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ARTICLE

Apps to Promote Computational Thinking and Coding Skills to Young Age Children: A Pedagogical Challenge for the 21st Century Learners

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ABSTRACT

Background/purpose – At the beginning of the 21st century, Computational Thinking (CT) and coding were typically considered part of secondary education programs, focusing on programming and algorithm development. The early childhood classroom was not expected to find students who developed coding skills. Nevertheless, as has been the case lately, CT and coding have been characterized as fundamental skills of the 21st century, not only for computer scientists but all for citizens. However, through developmentally appropriate technologies, the development of coding skills is increasingly possible, and the result may be the advancement of CT fluency or at least familiarity in young age children. Given the enormous success of smart mobile devices and accompanying mobile apps, the question is whether apps provide the children of preschool and pre-primary school age with opportunities to cultivate their basic coding and CT skills. This study is a review article that presents a brief literature review on the apps that promote themselves that can cultivate CT and coding skills of young students.

Materials/methods – This paper presents a literature review of empirical studies on apps that promote themselves to support young children's learning of CT and coding skills.

Results – Despite the abundance of 'self-proclaimed educational' apps for children, there is a need for developmentally appropriate apps, specifically designed for young people to promote the development of CT concepts and coding skills in young children's life.

Conclusion – This study contributes to a small but growing body of literature investigating how children process and learn fundamental coding skills from touchscreen devices. The findings of this study provide evidence that young age children can facilitate early STEM learning and foundational coding skills from developmentally appropriate playful learning experiences on smart mobile devices.

Keywords – Mobile applications (apps); computational thinking; basic coding skills; preschool age; pre-primary school age.

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1. INTRODUCTION

Until recently, areas such as Computer Science (CS) or Computational Thinking (CT) were typically isolated into post-secondary education curriculum or below, with a focus on program development (Falkner, 2015). However, CS and CT are quickly redefining what it means to be a literate citizen of the 21st century (Papadakis, 2022). There is a reason for that. Researchers worldwide call for the need for CS and CT to become a new imperative for Western societies, societies that call for innovation, entrepreneurship, teamwork, and creative thinking. Wing (2006) said that CT is regarded as an essential skill that was ignited by the rise and widespread of computers, just as that the traditional '3 Rs' of reading, writing, and arithmetic serve as the basic skills students need to succeed by the advent of printing (Chen et al., 2017). CT can help get young people to engage with powerful ideas, unleash their creativity and express themselves in new and exciting ways, as well as to understand the rapidly changing world around them (Yu & Roque, 2018).

In fact, in many countries, digital game-based learning applications designed to support the more effective development of coding and CT skills in children aged 4 to 7 years old have begun to appear. New curricula around the globe point to the need to improve digital literacy, CT and coding to support a generation of children who will build the future of civilized countries (Falkner, 2015). This shift has prompted an uptake in pedagogies and frameworks in the education systems worldwide. Coding and CT can often meet difficulties to fit into a formal early childhood program, while some educators are discouraged from teaching young learners how to code for various reasons such as the lack of prior training or studies and/or extensive experience with coding (Papadakis, 2021). For that reason, learning initiatives to foster computational literacy are now actively being developed, such as the 'hour of code' in the United States and the 'code week' in the European Union (Strawhacker, Lee & Bers, 2018).

Furthermore, several computational tools and kits are currently available to help younger children with different coding backgrounds or levels of expertise grasp the most basic coding elements through interactive games and activities (Kyriakides, Meletiou-Mavrotheris & Prodromou, 2016). Mobile applications or apps for smart mobile devices that are used to teach young children coding skills and CT concepts with game-like activities have gained significant interest recently (e.g., ScratchJr, Kodable, etc.) (Papadakis, 2021). Research has shown that the most developmentally appropriate of them offer opportunities for interactions and collaborative learning while, at the same time, through playful ways encouraging children to explore coding (Papadakis, Kalogiannakis & Zaranis, 2021). Digital kids use smart screen devices and apps at increasing rates, while many apps are already advertised as 'educationally valuable'. Thus, it is critical to identify and evaluate whether and how these apps are designed to maximize educational benefits.

2. LITERATURE REVIEW

Coding and CT are the foundation of fast economic development and an increasingly technological society—a society that calls for innovation and entrepreneurship that can help spark needed economic growth (Harel, 2016). Currently, schools focus on preparing students to productively participate in a 21st-century society increasingly ruled by digital technology (Aranda & Ferguson, 2018). New curricula introduced in several countries such as England, Australia, New Zealand, United States have identified the need to educate both adults and youth for digital literacy and CS, as well as the need to promote deeper content learning and learning experiences in these areas since the years of early childhood (Falkner, 2015). As

these tools, practices, and approaches are universally applicable, they can be taught, not only through CS courses but as part of an integrated way with other curricular inputs at school and from an early age (Bers, 2018).

Early coding, or precoding, can be fun and exciting. Over three decades of research has led to the discovery that well-designed tools are beneficial in giving children the practice they need (Highfield et al., 2018) for improving learning, memory, executive functioning, general cognitive problems, etc. (Strawhacker & Bers, 2019). Although CT concepts and coding skills for young age groups have grown in popularity among academic researchers and industrial practitioners (Strawhacker & Bers, 2019), this research area is not new. Research has proven that children as young as four or five years of age can learn code-related skills such as sequencing and conditions along with literacy and numeracy (Papadakis, 2021). Furthermore, the sooner the children learn the basics of coding from a young age, the easier they will learn and expose themselves to computer language processing in the future (Papadakis et al., 2021).

In early childhood education settings, it is widely known that 'developmentally appropriate practices must guide decisions about whether and when to integrate technology and interactive media' (NAEYC & the Fred Rogers Center, 2012). Programming is a creative activity in itself. Thus, at the preschool level, children are not taught CT and coding as separate subjects but focus on abilities while engaging in coding activities such as algorithms and the opportunity to use programming to make things happen (Papadakis, 2022). In early childhood education, evidence suggests the positive effects of coding activities on attitudes and skills such as problem-solving and critical thinking (Bers, 2018; Strawhacker & Bers, 2019).

Over the intervening years, technology has become increasingly prevalent in the education sector, based on the growing interest and recognition that technology can improve how young children learn. With the advent of the iPad, the youth's engagement with digital devices such as tablet-type devices has grown exponentially since 2010 (Highfield, Paciga & Donohue, 2018). Instead, the exponential growth rate of smart mobile devices has dramatically increased the number of children of all ages in the civilized world having access to these devices (Kyriakides et al., 2016). These devices are particularly suited for the young population as they are light and very mobile and do not rely on specific motor skills as they do not require the respondents to use a keyboard or a mouse (Kucirkova, 2014).

Young children are increasingly heavy users of applications (or 'apps') for these devices, actively engaging in fun and play activities such as drawing and games (Lee, 2016). The term 'mobile application' or 'app' can be defined as a 'self-contained program' or 'piece of software' designed for a specific purpose or to fulfil a particular objective. A user can download the apps on various smart mobile devices from an online store such as Google Play - the app store for Android devices - or Apple store - the app store for Apple devices -.

Apps created for touchscreen devices are particularly suited for the young population, as children found them attractive, easy, and intuitive to use. These apps build on gamification, that is, implementing game features in non-game contexts, aimed at, for instance, increasing user's intentions to use the app, while they try teaching young students the fundamental concepts of CT and coding in a playful mood (Heikkilä & Mannila, 2018). Indeed, educationally sound apps supporting the development of coding skills, problem-

solving and creativity for young people (e.g., ScratchJr, Hopscotch, Lightbot, Daisy the Dinosaur, Kodable, etc.) have begun to appear around the globe (Papadakis, 2021).

Many researchers claim that the early introduction of coding skills requires technologies and developmentally appropriate practices for young children and considers cognitive limitations, maturity, and stage of development (Bers, 2018). Nevertheless, while the developers claim that their apps have real educational value, researchers know little about whether they are essential ingredients to promote learning (Papadakis et al., 2021). Though many apps in the market claim to be educational, there is little research evidence to support that, making it difficult for even professionals to know what appropriate and effective app (Lee, 2016).

3. METHODOLOGY

This review aims to synthesize research on the impacts of using coding apps on CT and the basic coding skills of young children. The Goal, Question, Metrics (GQM) approach was adopted as it stands for a systematic approach for defining and evaluating a set of stated operational goals using measurements. A protocol following method guidelines by Kitchenham (2004) is reported in three phases: planning, conducting and reporting the review to achieve the following goals: 1) to maximize the literature coverage; 2) to identify and include the related work classified as a study, and 3) to collect, organize, synthesize, and analyze data from widely divergent sources based on the defined research questions.

4. RESULTS

The findings of this study provide evidence that young age children can facilitate early STEM learning and foundational coding skills from playful learning experiences on smart mobile devices. This study contributes to a small but growing body of literature investigating how children process and learn fundamental coding skills from touchscreen devices. This study agrees with other studies' results confirming ScratchJr as a developmentally appropriate coding app to engage children in CT and coding activities and provide a space for them to encounter ideas from CS (Leidl, Bers & Mihm, 2017). Various researchers agree that ScratchJr is an app that can teach young children to code while designing their own stories, animations, and games (Walsh & Campbell, 2018). The design characteristics behind the ScratchJr interface has been to create an environment, which is easily 'communicated' where young children can create their projects (Heikkilä & Mannila, 2018). Therefore, we can conclude that teachers and parents must look for developmentally appropriate coding apps such as ScratchJr to engage children in CT and foundational coding skills (Leidl et al., 2017).

The review also found three other apps (Kodable, Daisy the Dinosaur and the Lightbot Jr), which are available either in the Google and/or the Apple's app stores, that the empirical research highlights the fact that can help young children learn basic coding skills via structured app play, although the level of difficulty differs between the apps. All these apps were also appealing to children. This study also revealed apps that claim to be educational. Some promote awards and distinctions verifying their educational value in their websites, such as 'Rated Best of the Best' or 'Certified by …'. Also, there is another category of coding apps such as Bitsbox or Osmo Coding Awbie, etc. These apps use hands-on physical blocks to control characters or create projects, so we did not include these types of apps in this review.

5. DISCUSSION

Educational apps that feature CT and coding skills are becoming more widely available, but, as our research suggests, these are not being utilized. These issues need to be addressed to make CT integration valuable and sufficient early childhood education. In conclusion, there is a need for new and innovative technologies and rigorous designs and interfaces, specifically designed for young people to promote the development of CT concepts and coding skills in young children's lives (Sullivan & Bers, 2016). In this study, we do not claim that these apps do not have educational value, but as we could not find scientific research to certify that value, we must be sceptical about their ability to deliver an optimal educational experience.

6. CONCLUSION

Nevertheless, when well designed, the technology can improve the teaching and learning practice offering meaningful opportunities for young children to learn in inclusive settings and engage in a new, meaningful, positive and powerful way. Given that the quality of early learning experiences predicts future educational attainment, it has become increasingly important to use innovative pedagogical approaches to engage learners in CT and coding skills in the early years.

7. SUGGESTIONS

It is widely known that not all modern technology is designed to be appropriate and valuable for early learners. So, teachers and parents need to be thinking about how they employ these new interactive technologies (Lee, 2016). There is a great need for high-quality professional development programs to empower teachers with new tools to integrate educational technology into their practice (NAEYC & the Fred Rogers Center, 2012). These issues need to be addressed to make CT integration valuable and sufficient early childhood education.

DECLARATIONS

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ABOUT THE CONTRIBUTOR

Dr **Stamatios Papadakis** has been a postdoctoral researcher in Educational Technology, with emphasis on mobile learning, at the Department of Preschool Education at the University of Crete, Greece, since 2016. His scientific and research interests include studying mobile learning, especially on the use of smart mobile devices and their accompanying mobile applications (apps) in Preschool and Primary Education, focusing on developing Computational Thinking and students' understanding of numbers. Furthermore, he currently investigates how a STEM learning approach influences learning achievement through a context-aware mobile learning environment in the preschool classroom and explain the effects on preschoolers learning outcomes.

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