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Raising a programmer: Teaching Saudi children how to code

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ABSTRACT

Teaching computer coding to children from a young age provides with them a competitive advantage for the future in a continually changing workplace. Programming strengthens logical and critical thinking as well as problem solving skills, which lead to creative solutions for today's problems. The Little Programmer is an application for mobile devices that introduces the basic programming concepts to Arab children aged (8-12) years. It aims to develop a sense of coding and its importance among those children. User trials results showed that the application was helpful and allowed its users to identify the concepts of computer programming with immense curiosity. Moreover, it showed that linking difficult or newer concepts to familiar entities and objects through visualization can facilitate the learner to grasp innovative knowledge.

Introduction

Technology has enforced a great influence on the daily practices. Many individuals utilize various technologies to improve their lifestyle. IT specialists employ functional tools for performing differential activities efficiently. The basic aim of this study is to identify the awareness level of computer programming among youngsters in Saudi Arabia. Individuals, who are sanctified with creative ideas and possess the necessary technical skills to transform their ideas into reality, have made a great fortune over the last two decades in the IT industry. Larry Page and Sergey Brin created Google, Mark Zuckerberg developed Facebook, Jack Dorsey launched Twitter and Foursquare, and Jeff Bezos developed Amazon. They all carried few things in common: a) They were relatively young when they initiated their businesses; some of them were still university students, b) they had valuable ideas and most outstandingly, 3) they were technically equipped to turn those exciting ideas into practical applications.

Programming knowledge has become a necessity for implementing technological modifications as an entrepreneur. It is directly associated with the individuals' empowering and developing opportunities for successful completion of their goals. Therefore, the young generation is referred to as 'digital natives' because of the higher extent of technology usage. However, most of the people use technology for browsing, chatting, or gaming purposes. They are consumers rather than creators. As mentioned by Resnick, it is like they 'read' but do not 'write'; "As we see it, digital fluency requires not just the ability to chat, browse, and interact but also the ability to design, create, and invent with new media" (Resnick, et al. 2009). This statement concluded that children consume technology rather than creating it. Formal education focuses on teaching the students about the basic literacy skills, especially at lower levels (5-11 years old). Technology has transformed to a higher extent, which has led towards the new set of techniques. Enduring learning has become a part of adults' life to remain competitive and employable in a globalized and networked economy (Head, van Hoeck, and Garson, 2015). Similarly, many

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companies have relied on learning to train their labour force (Baggen, et al. 2016). The basic skills should be developed among children for using technology efficiently. In addition to reading, writing, and mathematics, there is a significant need to learn problem solving, logics, and critical thinking skills, which are also essential to learn computer programming. In other words, children should be called to learn computational thinking (Kafai and Burke, 2014). Majority of schools offer a limited number of programming subjects to their students. In 2013, Mr. Barack Obama urged the America's youth to adopt computer programming in a recorded speech: "Do not just buy a new video game, make one. Do not just download the latest app, help design it. Do not just play on your phone, program it" (Ohannessian, 2013). Three years later, Bill Gates and Mark Zuckerberg set an alarm in United States during 2016. A letter that was addressed to the United States Congress urged to recognize and support the needs of American children, teens and youth to learn about coding. It stated, "At a time when every industry in every state is impacted by advances in computer technology, our schools should give all students the opportunity to understand how this technology works, to learn how to be creators, coders, and makers — not just consumers" (Brown, 2016).

In Saudi Arabia, computer coding has emerged as a critical skill because 24% of the population is under the age of 15 years (GASTAT, 2016). However, programming is briefly introduced to the students within secondary schools. Programming is rather taught comprehensively to computer science and engineering students in universities. However, it is not available as an elective course for other students, studying distinctive subjects. During the data collection phase of this project, many students at technical schools, who were learning computer programming, have reported that they faced difficulties while learning programming. They encountered problems especially, when it comes to grasp some of the basic concepts of programming, as they are almost completely new.

In accordance with the Pentecostal 10th plan of development in Saudi Arabia (GASTAT, 2016), modern education is amongst the pillars for a knowledge-based society, and the government has aimed to achieve it for the people. In April 2016, Saudi Arabia announced its future vision that intended to transform the country's economy from primarily an oil-producing economy, into one that depends on other sustainable resources. The vision 2030, in accordance with education, training and entrepreneurship, is considered as a major aspect for the development of Saudi Society.

The study developed a mobile learning environment to introduce basic programming concepts to Saudi children by providing the opportunity for practicing programming at a young age using educational technology. The Little Programmer is a mobile application designed to create an interactive e-learning environment for Arabic-speaking elementary school children aged (8-12) years. This application was solely made to allow children for understanding the programming concepts to change their perspectives about technology and to teach them about creative thinking and problem solving skills. The children, who would learn programming, can be better equipped to contribute in development and vision of a country.

Educational Technology for Children

Educational technology refers to the effective use of technological tools in learning. The actual concept of educational technology can be defined as "the study and ethical practice of facilitating learning and improving performance by creating, using and managing appropriate technological processes and resources" (Januszewski, 2013). Educational technology involves many perspectives; therefore, the study has focused on using educational technology for teaching children (primary school level).

Technology has helped to accelerate the pace of change by communication and learning. Majority of the primary schools have developed their processes in accordance with digital revolution. Technology would help children to prepare for their careers in an efficient manner. Consuming technology in the classroom would provide an opportunity to the children for better interaction and encouraged collaboration in multiple projects (CommonSense, 2013). Children become stimulated about using technology in the classrooms; therefore, such technologies are more appropriate for the students to become aware of a dynamic world.

It is note-worthy that the existence of some opinions is concerned with the negative impact of technology on children at a young age (Taylor, 2010). However, several researchers agreed that there is a lack of sufficient evidence, which suggested the accurate impact of technology on children's development. This study has supported technologies' benefits and demerits (Bavelier, 2010). Hence, technology should not be ignored in childhood as a vital learning medium. In order to take benefits from its great potential and limit the negative aspects, parents and educators should take proper measures. For instance, setting time limitations on using computers and mobile devices as well as balancing the time spent on machines with outdoor activities, playing with peers and reading books.

Mobile devices, such as tablets, have provided an efficient learning opportunity for youth. Mobile learning (also known as m-learning) involves a process of education through multiple devices. According to Sharples et al. (2009), mobile learning is the process to get familiar with technology through exploration and conversation across multiple contexts, amongst interactive technologies (Sharples et al. 2009). Kerren explained that "Mobile learning emerged as an important research field and visualizations play an important role in this area" (Kerren, 2012).

Research presented by Roschelle et al. (2000) showed several examples of how computer-based applications could be used to enhance children's learning by supporting four fundamental characteristics of learning, which include: 1) active engagement, 2) participation in groups, 3) frequent interaction and feedback, and 4) connection to real-world context. In Little Programmer, three of these characteristics were achieved using differential tools by using a

learner-centred design. Some of the popular educational technology instruments used for child learning on these tablets include videos, multimedia and animation.

Interactivity allows the learner to discover solutions of effortless problems, crack puzzles, and converse with the application. Animation is defined as creating simulation movements with the aid of computer (AIM center for animation & interactive media). It displays a sequence of pictures and combines them together to develop an illusion of continuous motion. Animation is capable to entertain and simplify complex processes as well as to explain difficult-to-understand concepts. Visualization is a technique used to convey information via images, diagrams, videos or animations. Moreover, it is an effective way to explain concrete and abstract ideas. In the case of teaching the concepts of programming, linking new abstract concepts to known objects, environments or definitions through building analogies is a powerful tool. This aspect would keep the young learners engaged in the subject as compared to passive learning through reading about the same concept from a book. Video as a learning medium engages viewers by encouraging them about a subject or concept. The Little Programmer has been developed as a mobile application that could be used at schools or at homes, making it portable and easy to access. This application uses interactivity, animation, visualizations, and videos to deliver learning contents to the young learners.

Educational Technology in Saudi Arabia

The effort to implement Educational Technology in Saudi Arabia has always been a priority. The latest Pentecostal plan (2015–2019) (GASTAT, 2016) has specifically emphasized to enhance the elements of information society and to improve the knowledge acquiring options. The National Centre for e-learning and distance learning adopted many projects that served the transformation to a digital society and implementing e-learning in different public learning institutes. For instance, the development of Saudi Digital Library Project and JUSUR (bridges) was done through LMS (Learning Management System) and LCMS (Learning Content Management System). The use of educational technology in the Saudi educational system was also introduced through training programs, developing, and using new instruction methods.

The Ministry of Education is working to improve the quality of education in public schools, which includes the use of latest educational technology in teaching. In addition, it aims to advance the technical courses at schools by providing better solutions. However, some studies suggested that e-learning in Saudi Arabia is still limited (Al-Harbi, 2011). It has also been reported that its quality and usefulness for students are not adequately measured. Thus, no clear evidence to suggest its clear benefits was found (Abou Hassana, 2008). In another recent study, e-learning was used to teach mathematics to primary school students in the form of online games and activities. This study reported the e-learning pedagogy is a significant tool for improving mathematics education in Saudi Arabia (Yamani, 2014).

In the last three years (2015-2017), e-learning and online distance learning played a vital role in providing education to students in the southern parts of the kingdom, due to the war in Yemen. As a reason, the schools had to remain closed for extended periods during the academic year. As for teaching computer and IT subjects, it has appeared that current focus regarding education and technology in Saudi Arabia is specifically placed on the instructional tools rather than the actual learning content or the curriculum of technical subjects. Saudi primary public schools have minimum number of organized computer labs and guidance for computer programs in their curriculum. On the other hand, private and international primary schools offer some computer courses. However, none of these schools, which have been surveyed in the city of Jeddah, offered programming lessons as part of their IT education or computer training skills.

Students, who were interviewed for this project, stated that they were interested in learning programming and excited to produce their own piece of software. Similarly, their teachers and training coaches at children's training centres, who are currently offering young learners a range of technical workshops, agreed that children at this age are better able to grasp new concepts, such as logical operations in programming languages. These workshops included MineCraft (2016), littleBits (2016) and Lego programming (2016). Therefore, there was a great enthusiasm towards the current project and a strong will to participate during different stages.

Related Work

Programming is a creative activity, which engages the children in writing data processing algorithms; however, children usually enjoy creating games, mixing music, designing websites or just playing around with the code. Once computer-programming concepts are fully understood; children would be able to write their own story by building creative software.

The importance of programming instructions to young learners has been recognized by Kafai & Burke (2014). Many tools are being provided to support this process by the academic world along with the IT industry. In addition, many books from reputable publishers are currently published that involve teaching differential programming to children from learning Java to Python applications (Vorderman, 2014; McCue, 2014; Briggs, 2012). Books are used as references for further knowledge, while significant young learners choose to learn by simply logging into websites or downloading an application to

lean with the guidance and support of these electronic tools. A number of teaching websites and mobile application that develop programming have been listed here. MIT labs are a visual programming environment that introduce programming by using drag and drop interfaces, known as Scratch (Maloney, et al. 2004). The learner can play either online (register to the website) or offline (downloaded software). Concepts such as loops, count, input, output, conditions are presented. Giving the reputation of MIT, there are many independent resources to teach it. It has been observed as more suitable tool for young learners. In addition, it also provides a mobile version.

Other website examples includes Code.org, which is a web based learning site that offers free coding tutorials through puzzle games, drag and drop instructions, and so forth. However, the content is thankfully available in wide range of languages, including Arabic, but this is limited to a very narrow number of tutorials as compared to English version. Alice (2000) teaches children about computer programming in a 3D environment for free (Cooper, Dann and Pausch, 2000). In addition, a multiple programming websites for children exists such as Tynker (2016), Stencyl (2016), Robomind (2016), Botlogic (2016), and Run Marco (2016). The list of tools, which are compatible for mobile devices and serve learners, includes Hopescotch (2016), where children can create their popular game versions. It introduces some programming concepts such as abstraction, variables, loops and conditions while playing and making a game through drag and drop-programming interface. The main disadvantage is that the learner cannot see any real code. Other examples are Javvy (2016) and Lightbot (2016).

Each tool has certain advantages and limitations; however, except for code.org, none of the application provides any Arabic content. Therefore, children would take a considerable amount of time to get familiar with these websites and applications, who do not have the adequate command of/over the English language. These tools might be completely inaccessible for children with no basic knowledge of the foreign language.

Majority of the learning resources and teaching programs, which have been used during the study, did not explain the programming concepts. They were mostly introduced as part of game or puzzle; but, they were not explained as a standalone concept. Therefore, they might not be suitable for early learners of coding as a player/child must have some familiarity with the programming vocabulary.

The Little Programmer: Data Gathering Results

The Little Programmer is a learning application that aimed to introduce the programming concepts to children aged (8-12) years' old in an environment that uses Arabic language to explain different concepts. Qualitative and quantitative research methods have been used during data collection, including questionnaires, individual interviews, and direct observations in the field at schools and training centers in Jeddah. Below are the detailed descriptions of the outcome of these methods:

Data Gathering by Interviews in the Field

The purpose of using this method is: (a) to gather information from teachers and administrators from their working experiences; (b) to learn about optimal ways to deliver information to children; and (c) to know what children's preferences are, in order to establish requirements for a successful learning environment. The interviews were divided into groups as follows:

1) The interviews have been conducted from adult primary schools headmasters and teachers, private center's coaches, and educational consulting companies. The interviews included meeting with thirteen school administrators and computer teachers of five different private, international and public schools in Jeddah. It also included three directors and two training coaches at two private training centers. In addition, two consultants of an education consultancy, who works with a large number of private schools, were also interviewed through this process.

2) Primary school students were also recruited for the interviews. The team interviewed sixty-four primary school female only students in Jeddah due to gender segregation in Saudi school. When analyzing the results, it has been concluded that 54% of students agreed that they know how to use a computer, while the other half 46% stated the opposite by informing that they do not know how to use a computer and some of them did not own a dedicated personal computer at home. Out of the 54% students, who reported that they did use computers; 83% of them preferred to use tablets for learning or playing, while the rest preferred to use personal computers. 77% of the same group students stated digital games as their favorite technical activities. 75% of those children encounter difficulties when playing digital games designed in English, while 25% prefer to play English games. Those students study at international schools, where the main teaching language is English.

Data Gathering by Questionnaires

The questionnaires were divided and distributed into two groups as follows:

(1) Paper-based Questionnaires were distributed among sixty-eight primary schools teachers in two public and three private and international schools.

(2) Electronic Questionnaires were distributed among parents and university students, studying programming. The first questionnaire received response from two hundred parents of primary schools children. The second questionnaire was distributed among one hundred and twenty-five university students and graduates of computing faculties, who have already studied one of the programming courses. Results showed that 88% of

teachers found various benefits for using computer technologies as compared to traditional methods of teaching, while 10% of them prefer traditional methods in teaching and 2% of them did not find any difference.

When teachers were asked about the best content provided for the children, varied percentages were found between the four answers. 34% of the responses were in favour of videos, 12% of the responses were related with readable text, 43% of the responses supported animated activities, and 11% of the responses preferred audible texts. Moreover, 78% of children had their own tablet devices, 19% of them did not have tablets, but they were using one of their family member's tablets, while 3% of them did not have access to any tablet. In the same context, 85% of parents stated that their children liked to use tablets more than computers, while only 15% of children preferred to play on a computer. 89% of parents supported the existence of an Arabic interactive learning environment for children, while 11% preferred English environments.

64% of the total students and graduates of computing faculties recognized that they faced difficulties at the beginning of their programming studies; while 36% did not find any difficulty. When college students and graduates were asked about the most prominent difficulties; 34% of the answers pointed towards the educational material for beginners, while 46% of the responses indicated students' lack of sufficient English language skills. Moreover, 20% of the responses pointed towards lack of sufficient and reliable programming resources in Arabic, either offline (books) or online (websites, applications, videos, courses or presentations).

The major requirements that were established after the data gathering phase were related to the need for an e-learning mobile application running mainly on tablets that teaches Arabic-speaking children aged (8-12) years. One of the teachers raised an issue regarding privacy and children safety online. She preferred that the application would run offline properly. The Little Programmer can operate offline; however, due to the need to keep application's size reasonably small, the educational videos are stored externally and are accessed online.

Interface Design

The application has developed following Agile-D-Mobile (D-Mobile is a methodology for agile software development) methodology by considering the rapid changes that happen in software development such as risk handling, support small releases, user involvement and continuous updating. Referring to the fundamental characteristics of learning, active engagement of learners as well as the frequent interaction and feedback is presented in The Little Programmer through the watch, play & try learning objects at each level. The connection to the real world is applied by using familiar themes to children at the targeted age such as a school, a kitchen, and an office through visualization and videos. Creating interactive and rich learning content (videos, animation and different multimedia objects) are extremely expensive techniques (Rey-López, et al. 2008). The use of learning objects has now become vital for learning content (Meccawy, et al. 2007). The learning content in The Little Programmer is reusable learning objects (RLO), which were developed to be standalone (Fig. 1). They are not hardwired into the application; rather stored independently. All of the objects are stored in the android realm server apart from the videos, which are stored externally on YouTube as mentioned in the previous section.

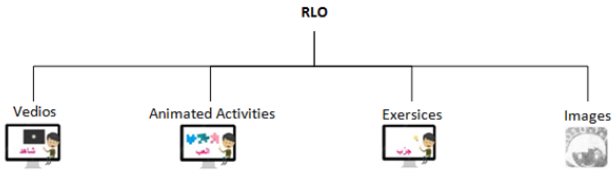

Figure 1: The little programmer reusable learning objects

While following Nielson's Usability Heuristics for User Interface Design (Nielsen, 1995), one of those heuristics states that there should be a match between system and the real world: "The system should speak the users' language, with words, phrases and concepts familiar to the user, rather than system-oriented terms. Follow real-world conventions, making information appear in a natural and logical order". Therefore, the system uses environments that are familiar to children; such as school, kitchen, office, etc. When creating the actual lessons for The Little Programmer, some questions needed to be answered: which programming concepts to be taught? And in which sequence?

It was decided to start from the basic knowledge about computer programming to set the foundation by teaching children. Such as, What is a program? What is an operating system? Who is the programmer? What does he do? Such concepts would be helpful for the children to enhance their abilities effectively. The goal was to start program as a story and set the scene. The sequence used for introducing the actual programming concepts followed a

convention that is taught in many computer programming courses, books, websites and other resources such as describing variables and constants, explaining program sequence, how to use inputs and outputs, loops and so forth.

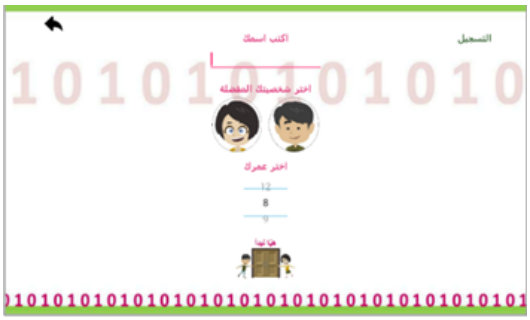

Figure 2: Registration Screen

The Little Programmer (Fig. 2) is currently available for android devices only. The first step after downloading the application is the registration. The user clicks on the register button and a short form will be appeared. A window will be displayed to enter a name, choose a boy or girl avatar, and select his/her age. Once registration is completed, the application displays the main screen. Each level introduce several programming concepts through: 1) a short video, 2) an animated activity and 3) a simple exercise. To aid the learner in navigating the application, the user would be advised to follow a given sequence (1, 2, 3 and so forth). In addition, the learner could try the exercise first, and then play with animation or watch the video. However, when it comes to moving from one level to another, the user cannot do so without finishing the current level (all three objects). This aspect has been enforced by the system to ensure that the learner views the content in the right pedagogical order. This style should be familiar to learners as it is similar to difficulty levels in games. Each completed object in a certain level awards the learner 5 points. A completed level is worth 15 points, and then the user can move one level up upon completion. If the learner has successfully completed all levels, a certificate will be created to congratulate the learner and recognize the achievement. In addition, the application has a related information screen that would give additional examples and information about the concept that is being taught in this particular level. It will be appeared after the learner has interacted with activity and before moving to the exercise section. Two levels of the application are described here.

Level One Interface Description

Figure 3 has presented the first level of The Little Programmer application. It used a school theme to explain five basic programming concepts (Operating System, Program, Programmer, Software, Programming Language), via an animated video, labelled WATCH (1). This is followed by a game an animated activity, labelled PLAY (2), and an interactive exercise, labelled TRY (3). The learner would also have the option to go back to the main screen (4).

Figure 3: Level one screen

Figure 4: Level one video screen

Figure 5: Level one animated activity screen

Video Screen

This screen plays videos stored on YouTube (Fig. 4). Therefore, the videos could only be viewed online. The reason is to reduce the application size as stated earlier.

Animated Activity Screen

Animated activity screen displays the animated activity; all the activities in the levels are done by dragging and dropping (Figure 5). Interaction: (1) if an icon is clicked for a long time, it can be dragged and dropped.

Exercise Screen

This screen displays the exercise of the level. The exercise of levels one and two are solved by selecting the correct answer, while level three exercises would be solved by filling the blanks (Figure 6). Interactions: (1) on clicking, the learner can choose the correct answer.

Related Information Screen

This screen displays information related to the programming concepts of the level, and it will be displayed after doing the animated activity. For level one, there are four related information screens; a sample is presented in (Fig. 7).

Figure 6: Level one exercise screen

Figure 7: Level one related Information screen

Level Two Interfaces Description

Level two follows the same convention explained in the previous section, which includes video, animation and exercises. Code, Sequence of code, Integer, Double, Boolean, Character, String were introduced. It takes place in a kitchen environment as could be seen in the following figures: video screen (Fig. 8), animation screen (Fig. 9) and exercise screen (Fig. 10).

Figure 8: Level two video screen

Figure 9: Level two animated activity screen

Figure 10: The Little Programmer level two exercise screen

Results

The Little Programmer application was tested by the similar group of students, who were involved during the data collection process. The testing took place at a school under the teacher's supervision. The application received positive responses from the students and teachers. The students were asked to use application on tablets. The focus was on the first three levels (basic concepts). A post trial test was given to these students. The results showed that majority of those students (71%) correctly answered the questions related to the programming concepts that were provided through the application animations and activities. In addition, they were able to correctly express the meaning of these concepts during following 1-1 interviews. However, more empirical tests were required to test the understanding level from the pedagogical perspective. As for usability tests, children did not face any difficulty while using and navigating between screens. Acceptance and performance tests showed that the application's interface design, colors, themes, languages and the clarity of icons met the user's requirements and functioned with a trivial number of performance issues. However, children, who were good at reading, did not face any difficulty in understanding the given instructions, while those who were not needed some help in reading the instructions.

Discussion

The development of coding skills plays a major role in understanding technology. Such skills would be significant for understanding the core aspects of technological features. In addition, they would enable individuals to create their own pieces of software. Therefore, children, having specialized nature of coding concepts, would result in the better learning processes. Children are using technologies, especially tablets in their daily activities. Thus, students, who are digital natives, have great capacity to learn through educational technology. Using interactive tools, such as animations, videos and games, provided an exciting learning environment that encouraged children to participate in learning.

The main goal of programming education is to give children a strong ability to use coding concepts in other fields. It helps in providing children the opportunity to practice programming at young ages and to train them in abstract, logical, and computational thinking. Instead of consuming the technology without knowing how it works or have been built merely as consumers (readers); they become developers and creators (writers). Most of the children preferred to use tablets in learning and playing. Moreover, their parents and teachers liked the idea of introducing basic programming concepts to children through an educational game as a tablet application. Arabic interactive learning environment is highly encouraged by the schools to eradicate the language barriers among learners.

Conclusion

The Little Programmer has been used as a witness to test the users' (Children) acceptance and benefits from using a mobile interactive animated application in teaching programming to Arab children. It has been identified that the development of an animated interactive application, which introduces the basic programming concepts, using their Arabic mother tongue, would be helpful for improvising academic and learning skills effectively. In addition, this study has found that linking difficult or new concepts to familiar entities through visualization can help the learner to grasp novel knowledge. It is hoped that by using educational technology to teach programming, this skill would become a second nature to children similar to mathematical and reading skills.

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