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Educational apps from the Android Google Play for Greek preschoolers: A systematic review

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ABSTRACT

In the seven years since the introduction of the tablet (Apple iPad) in 2010, the use of software for smart mobile devices has grown rapidly in popularity and has become a hotly debated issue in the field of education and child development. However, the rise in popularity of mobile applications (apps) mainly addressed to young children is not in line with a corresponding increase in their quality, as there is conflicting evidence about the real value and suitability of educational apps. The purpose of this study was to examine whether self-proclaimed educational apps for Greek preschoolers have been designed in accordance with developmentally appropriate standards to contribute to the social, emotional and cognitive development of children in formal and informal learning environments. The study results were discouraging. The majority of the apps aimed to teach children the basics about numbers and letters. Overall, they were drill-and-practice-style, based on a low level of thinking skills, thereby promoting rote learning, and were unable to contribute to a deeper conceptual understanding of certain concepts.

1. Introduction

Today, the vast majority of children in the developed world, regardless of their ethnic or socioeconomic background, have access to a smart mobile device (Kyriakides, Meletiou-Mavrotheris, & Prodromou, 2016). Compared to other digital devices (e.g. laptops, mobile phones, and personal computers) the mobile devices with touch screens are by far the most popular among young children and this trend is growing rapidly (Ofcom, 2014; Papadakis & Kalogiannakis, 2017). The intuitive interface of a touch-screen tablet, the ease of installing new apps, the increased portability and autonomy are some of the features which may contribute to their growing popularity among preschool children (Papadakis, Kalogiannakis, & Zaranis, 2016b, 2016a; Falloon, 2014; Hirsh-Pasek et al., 2015; Lynch & Redpath, 2012; Neumann & Neumann, 2015).

There have been studies revealing that smart mobile devices, tablets in particular, may have a positive role on improving the teaching and learning of preschoolers (e.g. emerging literacy and mathematics skills) (Kyriakides et al., 2016; Neumann & Neumann, 2015). Unlike other forms of digital technology that are available in the preschool classroom (Fessakis, Lappas, & Mavroudi, 2015; Lynch & Redpath, 2012), the research on children's use of smartphones and tablets has shown that it presents very few technical challenges and, as a result, children quickly become enthusiastic users (Flewitt, Messer, & Kucirkova, 2015; Shifflet, Toledo, & Mattoon, 2012). As many preschoolers have not sufficiently developed the fine motor skills required to handle conventional computer peripherals such as mice and keyboards, tablets are an attractive tool to implement

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educational activities for this age group (Zaranis, Kalogiannakis, & Papadakis, 2013). International studies have shown that preschool-age children can handle the applications for such devices relatively easily (Hirsh-Pasek et al., 2015). In light of these shifting views regarding general technology use in early childhood, tablet computers have been described as particularly suitable for early childhood (Blackwell, Lauricella, & Wartella, 2016, p. 62).

Thus, there has been an explosive increase in the number of self-proclaimed educational apps which are available for free or for a fee in the two popular online stores (Google Play and App Store) (Kalogiannakis & Papadakis, 2017; Nadworny, 2017) and aim mostly at the age group below 10 years. Educational apps are defined by Hirsh-Pasek et al. (2015) those in which children "are cognitively active and engaged, when learning experiences are meaningful and socially interactive, and when learning is guided by a specific goal" (p. 5).

However, using smart mobile devices and their accompanying apps, inside and outside the school environment, is not a panacea (Fabian & MacLean, 2014). As stated by Guernsey, Levine, Chiong, and Severns (2012), in the early days of the "Wild West" of apps (p. 9) most apps for preschoolers which were advertised as educational, had very little educational value (Kucirkova, 2016). After reviewing the relevant literature, a key issue emerged regarding the quality of the self-proclaimed educational applications (Neumann & Neumann, 2015). Children's experiences with smart mobile devices, as well as their ability to take part in rich, engaging and dynamic learning environments (Kucirkova, 2014a, 2014b, 2015), are closely linked to the quality of these apps (Neumann & Neumann, 2015; Sandvik, Smørdal, & Østerud, 2012; Verenikina & Kervin, 2011).

For instance, as Verenikina and Kervin (2011) state, several apps are marketed as having educational value for very young children, but, in fact at best, provide few if any educational benefits. Vaala, Ly, and Levine (2015) comment that the vast majority of apps do not meet the standard education requirements for the children of today and tomorrow. In most educational apps, the educational content is based only on the format of closed type questions such as multiple choice questions with only one possible answer. Most apps are not created with an open-type design which allows children to create their own content or explore something without their response being considered erroneous. Thus, children may theoretically be engaged with educational apps, but as they are not age or developmentally appropriate, children simply waste their time with apps which do not give them the opportunity to design, create and to express themselves (Bers & Resnick, 2015).

Since the introduction of the iPad and other tablets, various assessments about the suitability of educational apps for preschoolers were conducted in Western countries. In Greece, there has as yet been no such research for any age group. Additionally, in Greece, there are no state and/or private organizations, like the Common Sense Media or the Children's Technology Review, to test and evaluate educational mobile applications and thus provide a great deal of valuable information to teachers and/or parents.

The key research question under investigation is whether Android apps for preschoolers categorised as educational are appropriate in terms of content, design and of the types of knowledge they promote.

2. Educational mobile apps for preschoolers

Since their first appearance in 2010, iPads and other tablet type devices have been hailed as the medium expected to revolutionize the current practice of education (Allen, Hartley, & Cain, 2015; Kucirkova, 2014a). Characterizations and expressions such as "*are easy to use, trigger students' enthusiasm, increase students' interest, improve students' learning motivation, independence, creativity, etc.*" (Clark & Luckin, 2013, p. 4) or the "*Swiss army knife of technologies*" (O'Bannon & Thomas, 2015) go with almost any text that refers to these devices. The international academic community believes that smart mobile devices, and especially tablets, can serve as an important tool to improve learning and teaching, allowing preschool children to explore advanced concepts once thought to be very demanding and incompatible to that age group (Falloon, 2014; Kucirkova, 2014a; Pitchford, 2014; Yin & Fitzgerald, 2015).

A smart mobile device is an electronic device which, in addition to being relatively inexpensive and portable, has a low weight, great autonomy and increased connectivity with other devices or networks (via USB, WiFi, 3G, 4G, NFC, Bluetooth etc.). These devices generally have a built-in digital camera feature and capabilities for sound recording - playback of digital audio and video data. A smart mobile device comes with an operating system and the ability to use third-party applications. A mobile application or app is software optimized for use with smart mobile devices. The vast majority of adult users and teachers positively evaluate these particular characteristics of the devices and especially the potential educational benefits of thousands of apps (Cubelic & Larwin, 2014; Falloon, 2013; Mango, 2015).

Nowadays, young children are surrounded by technology and use it in their daily lives (Fessakis et al., 2015; Hsin, Li, & Tsai, 2014). Thus, more and more children under the age of eight, even from low-income families, now have access to mobile technology such as smartphones and tablets (Common Sense Media, 2013; Guernsey & Levine, 2016) because of a 'pass-back effect' (Chiong & Shuler, 2010). The 'pass-back effect' happens when a parent or adult passes his/her own device to a child to keep it busy, for example in a car or restaurant (Chiong & Shuler, 2010). These new devices are now being used as 'digital pacifiers' as parents often tend to offer such devices as a reward for children's good behaviour (Kabali et al., 2015).

In the last five years, in the United States, children have been spending more time on mobile devices than watching television (Kris, 2015). Similarly, in the UK, in a recent survey, Livingstone (2016) found that 25% of children aged 0–2 years had their own tablet, with the figure rising to 36% for children ranged in age from 3 to 5 years old. They use these devices for at least 1 h per day (Livingstone, 2016). Several studies have shown that pre-school-age children have the necessary skills to make use of the touch-screen interface using various gestures such as swipe, tap, touch, slide (Aziz, Batmaz, Stone, & Chung, 2013; Brewer et al., 2013; Nacher & Jaen, 2015; Nacher, Jaen, Navarro, Catala, & González, 2015) (see Fig. 1).

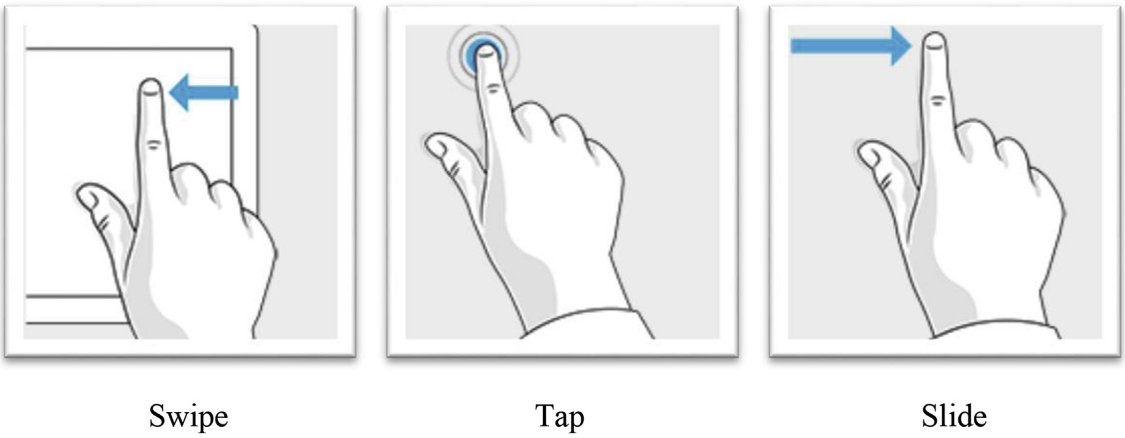


Fig. 1. Preschoolers' touchscreen gestures. Adapted from: Microsoft (2016).

The literature indicates that the increasing popularity of smart mobile devices is partly due to plenty of mobile apps (Papadakis & Kalogiannakis, 2017). Mobile apps have the potential to transform a smart mobile device into a learning and entertainment tool. Studies have shown that children engage with these apps in three ways: sensorimotor, emotional and verbal (Noorhidawati, Ghalebandi, & Siti Hajar, 2015). So, it comes as no surprise that the market for applications aimed at young children is constantly growing, especially in the last five years (Tian, Nagappan, Lo, & Hassan, 2015). As highlighted by Hirsh-Pasek et al. (2015), mobile applications are not just ubiquitous, but they are also a highly profitable business.

It is worth mentioning some data from the Federal Trade Commission (FTC) in the United States. When the online Apple Store (App Store) opened for business in July 2008 there were 552 applications available. The corresponding Google Android app store (Play Google) offered only 50 applications in October 2008 (Federal Trade Commission, 2012). In 2009 almost half of the 100 top-selling applications targeted preschool and primary school children. This figure rose to 75 percent in 2012 (Rideout, 2013). In June 2016, Android device users could choose between 2.2 million applications, while Apple device users between 2 million applications (Statista, 2016). Almost 1000 new applications are added every day in the two most popular app stores (Judge, Floyd, & Jeffs, 2015). A large percentage of these apps call themselves educational and suitable for use in formal and informal settings with preschool and early school-age children. Thus, there are now more than 100,000 educational apps in Apple's and Google's online stores (Dua & Meacham, 2016; Nadworny, 2017).

The independent educational organization Joan Ganz Cooney Center found in 2012 that more than 80 percent of the top-selling paid apps in the education category in the Apple app store are aimed at young children. Of these apps, 72 percent targeted preschoolers, a rise of 23 per cent over the previous year (Shuler, 2012; Vaala et al., 2015). To allow for easier access to these apps, Apple created a special section in the digital store for this age group (Judge et al., 2015). The educational apps targeted at preschoolers range from "learn the alphabet" and single word games, basic counting and mathematical operations, number identification games, memory games, reading stories, interactive books, card games and puzzles. There are also some more sophisticated apps which use an open, adaptive design allowing children to create their own content (Kucirkova, 2014a, 2014b). Most apps are free of charge while the mean price of the charged apps is US$ 1.02 (Statista, 2017).

3. The landscape of the self-proclaimed educational applications

For a long time, the debate on the use of technology in early childhood focused on the time children spent on different types of electronic media, rather than what exactly they do on the devices (Guernsey & Levine, 2016). This question has become even more pertinent considering the fact that, although the two most popular app stores are full of 'educational' content, this content does not meet the necessary criteria for educational software (Shapiro, 2014). In assessing the appropriateness of educational apps in Apple's app store, Watlington (2011) found that only 48% of the educational apps analysed could be classified as appropriate, and thus recommended for educational usage. Even today, four years after the first description of the app market as a 'digital Wild West of apps' (Guernsey et al., 2012), the market of mobile educational apps remains unregulated (Dua & Meacham, 2016; Vaala et al., 2015). The market for educational apps does not meet the changing needs and the new aspirations of the new digital generation (Papadakis, Kalogiannakis, & Zaranis, 2017).

There is a clear mismatch between the content of the apps being produced and the actual development needs of young children (Vaala et al., 2015). Several apps are either developmentally inappropriate or fail to activate the kinds of behaviours that researchers have found support the optimal development of children (Chau, 2014). For instance, as highlighted by Guernsey et al. (2012), various reading apps appear in the digital stores without providing any information whether the app developers have a specific scientific background in early literacy. Additionally, no information exists regarding whether and how the apps were tested by independent experts in the field, or if they were evaluated for their efficacy in whatever way.

Often teachers and parents find out that the software they supplied is either not adaptable to the level of the user, or doesn't teach the content that it claims to teach (Higgins, Boone, & Pierce, 2005). Additionally, there is a lack of criteria based on scientific research about what counts as 'real' educational value in an educational app (Kucirkova, 2014b). Thus, educators have many products to choose from, but little information on whether and how these digital tools enhance learning (Blackwell et al., 2016).

3.1. Why is it difficult to design and develop educational apps for children?

Why is there a discrepancy between the designation of an app as educational and its real educational value? Creating an educational application has not always been an easy process. A possible reason is that the educational value of an application is not only related to its content, but also to the design, methods, and analysis used to meet the needs of the target group (Judge et al., 2015).

To meet young children's developmental stage and cognitive abilities, apps need to adopt specific practices (Chau, 2014). In mobile educational applications, besides issues related to the pedagogical approach, other factors – such as the characteristics of the device and the target audience (i.e., child vs. adult) – should also be considered. Recent literature has shown that children should not be treated the same as 'young adults' as these age groups have very different characteristics and needs (Anthony et al., 2014). Thus, it is imperative that an app development team be aware of recent scholarly literature, and apply relevant scientific considerations in creating apps.

For instance, with the advent of touch-screen devices various usability issues emerged, such as the lack of physical feedback which is related to the use of 'soft buttons', as well as changes in the interaction style with which young children had to familiarize themselves (Zaranis et al., 2013). Design approaches that were used for decades and based on traditional interaction technologies (such as the keyboard or the mouse) needed a complete overhaul after touch-screen user interfaces were introduced. Pre-school children (<6 years) are a special group of users (Mohamad, Lakulu, & Samsudin, 2016) which, according to Piaget's theory of cognitive development, belong to the preoperational stage (covering the age range of 2 to about 7 years) (Lerner, Liben, & Mueller, 2015). At this stage, children are developing their motor skills and are limited in the amount of information they can mentally process (Vatavu, Cramariuc, & Schipor, 2015). However, prior research showed that the apps aimed at this age group very often used inappropriate gestures (pinch, tilt, flick, double tap) rather than more intuitive and functional touch gestures (tap, trace, swipe, drag, slide) (Neumann & Neumann, 2015).

Often, however, the guidelines for the design of mobile applications come from research or practical experience, which is based on different types of devices and/or different user groups (Brown et al., 2010; Masood & Thigambaram, 2015). Children have smaller fingers, weaker arms and lower handling skills (Anthony, Brown, Nias, Tate, & Mohan, 2012) and therefore they may not be able to target small defined areas with precision. Additionally, they cannot apply the drag-and-drop techniques on the touchscreen in the same smooth and effortless manner as an adult. Probably the only field in which young children predominate in comparison with adults is in their familiarity with the technology.

Content design for preschoolers is particularly demanding since they are pre-readers and thus the designers-developers cannot rely on text (in menus, buttons, messages) to handle the application (Chau, 2014). But, quite often, in applications targeted at preschoolers the developers use interfaces which contain excessive text messages (Judge et al., 2015). Contrary to the belief of app designers who use textual interfaces that parents will read the content to their children, research has shown that parents involve themselves in media activities of if the activities are fun for them (Takeuchi, 2011). Software engineers, designers and user interface experts should follow basic principles and guidelines to design effective educational applications, such as providing clear instructions or information, using multimedia elements properly, using multiple communication channels and appropriate multimodal features, eliminating negative social values and violent content, as well as avoiding the reproduction of cultural, ethnic or gender stereotypes (Chau, 2014; Goodwin & Highfield, 2012).

Additionally, various objections have been raised about the pedagogical appropriateness of apps for young children. There are many new companies producing educational apps very profit driven. Specialized on programming, designing and marketing, such publishers often miss a pedagogical foundation and evaluation (Notari, Hielscher, & King, 2016, p. 92). Internationally, there is little evidence of well-designed educational apps for infants (younger than 2 years), preschool children (2–5 years) and early school-age children (Papadakis et al., 2016b, 2016a). Designers and software engineers should use pedagogical principles based on recommendations for children younger than seven years. These include the use of open-ended, or open discovery oriented activities and classifying problems/challenges so as to improve children's knowledge and skills (Hourcade, 2015). Effective learning is facilitated within a flexible framework which supports practice, discovery and creativity as children are actively engaged through suitably modulated learning objectives (Hirsh-Pasek et al., 2015; Zurek, Torquati, & Acar, 2014). Specifically, in the case of young children, learning is optimized when children are cognitively active and entirely motivated, and when their learning experiences are meaningful, socially interactive and target oriented (Harvard Family Research Project, 2014). Hirsh-Pasek et al. (2015) have identified four key features that mobile applications must have to contribute to the learning of young children. A developmentally-appropriate educational app should prompt children to (a) actively participate, (b) engage with the educational content, (c) experience meaningful learning, and (d) allow for appropriate social interaction.

Even the American Academy of Pediatrics (AAP), which was for years against the use of digital media, on October 2016 abandoned its previous recommendation that parents ban young children of up to 2 years old using digital media (American Academy of Pediatrics, 2013). The AAP now advises parents who wish to use digital media with their children to choose high-quality educational apps (Guernsey, 2016), but this guideline is almost impossible to follow as most of the apps targeted at young children were not created to be educational (Papadakis et al., 2017). An excerpt of an interview with Björn Jeffrey, CEO of Toca Boca (one of the most popular app development companies in the world) describes how the software industry perceives the market of educational software. In an interview he gave in 2014 on the website Gamesandlearning.org, he said that "… *all the apps are in the education category because that is where parents look for children's products. Now are they, then, educational because they are in the education category? Not necessarily and looking at most of the apps, most probably not*." (Isafe, 2015).

We must also consider factors such as the cost of creating a developmentally appropriate educational app. There may be several noteworthy apps for children created by enthusiastic teachers, parents etc. Yet, in most cases, the few appropriate educational apps were developed and supported by specialized software development companies. One major reason, among others, is that the cost of developing apps which have a complex and adaptable interface and user-specific content ranges from around $250,000 to $1,500,000 (Yarmosh, 2015). The cost of developing an app is largely determined by both the specific characteristics of the app, as well as by the app design and content complexity (Yarmosh, 2015). Even simple apps that use standard components and custom graphics may have a development cost ranging between $1000 and $10,000 (Redbytes, 2016). The average cost of developing a serious app is close to $270,000 (Formotus, 2016). Additionally, if the app supports cloud-based and social media services, frequent upgrades and error correction, the development cost also rises exponentially. Considering the high cost of even a relatively simple application many legitimate questions are raised about the quality of educational apps which in a massive way are posted daily on various digital stores. Fast-produced and fast-selling content for a broad target audience is the key for high profits in the low priced app store market (Notari et al., 2016).

3.2. Why is choosing a developmentally appropriate educational app difficult?

Most applications, whether they belong to the drill & practice or the free expression games category, do not even focus on a single learning goal. Several early literacy and math apps are similar to unattractive worksheets or flashcard games which, due to the mechanistic nature of their learning model, offer few or no learning benefits (Chau, 2014). The drill & practice style apps could potentially enhance rote learning, but are unlikely to promote a deeper conceptual understanding of the field (Ravitch, 2010). Even if they are presented in a playful form, many apps tend to have repetitive and addictive characteristics in their design, without providing clear learning benefits (Neumann & Neumann, 2015). Most educational apps belong to the 'first wave' of the mobile revolution; namely apps which are simple digital worksheets, games and puzzles and have been reproduced in a digital format, without explicit consideration of how children learn, or how the unique multimodal capabilities and features of digital devices will be used (Hirsh-Pasek et al., 2015).

The digital market of educational apps is not only full of inappropriate self-proclaimed educational apps (Hirsh-Pasek et al., 2015), but it does not provide all the necessary information to assist teachers and parents in making decisions about how to choose and use apps (Vaala et al., 2015). The availability of hundreds of new applications daily prevents researchers, educators, and parents from systematically assessing new apps entering the digital market (Hirsh-Pasek et al., 2015; Kucirkova, Messer, Sheehy, & Panadero, 2014). Additionally, the popularity of apps in the digital app stores bears little relation their real educational value, as popularity is based on subjective classifications (users' comments and a five-star rating system), rather than on objective and clearly defined criteria (Bentrop, 2014). Android users in the Google Play store can rate or review each app at any time (Olmstead & Atkinson, 2015). A comparative analysis of the efficiency of the Google's star system and users' comments noted the lack of a reliable and valid measurement tool for the assessment of an educational app (Domnich et al., 2016). Similarly, Hirsh-Pasek et al. (2015) highlight the discrepancy between the classification of a self-proclaimed educational app based on Google's star system and its real educational value.

4. The research

4.1. The purpose of this study

The purpose of this study was to examine whether the educational apps with Greek content for Android mobile devices contain developmentally appropriate practices to promote preschoolers' optimal learning and development in formal and informal settings, as well as whether they are appropriate in terms of content and design.

4.2. Sample selection criteria

During the selection phase, the researchers considered the international literature (Chau, 2014; Goodwin & Highfield, 2012; Handal, El-Khoury, Campbell, & Cavanagh, 2013; Richards, Stebbins, & Moellering, 2013; Shuler, 2012; Watlington, 2011) to produce comparable results with similar international studies in educational apps with English content. The following criteria were used to select the sample: the apps had to:

- Belong to the educational category for preschoolers.
- Be available for free, trial or freemium version.

- Be compatible with the Android operating system. The apps did not need to run on the latest edition of the operating system, which during the period of the study was the Android 7.0 Nougat.
- Be available in Google's app store during the selection phase (December 2016).
- Contain Greek content.
- Be capable of being installed in both smartphones and tablets (this feature was not a necessary condition).

The Android operating system (Google) was selected instead of the competitive iOS (Apple), because, according to official figures, Android is the most popular operating system for smart mobile devices in the world, with a usage rate of 87.6% for the second quarter of 2016, and this increasing trend is likely to continue (International Data Corporation, 2016). In Greece, similarly, Android has become the most popular mobile operating system (Vodafone, 2016), and there are several smart mobile devices available on the market at all price ranges, as opposed to devices using competing operating systems.

In the aforementioned studies, the mean average number of applications per study ranged between 19 and 240. In the present study, initially, there was no limit on the number of apps that could be selected for evaluation. But, a thorough search on the Google Play store with the combined criteria (Category: “Education” or “Family” and “Age 5 and below” and content: “Greek”) gave rise to a selection of approximately 60 apps. Ultimately 40 apps were evaluated. The main reason 20 apps were excluded from the analysis was that the researchers observed that several of these were identical, as they had the same design, plot, and goals and differed mainly in their appearance using different colour themes. Many apps offer the same content with just a slightly different audio visual presentation (Notari et al., 2016). Also, several apps by a Greek research institute were excluded as the researchers considered that the low quality of these apps, might significantly alter the assessment results.

4.3. *The assessment tool*

The REVEAC scale (Rubric for the EValuation of Educational Apps for preschool Children) was used as an assessment tool (Papadakis et al., 2017). This scale differs from others in the literature in that it not only focuses on pedagogical or technical characteristics of an app, or even a single company's products, but also considers the multidimensional aspects of an educational app, as well as the peculiarities of the technological device. The rubric is notonly designed to assess the educational value of an app, but also to evaluate several additional features, such as, the amount of information provided to the parents during, and on completion of the app, the configuration options of the app, the degree to which an app can affect a preschooler's cognitive progress, etc. It also considers the existence of advertisements which may disrupt the user's attention, as well as the promotion of electronic transactions (in-app purchases). In summary, the REVEAC assesses the educational apps in the following four domains: educational content, design features, functionality and technical characteristics. The rubric has a high level of internal consistency (Cronbach alpha = 0.79) and an average inter-rater reliability of 0.72. The correlations between scale individual items range from 0.58 to 0.78 and are considered large (Shrout & Fleiss, 1979).

4.4. *Evaluation process*

To check that the rubric score is indeed consistent we used the following procedure. A single researcher, expert in the domain, who was familiar with the process reviewed the sample using the following procedure (see Fig. 2):

1. He/she visited the Google Play store and downloaded the sample apps.
2. He/she “locked” each app installation by disabling the apps' automatic updates. The necessary third-party app, Adobe AIR, was installed.
3. He/she recorded the app's star rating and user reviews.
4. He/she dealt (played) with each application until it was completed.
5. He/she evaluated each app using the assessment tool.

A second researcher then again reviewed the sample apps, along with all notes for general agreement on the app scores (assessment tool) and star rating and user reviews (digital store).

5. Evaluation results

5.1. *App categorization*

From a pedagogical perspective, ‘Apps for learning’ can be classified in various ways (Notari et al., 2016). As the same researchers' state one classification might focus on ‘instructional design’ criteria or address the ‘learning goals’ of a given app and another classification system might focus on motivational domains via ‘gamification’, ‘reward systems’ or the amount of ‘infotainment’ (Notari et al., 2016, p. 84). Additionally, in Greece, there is no public or private organization which provides some rudimentary form of assessment of digital interactive products aimed at children, let alone for mobile applications. Thus, in order to ensure that the results of this research be consistent with the results of other published studies, the

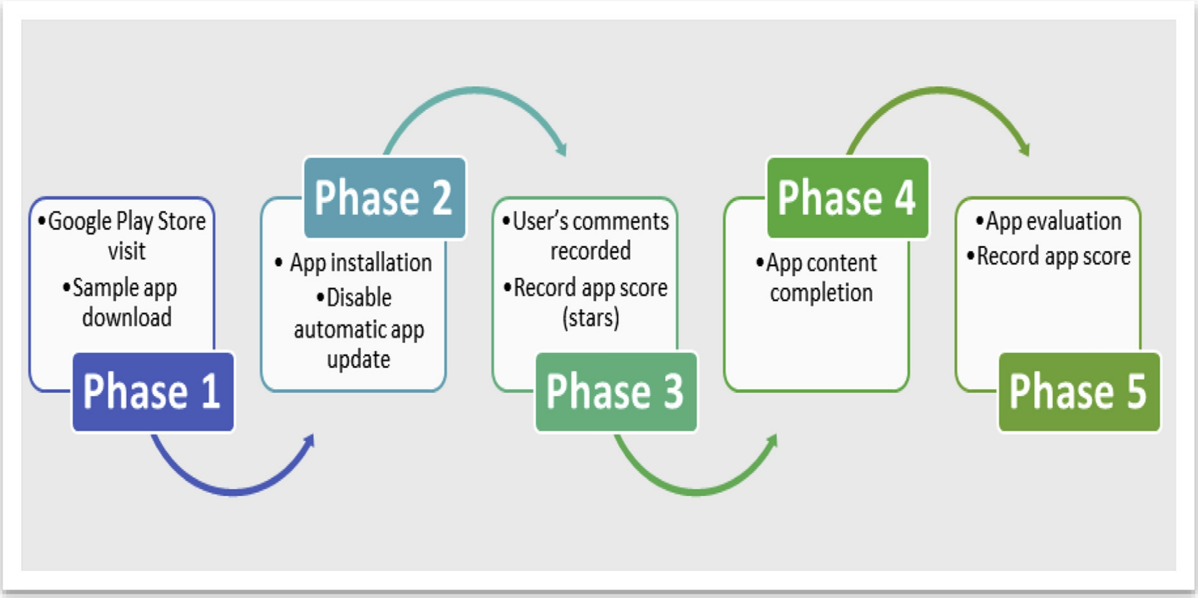


Fig. 2. The five stages of each app evaluation.

researchers considered relevant data from the literature in the categorization of the apps (Chau, 2014; Cohen, 2012; Federal Trade Commission, 2012; Judge et al., 2015; Noorhidawati et al., 2015; Sesame Workshop, 2012; Shuler, 2009, 2012). The researchers categorized the apps into three non-exclusive categories: games, interactive electronic books and open-ended apps (see Fig. 3). The electronic interactive books are applications that combine text with sound, narration, images, animation and video. These apps, in contrast to the traditional electronic books (e-books), have features such as word-by-word highlighting, and generally make extensive use of multimedia features that enable users to engage in an interactive exploration of the data (Chau, 2014). The game apps are typically combined with interactive features and educational content, either in the form of memory activities (like matching and/or show-hide numbers, letters, and images) or in a puzzle form. Open-ended apps have diverse content without a game goal and, as Chau (2014, p.82) states, these apps may be classified as either creativity or productivity tools. The apps of this type typically aim to develop children's creativity, for example, via forming new shapes (Noorhidawati et al., 2015).

The analysis showed that 5% of the sample apps was in the form of simple e-book (not interactive) format. In other words, they were an electronic copy of a print book that did not fully exploit the advantages of multimodal technologies. Interactive e-books, for instance, emphasised certain words and, in combination with their pronunciation, offered an enhanced and enjoyable learning experience to preschool children. Although studies have indicated that the use of interactive technology in e-book applications is not a panacea (Chiong, Ree, Takeuchi, & Erickson, 2012), the problem with these apps -regardless of the audio-visual features used-was the absence of a clear educational goal or strategy in their plot. These apps were another passive digital instrument in the hands of the children.

The remaining 95% of the apps were edutainment games, i.e. apps which, theoretically, aimed at strengthening children's literacy, mathematics, and life skills through a fun and entertaining approach (Okan, 2003). Almost all the apps were of the "drill & practice" type, where the task is learned through trial-and-error (Hirsh-Pasek et al., 2015). Questions were a mixture of multiple choice and short close answer format. The correct answer led to the next question of the same type. The apps, at best, tended to assess children's knowledge rather than trying to teach things. The apps were based on low levels of math, literacy and language skills, as well as weak critical thinking, problem-solving and reasoning skills, and did nothing more than promote "rote learning", a memorization technique which is based on repetition (Goodwin, 2013). Finally, there were no open-ended type apps. Some apps offered the possibility of colouring predefined shapes, but in any case, they cannot be regarded as aiming to develop children's creativity through play and learning.

5.2. Review of applications

The researchers used the results of the evaluation scale to gauge the extent to which the sample apps had adopted developmentally appropriate practices according to the needs of preschool children. More specifically:

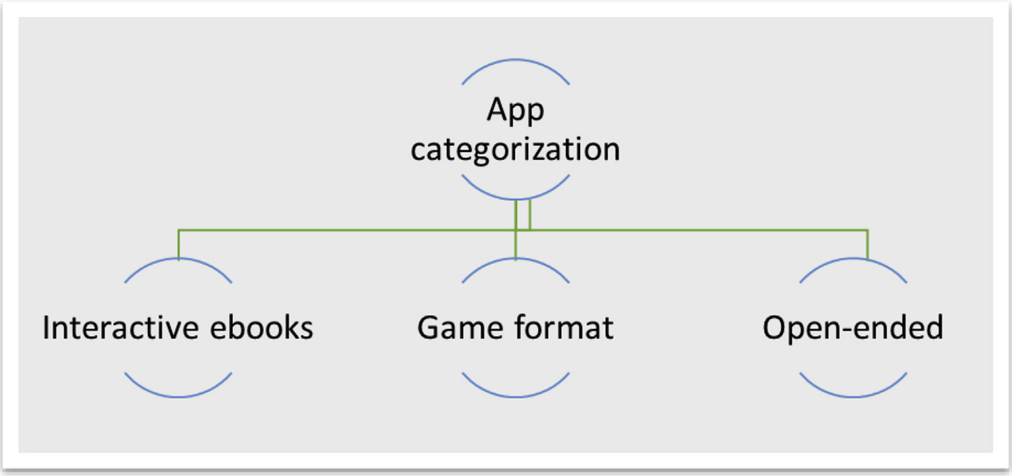


Fig. 3. A categorization of mobile apps for preschoolers.

- In the educational content section (knowledge package appropriateness, learning provision, levelling, motivation/engagement, error correction/feedback provision, progress monitoring/sharing and bias free) the apps had an average rating of 11 points (*Standard deviation* = 1.10) (*Minimum rate* = 7, *Maximum rate* = 28).
- In the design section (graphics, sound, layout/scenery and app/menu design) the apps had an average rating of 5.14 points (*Standard deviation* = *1.14*) (*Minimum rate* = 4, *Maximum rate* = 16).
- In the functionality section (child friendliness, autonomy, instructions and customization) the apps had an average rating of 4.75 points (*Standard deviation* = 0.93) (*Minimum rate* = 4, *Maximum rate* = 16).

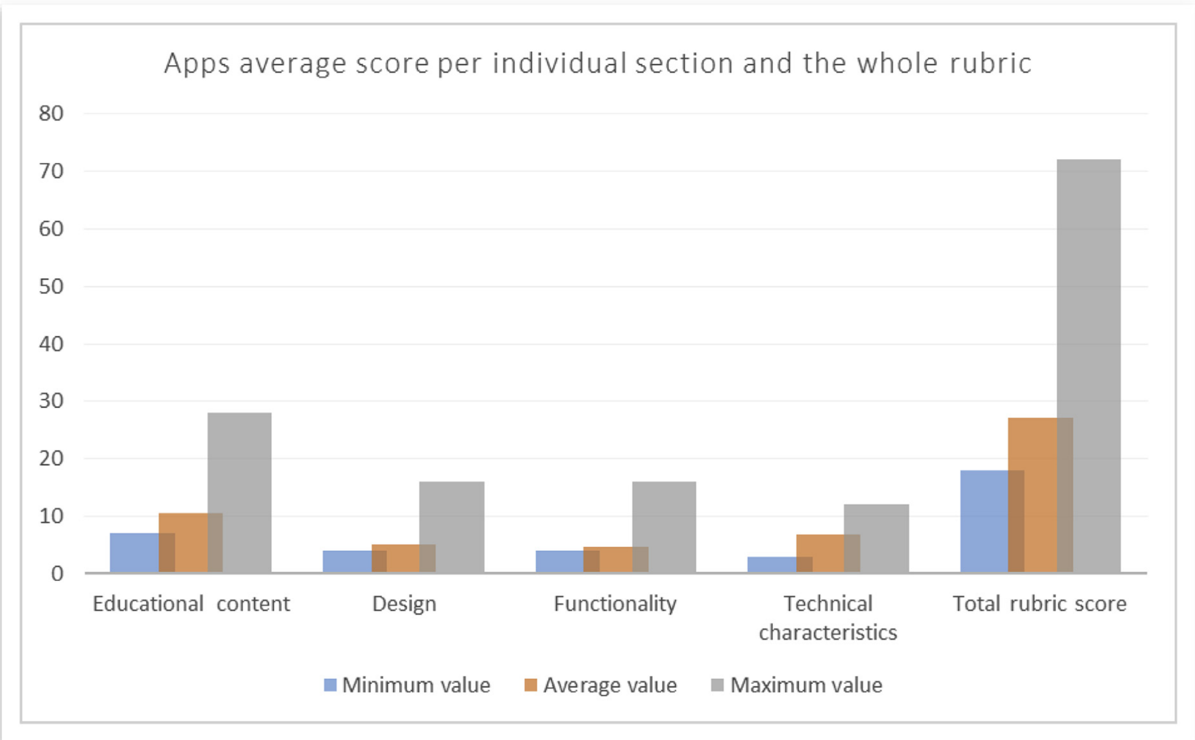


Fig. 4. Average app score for the whole rubric and the four individual sections.

- In the technical characteristics section (performance and reliability, advertising/electronic transactions and social interactions) the apps had an average rating of 6.75 points (*Standard deviation* = 1.55) (*Minimum rate* = 3, *Maximum rate* = 12).

The overall sample had an average score of 27.18 (*Standard deviation* = 2.60). The rubric scores ranged from minimum 18 to maximum 72 points. It is worth noting that both total averaged app score and the average score for each of the four sections highlighted the low quality of the sample apps (see Fig. 4). Only two apps were evaluated to be of a fair quality as they scored higher than average on the rubric score. However these same apps also had particularly low scores on subsections such as error correction/feedback provision, learning provision etc.

In addition, researchers wanted to explore whether users' opinions of these apps are in line with the rating of each app as indicated by the referral rubric. All apps, based on Google's 5-star rating system (minimum and maximum rates are 1–5) had scores ranging from 3.9 to 5. The average rating of the applications was 4.6 (standard deviation = 0.50). Thus, if a user searching for an app in Google's online store based his decision solely on an app score may conclude that the app is a remarkable educational tool.

It is worth noting that a variety of apps (created by a Greek public institution) were not included in this study. The reason was that after examining the apps the researchers felt it best to exclude them from the analysis due to their extremely poor quality and low scores in all rubric subsections. The excluded apps did not adversely affect the scoring of the remaining apps. Fig. 5 presents screenshots of these apps' user interface. Buttons, controls, menus etc., are missing. In these apps, the images were too small, and didn't adapt according to the mobile device's screen size. The apps asked children to draw something (an umbrella, a line, or a chicken), but the images were too small for finger operation.

Subsequently, researchers converted the rubric score to a five-point scale to verify the existence of an association between a subjective scoring system (Google's star system) and an objective scoring system (assessment rubric). However, from the overview of data (see Table 1 and Fig. 6), it seems clear that firstly there was no association between the rubric and users' scores. Secondly, the users tend to overestimate the educational quality of the apps they have downloaded on their smart mobile devices. The application of Pearson's Correlation Coefficient confirmed the above findings, as it showed that there was no statistically significant correlation between the rubric score and apps' score (number of stars) (r=0.91, $p > 0.05$).

In addition, the researchers attempted to investigate whether an app's score according to Google's rating system is associated with the number of users who rated the application. The number of users who rated the apps was not constant per application but instead presented a great variability. For instance, an app was highly rated by a single user only with 5 stars

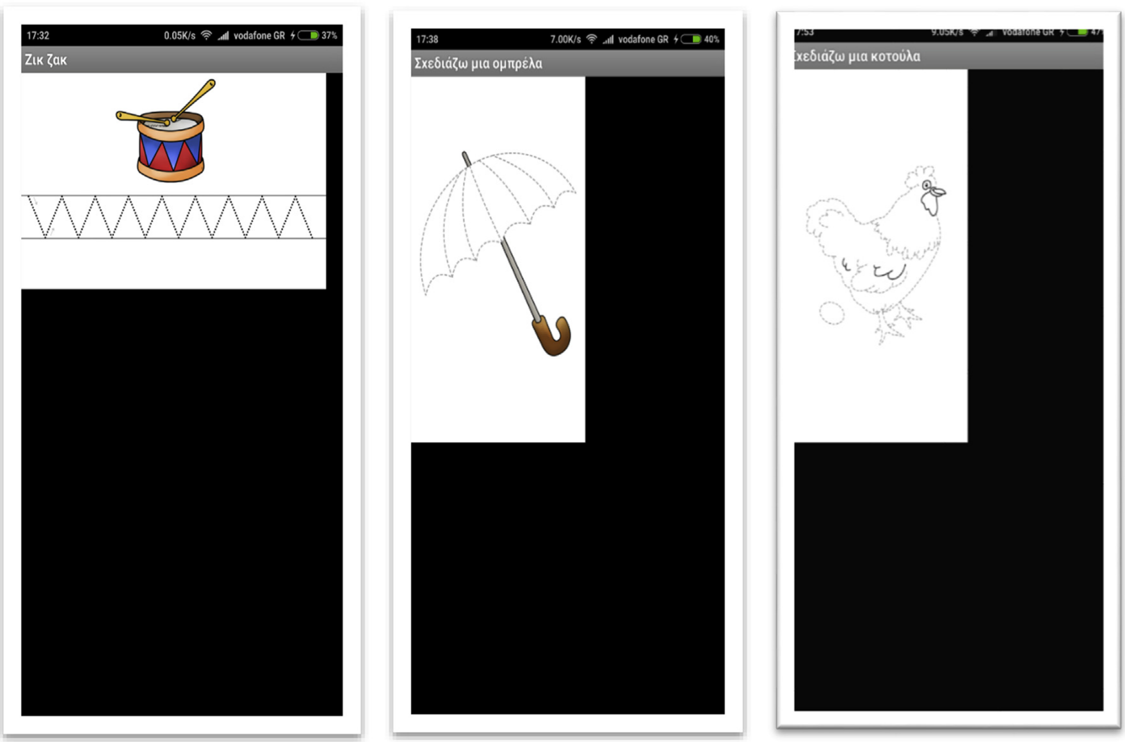


Fig. 5. Screenshots of poor quality apps.

Table 1
Differences in score between the users and the rubric.

	Rubric score	Google score
Minimum value	2.4	5.0
Maximum value	1.7	4.0
Mean value	1.89	4.67
Standard deviation	0.20	0.50

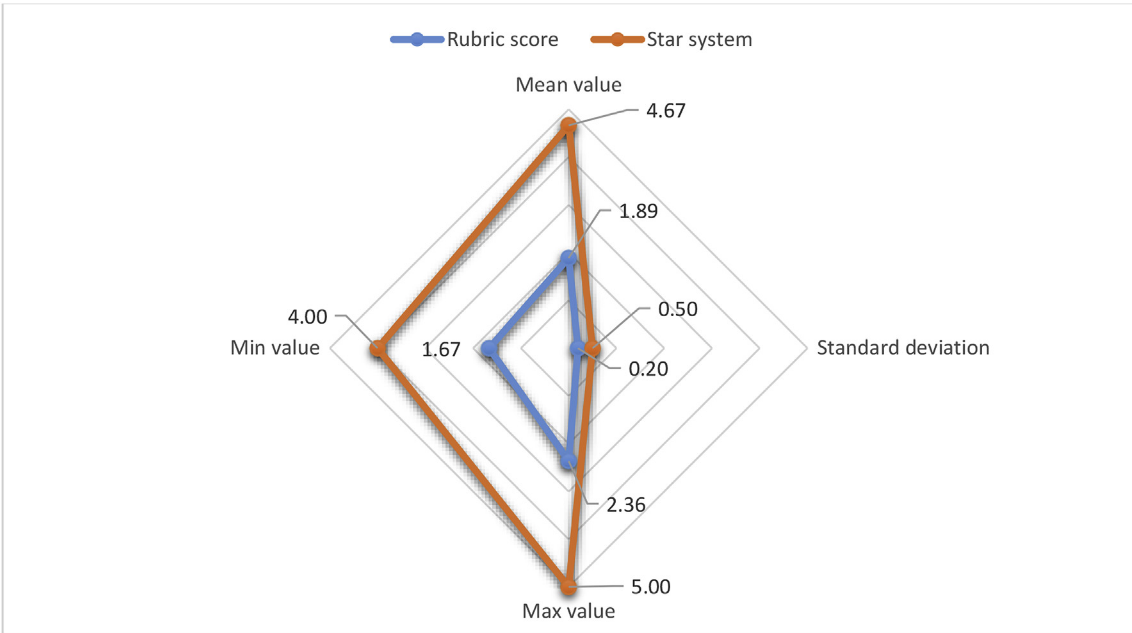


Fig. 6. A schematic representation of the difference in scores between the users and the rubric.

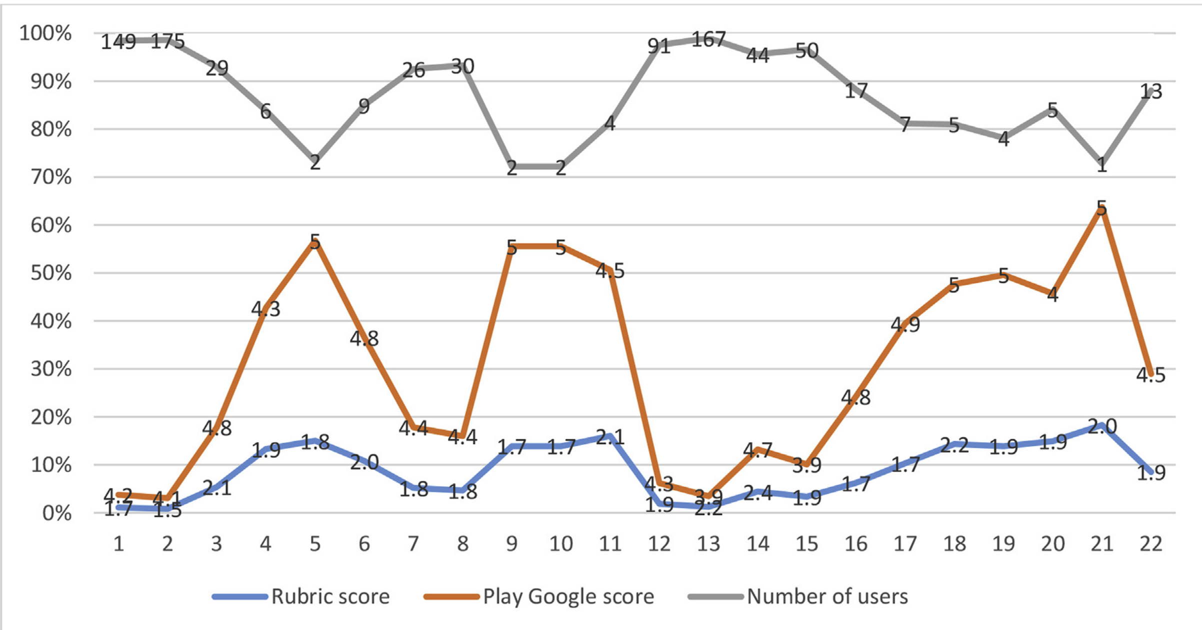


Fig. 7. The association between rubric score, users' score and number of users.

(rubric score: 2) while another app was rated by 175 users with an average of 4.1 stars (rubric score: 1.5). Fig. 7 presents the association between rubric score, users' score and the number of users, in 22 randomly selected apps.

Statistical analysis of the data was performed by applying Pearson correlation coefficient. The analysis showed that there was no statistically significant correlation between the app's score (number of stars) and the number of users who rated the application ($r = -0.38$, $p > 0.05$). Nevertheless, it is possible that the relatively low sample size has prevented detection of small effects. Additionally, the results of the same criterion showed that there was a medium statistically significant positive correlation between an app score (number of stars) and the number of users who had the app currently installed on at least one device (r=.48, $p < 0.05$). There is a close connection between the popularity of an app and its rating and number of downloads. The higher the score of an app, the greater the number of app installations. But, there was no correlation between the number of installations and an app's real educational value (rubric score) ($r = -0.12$, $p > 0.05$). The data obtained from the evaluation of several “educational” apps are presented in Annex I.

5.3. Descriptive evaluation of the applications

In the following paragraphs, the researchers describe several issues about the sample apps. Despite efforts made by the researchers to categorize the evaluation results into four sections based on rubric subsections, as the reader can verify, there are many overlapping areas of quality concerns to consider. For instance, the unclear demarcation of various interactive elements of an app between foreground and background or the use of text messages as feedback has been shown to adversely affect both the design and functionality of an app for preschoolers. The main observations were the following:

5.3.1. Design section

- Generally, there was poor sound quality in most apps, both during gameplay and in the feedback messages. Similarly, there was very low quality in the use of images and generally in the use of multimedia in most applications.
- Although several applications made use of interactive hotspots, in most cases, this was not successful. Many of the hotspots were activated in a way that was not directly related to the game's story, which was disorienting for the user. Also in some applications there was no clear demarcation between the various interactive elements of an app and the app background. It was often difficult for the user to distinguish which application components were part of the background data or constituted interactive elements that were associated with the game story (see Fig. 8a).
- In most applications, the user interface was not well designed or easy to use. An app is well designed and easy to use when the menu is hierarchically arranged and can be divided into various submenus. In some apps, the menus were not logically

a b c

Fig. 8. a, b, c. Problematic design issues.

arranged and often there was no correlation between the app controls (menus, buttons) and screen transitions. Also, in several applications, the user had to choose elements that were either too small (even for preschoolers' fingers) or were placed too close to each other. This often resulted in wrong choices and conflicting results. The research has shown that targets on a touch screen, size of 0.32 cm (0.125 inches) or less, are considered too small for both adults and children (Anthony et al., 2012) (see Fig. 8b and c).

- In some apps, the screens were loaded with too many components, such as buttons, characters, navigation arrows etc., which complicated handling.
- International research (Aziz et al., 2013) shows that the children aged 4 years and above can use up to seven different types of gestures during their interaction with touch screens (tap, drag/slide, free rotate, drag & drop, pinch, spread, and flick). Yet, several applications required using gestures beyond the capacity of preschoolers, such as the double tap. Additionally, there was an application which at different screening stages used different gestures. This created confusion even in the adult reviewer of the application.

Several applications did not allow the user to switch between app screens or return to the main menu screen using the app controls. Sometimes even a stop button was absent. In some cases the user's only option was to use the main buttons on the front of the device. This omission created confusion in the adult user, let alone a young child (see Fig. 9). At this point, it should be noted that the use of the “Home Button” does not terminate an application. The app keeps running in the background draining mobile device resources. The existence of this type of application on a mobile device causes stability problems, slow response time and decreased user satisfaction.

5.3.2. Educational content section

- The analysis showed that most applications focused on literacy (70%) and mathematics (30%). The literacy applications aimed at teaching children the alphabet (recognizing the letters and the sounds of the spoken letters of the alphabet), while the mathematics apps aimed at teaching children the basics about numbers. Yet, as opposed to previous studies (Guernsey et al., 2012), the apps did not attempt to develop a higher level of reading skills such as reading accuracy, fluency, and spelling skills or self-expression. In some applications, the children were required to learn the colours and shapes in a behaviourally relevant way and not through open-ended activities, e.g. to draw the other half of the shape for each item. There were also two applications that aimed to develop memory skills. But, there were no applications that focused on developing general cognitive skills such as sorting, classification, or children's sense of numbers as a quantity.
- The majority of the applications had interactive but closed-ended content, i.e., the activities that could not be modified or be extended by the user (see Fig. 10a, b, c). The applications tended to evaluate only the pre-existing knowledge level of the preschoolers and did not attempt to teach new concepts. Thus, a preschooler can be using an “educational” application, but must still be exposed to additional external sources to obtain new knowledge. Additionally, the majority of literacy applications contained a small number of words with respect to the international level, as is clear from relevant studies (Vaala et al., 2015). This raises doubts raised about the educational usefulness of these apps in terms of the number of words they can teach to preschoolers.

Fig. 9. An application without an end button. The user had to use the device controls.

a b c

Fig. 10. a, b, c. Examples of applications with closed-ended content.

- Almost all applications were of a behavioural type. The apps guided users to solve problems through “trial and error” questions and not through meaningful, active learning experiences. Often the user found the correct answer only after he/she had exhausted all possible −answers/options. For example, if the user did not know to answer the question “1 + 2”, she/he could “find” the correct answer through trial and error. But, in this manner, the preschooler never learns the fundamental principles of addition.
- Furthermore, in several apps, whenever the user chose to engage with the same app at different times, the app content was identical compared to what had been presented before. The randomization feature was absent, e.g. the appearance of a number from a predetermined and limited range of values. The above finding is indicative of low app quality, as this feature is inherent in all programming environments and is thus very simple to incorporate in the app's code, even by a novice programmer.
- Several apps were digital reproductions of common games such as jigsaw puzzles and matching cards. Essentially, there was a simple reproduction of analog materials and tools in a digital form (see Fig. 11).
- The few applications in the form of electronic books belonged to the “Read to Me” type. The vocabulary used was restricted, while the use of multimedia elements often distracted the user. Research has shown that e-books can be used as a basis for intervention development in expanding reading ability (Pearman & Lefever-Davis, 2006). In general, the researchers were not convinced that these apps can contribute to improving emergent literacy skills of preschoolers (reading, writing, speaking and numeracy).
- None of the sample applications monitored individual users' progress, and thus parents were not aware of their children's difficulties. Accordingly, feedback was not provided to the parents at the end of each app session. Also, none of the apps included a portfolio system to allow children to continue the app/game at a later time.

5.3.3. Functionality section

- In contrast to best practices, the sample apps did not include an on-screen character (avatar), which with either visual or auditory feedback would guide the preschooler while dealing with the application. This lack of support resulted in

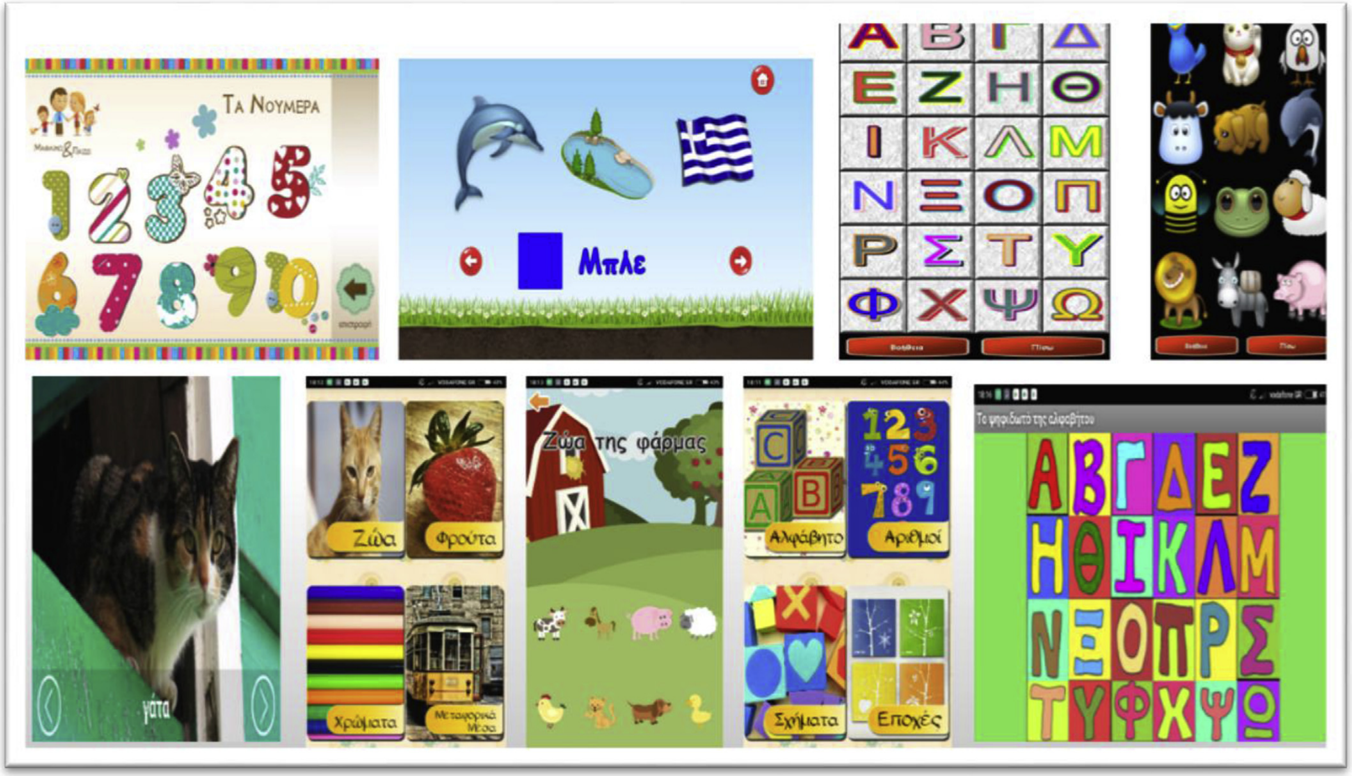
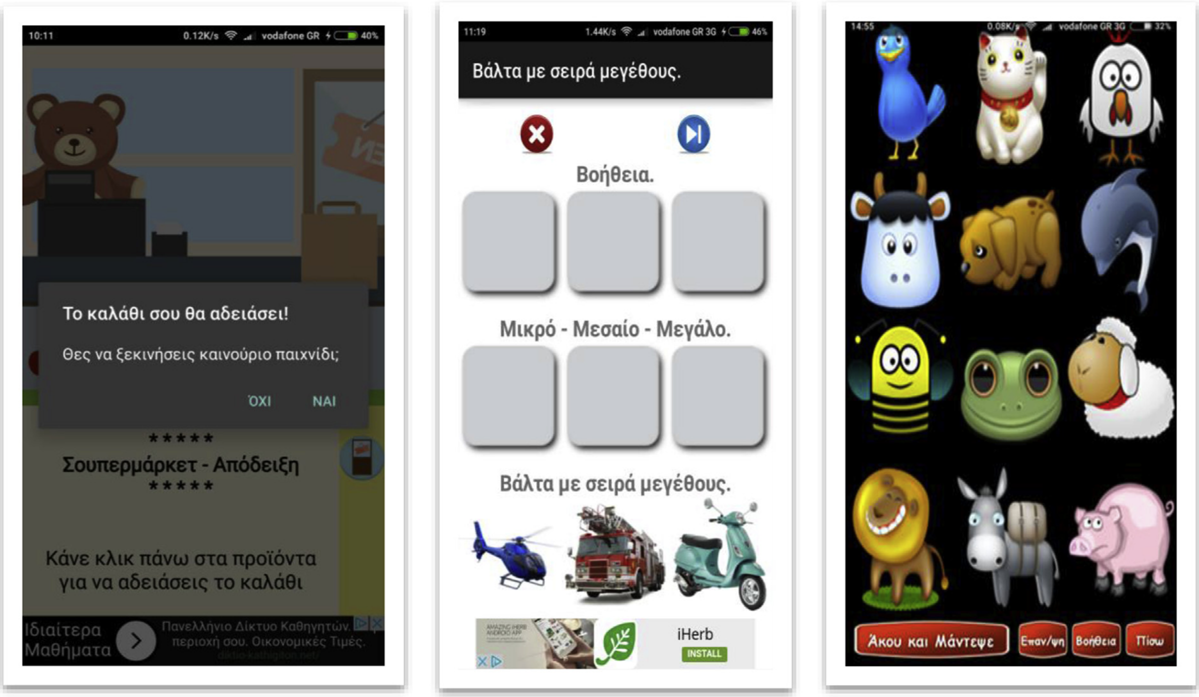


Fig. 11. Examples of analog material reproduction in a digital form.



a b c

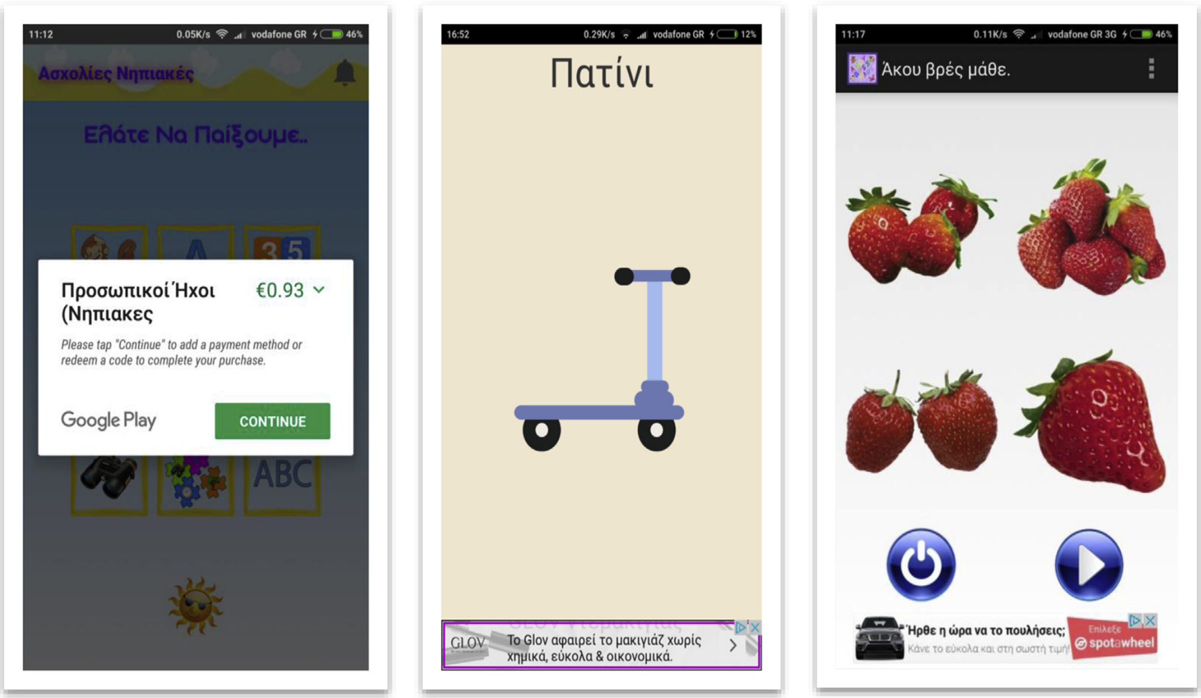
Fig. 12. a, b, c. Applications with problematic functionality.

constrained communication in most apps either in the form of instructions, messages or narrative synthesis. The absence of an avatar is a disadvantage as it has been shown that avatars help young children better understand the mechanics of an app (Chau, 2014).

- Some applications did not provide any guidance on how to use them. In addition, various applications provided guidance that can be considered incompatible with a user's age. The above feature is particularly important as the way in which the children interact with an app affects both their ability to understand and interact with the app content (Hiniker et al., 2015) (see Fig. 12a). There was an application which, although aimed at preschoolers, was based exclusively on the use of prewritten text in the drop-down menus, and/or on the main menu screen, instead of using graphical elements (see Fig. 12b). An opposite example in the utilization of good design practices in an app development is ScratchJr With ScratchJr, young children (ages 5–7) can program their own interactive stories and games (ScratchJr, 2017). For instance, the ScratchJr development team uses block images rather than text which join horizontally and not vertically. The reason is that it has been found that the horizontal alignment is more suitable for devices with small screens such as smart mobile devices (MIT Media Lab, 2016). ScratchJr was not included in the sample as it does not contain Greek content.
- Many apps did not provide a "palm rest" area, an area at the bottom of an app free of buttons and interactive elements, which could trigger app functions as the user touches them while dealing with the app. The lack of a "palm rest" area becomes more problematic in apps aimed at younger children and toddlers, as this age group has weak muscles in both shoulders and upper arms (Anthony et al., 2012). Due to the weight of the mobile devices, especially tablets, children very often sit on a chair with the device resting on their knees. Thus, due to the accidental contact of the child's body with the tablet surface, various functions of the application are activated. On the contrary, in properly designed apps, this area even -if this contains buttons and other GUI elements-is automatically auto-disabled or hidden, so as not to hinder the app functionality (see Fig. 12c).
- Most of the apps did not offer customization. Even applications that allowed some level of customization, this was rudimentary and limited to an option to enable or disable the background music and/or the application sound. Furthermore all apps lacked essential customization options for educational apps, such as the number of response options shown in quizzes. Similarly, none of the apps automatically increased the level of difficulty in response to the users' performance.

5.3.4. Technical characteristics sections

- Most applications were not updated on a regular basis. Although this criterion is not an absolute indicator of an app quality, according to Google's data, there were apps which were last updated in 2012.



a b c

Fig. 13. a, b, c. Applications with embedded advertisements or in-app purchases.

- The existence of advertisements was particularly intense in several applications. These advertisements occupied proportionately excessive screen space, and as research has shown, they distract and disorient the young user (Neumann & Neumann, 2015). Some advertisements offered purchases within the app or from external sites while others offered downloads of movies, video games or other media from unauthorized sources. In contrast to the adoption of well-designed practices, none of the applications offered a separate "parent section" or "parental gate". For example, well-designed applications prior the purchase of any product or service via internet or the download of third-party applications, demand that the user solve a complex mathematical operation or use a combination of complex gestures, according to the user's chronological age, to ensure that a responsible older teen or an adult is supervising (see Fig. 13a, b, c).
- There were applications that closed unexpectedly repeatedly across multiple devices and diverse versions of the Android operating system.
- For most of the apps, there was also a poor description on Google's online store. The average number of words per app ranged from 3 to 544 words (mean 127 words, standard deviation 135 words). The number is small compared to other international studies, which range from 300 to 400 words (Vaala et al., 2015). Almost all applications in their description did not contain information regarding the scientific background and the educational experience of the development team, or the evaluation process during the different phases of app development. There was also no information regarding the educational content of the app, the learning objectives, etc.
- The applications did not provide information about data collection policies, especially about the handling of personal information. Thus, when parents downloaded an application from the online store, they did not know if and what kind of information was collected while an app was being used. Only two applications, on their websites, had an implicit reference to non-collection and sharing of personal data.
- Many of these apps, did not precisely define the age group targeted, but somewhat arbitrarily stated that "children", "toddlers" or "preschool children" were the target group.
- None of the apps offered children the opportunity to send and share their creations via the internet or a virtual private network using the enriched connectivity features of smart mobile devices (WiFi, NFC, Bluetooth, etc.).
- Similarly, the apps did not provide children with the opportunity for synchronous play (the simultaneous involvement of two or more users) whether through the internet or simply by enabling multi-monitor display, depriving young children of the possibility of cooperative behaviour and the development of social interaction.
- The lack of social support was also observed in the design apps, which were restricted to the existence of a white canvas and storage features. These apps did not even provide the possibility for a child to interact using a digital camera.

6. Discussion

The aim of this study, was to examine whether self-proclaimed educational apps with Greek content for Android devices were created with developmentally appropriate practices to meet the needs of preschool children. Given that mobile apps are a new topic for research, this study is the first attempt to capture the dynamic aspects and distinct characteristics of this field in Greece. It is apparent from the results presented so far that the apps are negatively evaluated regarding their impact on the cognitive, emotional, social, and behavioural development of preschoolers. Most of the sample applications were not developmentally appropriate, i.e., they were not designed to be used in a way that promotes preschoolers' optimal development, and their content and design was also not considered appropriate.

Research findings support the view that interactive electronic media such as mobile learning applications and e-books can improve the early reading skills and other cognitive skills of preschoolers (Kucirkova, 2014a; Roseberry, Hirsh-Pasek, & Golinkoff, 2014). In addition, e-books can be particularly useful in promoting vocabulary acquisition and reading comprehension, as many of these products may be particularly appealing to children. Using multiple communication channels (integrated animations, moving texts, graphics, rollover effects and sounds) they provide the young user with an engaging, immersive, and entertaining experience (Radesky, Schumacher, & Zuckerman, 2015). In this study, the applications belonging to the e-book category did not make full use of the technological capabilities of smart mobile devices to stimulate a rich visual experience or to promote emergent literacy in a fun way, such as naming digits and letters and phonological awareness (Calvert, 2008). Yet, the biggest problem with these apps -irrespective of the use of audio-visual aids-was the absence of a clear and objective educational goal. Thus, the applications were limited by these passive factors.

The result of this study showed that almost all the sample apps were based on the behavioural theory and were simple drill and practice apps, flash card-based, or game-based apps which may be motivational to users, but do not encourage authentic learning. The apps based their teaching on transmission models that encourage the rote learning of knowledge, without being interested in promoting a deeper conceptual understanding of emerging concepts and complex processes (Hirsh-Pasek et al., 2015). As is known, the more an educational software supports constructivist activities, the more likely it is to have a positive effect on the learning process (Kucirkova et al., 2014). Most included applications focused on basic skills, such as number and letter recognition. This coincides with the results of research done by other scientists indicating the limited variability in the content of the apps with regard to a targeted age group (Chau, 2014; Vaala et al., 2015).

Thus, we can say that the field of educational Android apps for Greek preschoolers faces a severe shortage of educational content which is consistent with the developmental needs of this age group. In accordance with existing studies (Crescenzi, Jewitt, & Price, 2014; Larkin, 2013; Hirsh-Pasek et al., 2015), we found that the design of all the apps we reviewed have inadequacies in representing the accuracy and richness of the educational content (mathematics, literacy, etc). Also, similar to other studies, we found that the most successful, best-selling learning app might not be the most useful from a pedagogical perspective (Crescenzi et al., 2014). Additionally, for Greek content, as with English content apps, hastilyproduced and fast-selling content for a broad target audience is the key for high profits in the low-priced app store market (Crescenzi et al., 2014).

All applications were accompanied by a poor description of their content, their development teams, as well as their evaluation process. Finally, they were unable to play a key role in the education of young children, as they fail to promote multiple aspects of their cognitive and social development. These results are consistent with other studies which highlight the discrepancy between the number of self-proclaimed educational apps and their low educational value (Chau, 2014; Dua & Meacham, 2016; Falloon, 2013; Goodwin & Highfield, 2012; Hirsh-Pasek et al., 2015; Shuler, 2012; Vaala et al., 2015; Watlington, 2011). Although frameworks and evaluation rubrics have proposed specific design features that may promote learning, the currently available "educational" apps rarely align with these suggestions, nor is there a unified definition of educational quality (Blackwell et al., 2016, p. 66).

However, in Greece, the impressively small number of 'educational' apps for preschoolers was unexpected. It can also be considered a negative factor that in Greece there are no public or private institutions as there are in the United States such as PBS Kids (www.pbskids.org), the Sesame Workshop (www.sesameworkshop.org), Common Sense Media (www.commonsensemedia.org), Resources for Early Learning (www.resourcesforearlylearning.org), Zero to Three (www.zerotothree.org) etc. (Radesky et al., 2015), which can provide high-quality counselling and support services for parents and educators to select appropriate mobile educational material.

There was no correlation between objective (rubric) and subjective app scores (Google's star rating system). We also found a mismatch between the objective score of an application and the subjective user comments, which is consistent with previous studies (Bentrop, 2014; Hirsh-Pasek et al., 2015; Stoyanov et al., 2015). In all cases, the applications seem to be overvalued in terms of their real educational value. Another issue worth mentioning is the discrepancy observed between the user comments and ratings. In Google's online store, there were few comments-reviews made by Greek language users who had downloaded the apps, and they were comparatively much fewer than the English language apps had. Overall, analyzing users' feedback (comments - reviews) we considered that most adults who downloaded an app had a positive or very positive attitude towards the app. This finding raises concerns about the internal evaluation system used by parents and other adults who download an app. It seems that the adults are influenced in their judgment by the 'superficial' characteristics of an app (sound, colours) and are not able to evaluate the quality of the educational content of the app. The most successful, best-selling learning app might not be the most useful from a pedagogical perspective (Notari et al., 2016).

Of particular concern is if a user's judgement is affected by other users' posts or the number of stars an app has. The above assumption is a weighty matter if we consider that both evaluation methods mentioned above are very subjective. Any user who has downloaded an application can comment or rate the app. As Notari et al. (2016) state most of apps classifications and reviews are a bit fuzzy and often imply a specific use-case of an app, which might be used quite differently as well. Finally, an additional element of concern, resulting from our research in both Google's online store and the websites of applications is the absence of information regarding policy on the scope of collection and the potential uses of the personal data.

7. Research limitations - extensions

Undoubtedly the field of mobile educational applications for preschool children is chaotic and unregulated. Although the most rapidly growing segment of the app market is dominated by two digital marketplaces (Apple iOS App Store and Google Android Play Store) the volume of apps in both stores is huge and still growing. Each of these two digital stores contain more than 100,000 applications which are advertised as educational or suitable for young children (Apple, 2016; Olmstead & Atkinson, 2015). Additionally, the mobile market for children is full of other companies that manufacture specialized devices for children such as the LeapFrog, popular mobile platforms such as the Nintendo DS, as well as other well-known game consoles such as the Microsoft's Xbox Kinect and the Nintendo's Wii (Chau, 2014). Each of these platforms has its own digital library including, games, applications etc.

In this study, which is part of a larger research project, it was impossible to take into consideration the different types of devices and their respective applications. The present research has several limitations.

- The evaluation of the apps was performed according to the criteria of the REVEAC scale (Papadakis et al., 2017). No children participated in the research, thus, the generalizability of the study findings is limited by the nature of the setting. The assessment of the design and content of an application can only be completed through direct observation and recording of the actual experiences of children when dealing with the intended application (Chau, 2014; Noorhidawati et al., 2015). For example, studies suggest that children perform better with small touchscreens (3.5-inch screen size) rather than large

Table A1
Indicative scoring table of some of the sample applications.

App number	1*	2	3	4	5	6	7	8	9	10	11
Application category	Game	Game	Game	Game	Game	Game	Game	Game	Game	Game	Game
Educational content section Total score	10	10	11	10	10	10	10	11	15	11	10
Knowledge package appropriateness	1	1	2	1	1	1	1	2	3	2	1
Learning provision	1	1	1	1	1	1	1	1	2	1	1
Levelling	1	1	1	1	1	1	1	1	1	1	1
Motivation/Engagement	1	1	1	1	1	1	1	1	2	1	1
Error correction/Feedback provision	1	1	1	1	1	1	1	1	2	1	1
Progress monitoring/Sharing	1	1	1	1	1	1	1	1	1	1	1
Bias free	4	4	4	4	4	4	4	4	4	4	4
Design section Total score	4	7	5	4	5	8	6	6	8	4	4
Graphics	1	2	2	1	2	2	2	1	2	1	1
Sound	1	1	1	1	1	2	2	2	2	1	1
Layout/scenery	1	2	1	1	1	2	1	2	2	1	1
App/Menu design	1	2	1	1	1	2	1	1	2	1	1
Functionality section Total score	5	5	7	6	5	6	5	5	5	4	4
Child friendliness	1	2	2	1	1	2	2	1	1	1	1
Autonomy	2	1	2	2	2	1	1	1	2	1	1
Instruction existence	1	1	1	1	1	1	1	1	1	1	1
Configuration ability	1	1	2	2	1	2	1	2	1	1	1
Technical characteristics section Total score	6	6	6	6	6	6	6	9	9	9	9
Performance/Reliability	4	4	4	4	4	4	4	4	4	4	4
Advertisements/Electronic transactions	1	1	1	1	1	1	1	4	4	4	4
Social interactions	1	1	1	1	1	1	1	1	1	1	1
Rubric Total score	25	28	29	26	26	30	27	31	37	28	27
Rubric points conversion on a fivepoint scale	1,7	1,9	2,0	1,8	1,8	2,1	1,9	2,2	2,6	1,9	1,9
App score on Google Play	4,2	4,3	4,8	4,4	4,4	4,5	4,3	3,9	4,7	3,9	0,0
Number of users who rated the application	149	6	9	26	30	4	91	167	44	50	0
Data policy reference	Yes	No	No	No	No	No	No	No	No	No	No

Table A1 (*continued*)

App number	1*	2	3	4	5	6	7	8	9	10	11
App description (Number of Words)	34	159	527	120	62	163	45	88	91	74	28
Development team reference	No	No	No	No	No	No	No	No	No	No	No
Number of app installations	10.000 – 50.000	1.000 – 5.000	1.000 – 5.000	10.000 – 50.000	5.000 – 10.000	1.000 – 5.000	10.000 - 50.000	10.000 – 50.000	1.000 – 5.000	5.000 – 10.000	100 – 500
App last update	July 2016	August 2016	August 2016	June 2015	January 2016	August 2016	Apple, 2016	June 2012	October 2016	October 2014	March 2014

*Application names.
1.The kindergarten Lite.
2.Supermarket - Learn & Play.
3.Learn the numbers.
4.Infant occupations.
5.Look Listen Learn.
6.Days, Months & Seasons.
7.Learn the animals.
8.Play & learn.
9.The Suitcase.
10.Letters & numbers.
11.Design an umbrella.

(10.1-inch screen size) (Vatavu et al., 2015). Moreover, the researchers —as adults-responded to various app gestures. But, it is not certain that a child could respond with the same ease in the visual and motor coordination that each app required.

- A broader study is required that will examine whether there is a “gap app” between the free and paid. In other words, are the paid applications so radically different in the assessment points from the free apps or are they simply enriched versions of the free apps, without offering kids a meaningful experience, as is the case with trial applications. For example, the paid apps don't include advertisements, a characteristic that was found to be a negative factor in several applications.
- Also, it would be useful for research purposes to conduct a combined study between the free and paid apps for Android and iOS devices (cheap vs. expensive devices). The results of such research are critical for countries like Greece, which are affected by the economic crisis and where even middle-class people have turned to free applications and the plethora of cheap Android devices.
- In addition, it would be useful for further studies to investigate whether an educational app which is available from both digital stores (iTunes and Google Play) differs qualitatively in the individual rubric axes and ultimately in its true educational value.

8. Conclusion

It is a fact that we cannot isolate children from technology, but we can ensure that they are not harmed in any meaningful way (Ebbeck, Yim, Chan, & Goh, 2016; Parette, Quesenberry, & Blum, 2010). In the 21st century, children are growing up in media-rich homes with touchscreens and digital devices and are frequent users of these media (Guernsey, 2016; Lauricella, Wartella, & Rideout, 2015; Wartella, 2015). Similarly, the constantly evolving market of mobile applications offers parents new digital products for the education of young children (Judge et al., 2015). In connection with the debate about children's exposure to digital media, all those involved in educational technology have agreed that the real question that had to be asked is not how much time it is appropriate for children to “consume”, but what to “consume”. With the rapid proliferation of mobile devices and applications the concerns about app content become even more topical and complicated (Guernsey, 2012).

The present study found that the sample apps in no way justify their title as educational, as they do not meet the developmental needs of the target age group. Thus, the present results are in line with other studies in supporting that special attention must be paid to the design and content of “educational” mobile apps, if we wish the numerous advantages of smart mobile devices to translate into productive learning (Falloon, 2013). Additionally, the present study is in accordance with a number of research studies (Guernsey et al., 2012; Hirsh-Pasek et al., 2015; Kucirkova, 2014a; Tian et al., 2015; Vaala et al., 2015) which highlight the need for a reliable and effective framework for monitoring and evaluating mobile content through which parents and teachers can download apps with real educational value for preschoolers. This study like other studies suggests avenues of investigation for the design of apps to be used in early years settings (Crescenzi et al., 2014, p. 94).

In conclusion, the real question is not whether technology belongs in early childhood education, but rather, how we can leverage the efficiency of digital tools to best serve young learners (Shapiro, 2014). In this context, researchers, educators, mobile developers, and designers must ensure that the applications aimed at young children have a solid theoretical basis and follow high-quality standards so as to contribute efficiently to the progress of young children's development.

Declaration of competing interests

All authors have completed a declaration of competing interests and declare no financial relationships that may be relevant to the submitted work; and have no non-financial interests that may be relevant to the submitted work.

Appendix. Annex

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