancement of Artificial Intelligence (AAAI) and the Computer Science Teachers Association (CSTA) announced a joint initiative to develop national guidelines for supporting AI education in K-12 students. Moreover, initiatives such as the AI for K-12 working group (AI4K12) and AI4All (http://ai-4-all.org) were established to define what students should know and be able to do with AI, as well as to develop national guidelines and collect resources (e.g., videos, demos, software, and activity descriptions) for AI education in the USA.

General game playing is an exciting topic that is still young but on the verge of maturing, which touches upon a broad range of aspects of AI and ML. Giannakos et al. (this volume) conducted a literature review on the confluence of digital games and AI/ML education and created a general overview of games that have the capacity to support pre-college AI/ML education. The goal of this work is to provide a springboard for other scholars and practitioners to put into practice, experiment with, compare, and adapt the games and software listed to meet the needs of their students. The results depict how different games can enable opportunities for young people to engage with AI and ML, as well as for instructors and parents who want to teach a number of different concepts and topics in AI and ML.

### 3.7. Instructional Design of Non-formal Making-Based Coding Activities

Making has received growing interest in formal and non-formal science learning. However, the characteristics and design of such activities are not always clear or pedagogically efficient. Instructional models have been extensively used to align the design of learning activities with learning goals and objectives. Papavlasopoulou and Giannakos (this volume) illustrate and discuss the learning design of non-formal making-based coding activities, using the ADDIE instructional model. Utilizing the experience and results from empirical studies that have been implemented for over three years in the context of making-based coding workshops called Kodeløypa, they offer a set of best practices and lessons learned.

### 3.8. Games for Artificial Intelligence and Machine Learning Literacy

Access to technology and the ability to benefit from its use, as well as the skills and capabilities to innovate, design, program, make, and build digital technology, are all seen as pivotal for children's science learning. Makerspaces, FabLabs, and different kinds of coding clubs have started to offer children digital technology skills and competences. However, the potential of those environments in empowering children to make and shape digital technology remains poorly explored so far.

Kinnula et al. (this volume) investigate the potential of such environments to empower children to make and shape digital technology. The authors offer guidelines for practitioners working with children and their digital technology education in the context of non-formal learning and FabLabs. The special emphasis on these guidelines is enabling ways of working that respect and empower children. These guidelines should be useful for both teachers and facilitators when planning and implementing children's projects in FabLabs, with special emphasis on school visits to FabLab premises. The insights of this chapter should be useful broadly for researchers interested in the empowerment of children to make and shape digital technology through design and making, as well as for FabLab personnel – instructors and managers alike – and for teachers or city administrative staff who plan to work in collaboration with a local FabLab.

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

In the closing chapter of this volume, Giannakos proposes a conceptualization of informal and non-formal science education through an ecosystem model. The conceptualization of science 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). The learning ecosystem perspective aims to improve our current understanding of how various factors need to cooperate, coordinate, and collaborate to enable efficient and meaningful science learning in informal and non-formal learning settings.

## 4. Conclusions and the Way Ahead

The advances in technologies, manufacturing equipment, and learning spaces offer diverse opportunities for non-formal and informal science learning, especially when supported by coding, making and engaging, and joyful practices and designed in an appropriate pedagogical manner. From current research, it is difficult to tell what aspects of environments, technologies, applications, equipment, and practices can have a positive impact.

The current drive in many countries to teach STEM subjects to young people has the potential to further research initiatives into how information and communications technology (ICT), practices, and spaces have the capacity to enable non-formal and informal science learning. However, there are a number of challenges in ensuring that procedures/practices, tools, and environments embody appropriate progression and engender motivation and joy, which are critical for non-formal and informal learning contexts.

To explore the future of various spaces and ICT tools to foster engagement and creativity in science learning, we seek to promote interest in contemporary tools, practices, and affordances, such as computing and coding, and to put them into practice in different spaces such as hackerspaces, makerspaces, TechShops, FabLabs, and so on. This will allow us to better understand and improve their qualities as well as to accelerate the process of disciplinary convergence. In this volume, we present different works, coming from researchers with different backgrounds, showcasing the importance of disciplinary convergence. Bridging relevant disciplines such as learning sciences, science education, computer science, and design, among others, has the capacity to encourage ambitious research projects tackling the major themes of science education, including educational policy, instructor development, emerging science literacies, theory development, science learner empowerment, the development of appropriate environments and technologies, and practice development, to mention but a few.

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