SELF-PRACTICING OF LOGIC CIRCUITS THROUGH MOBILE DEVICES: LECTURERS' AND STUDENTS' PERCEPTIONS

Mazyar Seraj[1,2], Cornelia S. Große[1], Rolf Drechsler[1,2]

[1]Institute of Computer Science, University of Bremen, 28359 Bremen, Germany
[2]Cyber-Physical Systems, DFKI GmbH, 28359 Bremen, Germany
{seraj, cornelia.grosse, drechsler}@uni-bremen.de

Abstract

Electronic devices are widely-used in modern life, and among the multitude of application possibilities, educational technology in order to facilitate learning and practicing becomes more and more important. Portable devices such as smartphones and tablet PCs make learning and teaching materials more accessible to students and lecturers. Although there already exists a large number of mobile-based learning applications, there is still a lack of studies which investigate lecturers' and students' perceptions of mobile-based learning environments. These issues are investigated in this paper. In order to ascertain perceptions of students and lecturers, a web-based questionnaire study was conducted. Two objectives were pursued: (i) to investigate lecturers' and students' perceptions of improvements in technical subjects through self-practicing with mobile devices, and (ii) to demonstrate common difficulties of students in the learning and practicing process in a core subject for computer science students, namely logic circuits and hardware description languages (HDL). The results showed that according to the lecturers' view, a substantial number of students experience difficulties with logic circuits and their implementation via HDL. Furthermore, the findings show that students who are interested in the field of logic circuits think positive of practicing on graphical and code view of logic circuits via mobile devices.

Keywords: e-learning, logic circuits, mobile-based learning, self-practicing, mobile devices.

1 INTRODUCTION

In computer science, logic circuits are a core topic for students which is usually taught in digital circuits and computer architecture courses. Students learn about different types of logical gates, their functionalities, and how larger circuits can be designed using these gates [1]. Different representations are used, in particular graphical representations and Boolean functions, to explain the functionality of different logical gates [1, 2]. Furthermore, code-based representations of logic circuits demonstrate the implementation of logic circuits via Hardware Description Languages (HDL) such as Verilog and VHDL [2, 3]. Apart from learning the subject in face-to-face courses, there is a number of computer science students who are eager to learn and practice more on the topic. In this way, electronic environments provide facilities to practice in a stimulant environment [4].

As electronic devices have become essential in modern life, it is possible to apply these devices in an educational setting in order to facilitate learning and practicing [4, 5, 6]. Furthermore, electronic-learning (e-learning) environments eliminate several limitations of traditional learning such as barriers in learning time and place [4, 7]. In recent years, many studies demonstrated how to support students in e-learning environments [8, 9, 10, 11]. Nowadays, smart phones are commonly used by students. These devices are portable computers that can be used for different purposes using a wide variety of applications [12]. Following on from computer-based and web-based learning, mobile-based learning (m-learning) is introduced as a new generation of integration of technical devices in learning environments [13] and provides a third generation of e-learning [6, 12]. However, the question how a mobile device with small screen and keypad size can be used to foster learning of technical subjects is challenging.

The goal of the present study was to identify common challenges for computer science students in the process of learning about logic circuits. In addition, opinions on practicing the topic via mobile devices were investigated. The main contribution of this paper is (i) exploring lecturers' and students' experiences with respect to common difficulties in the context of logic circuits, (ii) investigating lecturers' opinions on students' self-practicing logic circuits through mobile devices, and (iii) investigating students' opinions on the usefulness of self-practicing logic circuits via mobile devices.

The paper is structured as follows: in the next section a brief overview of e-learning technologies and m-learning applications are provided. The research questions are presented in the following section. Subsequently, methods and results are presented. The paper closes with discussion, conclusions and future work.

2 LITERATURE REVIEW

E-learning technologies are created and used for learning and practicing beyond time and location boundaries. Following computer-based and web-based learning systems, mobile devices such as mobile phones and tablet PCs have been used to facilitate the learning process [7]. Mobile devices are dynamic because of their small size which makes them available and being used everywhere [12]. This advantage enables mobile devices to provide flexibility in learning and being easily used in ubiquitous learning environments [6, 12, 14].

However, the small size of screen and keypad are main limitations in designing and developing m-learning applications [11, 12]. Despite these restrictions, advantages of m-learning are highlighted [9, 11, 12]: Mobile devices provide instructional opportunities such as learning in any location and at any time with minimal cost [12, 14, 15]. However, motivating students to learn via mobile devices conflicts with reluctance concerning the small screen and keypad size and the possibility of cheating activities [16].

In an evaluation study, students responded favorably to two m-learning applications on digital logic and digital signal processing which were developed for electrical engineering students in both Android and iOS mobile platforms; in addition, the results showed improvement with respect to learning outcomes [10]. In [11], an interactive m-learning prototype was designed and developed which assists computer science students in getting a better understanding of Dijkstra's shortest path algorithm. The results show that users' satisfaction can be maintained via both mobile phones and tablet PCs; however, the study also shows that users are aware of limitations of using mobile technology such as small screen size compared to personal computers and laptops.

On the other hand, although a substantial number of m-learning applications has already been developed, there still is a lack of studies investigating lecturers' and students' perceptions of m-learning environments [16]. Thus, in the present paper, the level of helpfulness of m-learning environments is investigated in the field of logic circuits among computer science students and their lecturers.

3 RESEARCH QUESTIONS

In the present work, the following research questions were addressed:

1. What kind of information visualization in m-learning applications would be helpful for students to have more self-practicing on logic circuits?
2. What is the most difficult part of learning HDLs from students' point of view?
3. To what extent do lecturers and students consider e-learning applications in the teaching and learning process?
4. What is the attitude of lecturers and students towards mobile technology for practicing on technical subjects like logic circuits?
5. What is the preference of students who are interested in the field of logic circuits concerning self-practicing via mobile devices?

4 METHOD

This paper presents the results of an online questionnaire study performed to identify lecturers' and students' experiences and opinions in learning about logic circuits. The questions comprised both open and multiple choice questions [17]. They were divided into two questionnaires, one for the lecturers and one for the students. The lecturers' questions were designed to extract their experiences in teaching logic circuits and related subjects. Furthermore, the lecturers' perceptions about practicing technical subjects – in particular, logic circuits – via mobile devices were assessed. The students' questions focused on their difficulties in the area of logic circuits. Students' opinion on practicing logic

circuits via electronic devices – in particular, mobile devices – was examined. We got lecturers' and students' responses with respect to five and six categories, respectively:

Lecturers were asked to identify:

1. Their interests in the field of logic circuits and related fields. Two dichotomous questions were designed in the form of "*Yes or No*" questions.
2. The percentage of students having difficulties with logic circuits and the implementation in Verilog or VHDL (which are common HDLs). The lecturers were asked to indicate the percentage of students who have difficulties in the field of logic circuits; the answer options to this multiple choice question were "0-20%", "21-40%", "41-60%", "61-80%", and "81-100%".
3. The number of examples of a specific problem that they usually use. This multiple choice question contained five answer options: "I don't show any examples", "one example", "two examples", "three examples", and "more than three examples".
4. The technology which is used in the learning process to facilitate students' self-practicing. The lecturers could choose among four choices: "yes, computer-based application", "yes, web-based application", "yes, both web and computer-based applications", "no, I don't use e-learning technologies".
5. The usefulness of m-learning applications in order to improve students' self-practicing. Lecturers were asked three open questions. They were designed in the form of "*Yes, because of …" or* "*No, because of …*". For instance, they were asked to express their opinion about the usefulness of an m-learning application integrating code and graphical view of logic circuits.

Students were asked to identify:

1. Their interest in the field of logic circuits and related fields. Three dichotomous questions were designed in the form of "*Yes or No*" questions. They assessed the level of students' experience and interest in the field of logic circuits and HDL. If participants did not have experience and interest in this area, they were exempted from answering the rest of the questions and not included in the analyses.
2. The type of HDL they usually use for the purpose of designing logic circuits and the most difficult aspect of learning them. Two questions asked the students to indicate the type of HDL that they have worked with, and to indicate the most difficult part of learning HDLs.
3. Whether they have enough time to practice on this subject. A dichotomous "*Yes or No*" question asked whether they have enough time to practice on a technical subject like logic circuits.
4. Their level of knowledge in the field of logic circuits and HDLs. Six technical multiple choice questions assessed their level of knowledge in the field of logic circuits and HDL (in particular, Verilog), e.g. "*Which Verilog code implements a 2-4 line decoder correctly?*" All questions were presented along with one correct and two faulty solutions. In addition, the answer option "*I can't answer this immediately*" was included in order to give the students the opportunity to move on through the questions without deciding for a specific answer.
5. How much they are interested in using electronic devices for more practice on a technical subject like logic circuits. The students' interest to practice logic circuits via mobile devices was assessed using one question; the answer options were "very low", "low", "medium", "high", and "very high".
6. The usefulness of an m-learning application integrating code and graphical view of logic circuits for self-practicing purposes. Students were asked an open question which was designed in the form of "*Yes, because of …" or* "*No, because of …*". For instance, they were asked to express whether electronic devices motivate them to practice more on a technical subject like logic circuits.

Furthermore, demographic questions addressed gender, age, level of education, and field of expertise. Students were asked to indicate the years of using smart mobile devices. In addition, they were asked to indicate the mobile operating system which they usually use.

Lecturers and students from the Faculty of Mathematics and Computer Science of a German university participated in this online questionnaire study. The first group of participants included ten lecturers with experience in teaching logic circuits. In the second group of participants, 79 students began answering the questionnaire; however, due to missing prior knowledge in the area of logic circuits, only 57 completed the questionnaire and were included in the analyses. All these students had a computer science background and prior knowledge in logic circuits or related fields.

Among the students, nine were PhD candidates, 16 were master degree students, and 32 were studying bachelor degree in the field of computer science or related fields. Furthermore, all the students worked with electronic devices for the purpose of having more practice on technical subjects.

The online questionnaire was designed in English and German to facilitate the answering process for the participants. We used simple and everyday language to present the content. Any complex questions which contain more than one meaning or direct participants to choose a specific answer were eschewed [17]. A high quality of the collected data in the lecturer's part was ensured by restricting the participation to lecturers with teaching experience in logic circuits and related fields.

Before answering the questions, the participants were shortly briefed and informed about the study and data protection details. All participants took part voluntarily and without payment. Completing the questionnaire took about 5 minutes for the lecturers and about 20 minutes for the students.

The answers were analyzed and the results were drawn to demonstrate participants' opinions about the topic as well as their perceptions about using mobile devices as a learning tool for the purpose of improvement through self-practicing.

5 RESULTS

Lecturers' and students' opinions about e-learning technologies were assessed. In addition, common difficulties in the context of logic circuits were addressed by both lecturers and students. Lecturers and students also expressed their perceptions on self-practicing in the field of logic circuits through m-learning applications. They stated their opinion about the usefulness of electronic devices – in particular, mobile devices – for teaching and practicing purposes in the field of logic circuits.

5.1 Lecturers

The online questionnaire for the lecturers covered different aspects of teaching experiences and lecturer's perceptions of e-learning, and particularly, m-learning technology. The questions mainly focused on the lecturers' (i) special interests and teaching experience, (ii) their opinion on percentage of students having difficulties in the field of logic circuits, (iii) the number of examples of a specific problem that they usually use, and (iv) current technology which is used to enable students to practice independently. Furthermore, their perception of using mobile devices to improve students' self-practicing in this topic is addressed.

5.1.1 Demographic questions, special interests and teaching experience

Ten lecturers participated in the lecturer part (2 females, 8 males; age: M = 32.80, SD = 7.51). All reported teaching experience in logic circuits. Eight lecturers indicated that they have taught HDLs – Verilog and VHDL in particular. Five lecturers indicated special interest in logic circuits and six of them were especially interested in the field of circuit design.

On average, less than two examples are presented in order to demonstrate a specific problem in the area of logic circuits; four lecturers indicated using one example, five lecturers indicated using two examples; only one lecturer indicated that he would use more than three examples for one specific problem.

5.1.2 Students who have difficulties in the area of logic circuits

Seven lecturers (out of 10) assume that between 41 and 80% of the students have difficulties within the area of logic circuits and their implementation via Verilog and/or VHDL. Two lecturers (out of 10) assume that the percentage of students struggling with logic circuits and their implementation via Verilog and/or VHDL is between 21 and 40%; only one lecturer assumes the percentage of difficulties among students below 20% (see Fig. 1).

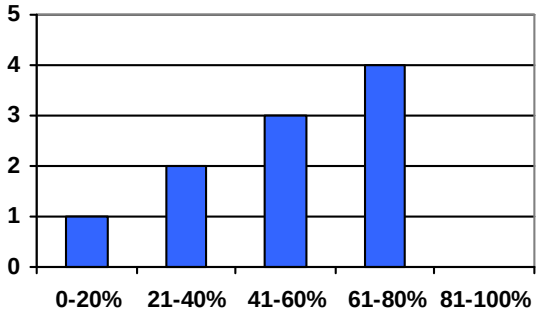

Figure 1. Lecturers' opinion about the percentage of students with difficulties in logic circuits.

5.1.3 Current technologies used by lecturers

Five lecturers indicated that they use e-technologies – in particular computer and web-based learning applications – to enable students to practice independently in the field of logic circuits. Furthermore, nine lecturers assumed that e-technologies are useful for students to gain better understanding of the subject.

In contrast, e-technologies are not used by five lecturers, while, at the same time, four of them indicate that e-technologies would be helpful in order to gain a better understanding of the topic. They mentioned in an open question that e-technologies can provide simulation environments and an opportunity to interact with different parts of circuits and thus better understand their functions. Furthermore, they expressed that the development process of logic circuits can be better learned by having exercise on HDL, and through interaction in e-technology settings, content can be conveyed well.

5.1.4 Consideration of m-learning applications for self-practicing

Nine lecturers indicated that they do not consider using mobile devices in the teaching and learning process. As reasons they mention the small screen interface, high development costs, and the questionable additional benefit compared with a learning process without electronic support or one with computer-based learning programs. Only one lecturer explicitly stated that mobile devices could substantially improve the learning process.

However, when it comes to assessing the helpfulness of m-learning applications – integrating code and graphical view of logic circuits – for students, independent of the question whether the lecturers actually use them or not, the number of lecturers indicating that m-learning applications would be helpful is substantially increased to six. As advantages of m-learning applications, their simple use, immediate feedback at anytime and anywhere, interaction possibilities, and supporting visualization were highlighted by the lecturers. However, four lecturers do not share this positive opinion concerning m-learning applications in the area of logic circuits; reluctance especially concerns the still open question of specific advantages of m-learning applications compared to computer-based learning applications.

In sum, lecturers indicted that more than half of the students have difficulties with learning about logic circuits and their implementation in Verilog or VHDL. Furthermore, on average, for a specific problem, lecturers present less than two examples to the students. More than half of the lecturers assume that e-technologies would be helpful for students to have more practice in logic circuits. Although m-learning applications are not used by lecturers in the field of logic circuits, integrating code and graphical view of logic circuits in an m-learning application is considered to be useful for students in the lecturers' point of view.

5.2 Students

The students' questionnaire was designed to assess students' experiences in the field of logic circuits and their implementation using HDL. Furthermore, students' concrete difficulties and perceptions about e-learning and m-learning were addressed. With this regard, four main aspects have been taken into account: (i) students' areas of interest and experience in logic circuits and HDLs such as Verilog and VHDL, (ii) students' issues and difficulties in learning HDLs, (iii) their opinion on using electronic devices for more practice in a technical subject like logic circuits, and (iv) their opinion on m-learning applications in the field of logic circuits and HDLs.

5.2.1 Demographic questions and experience

57 students were included in the analyses (6 females, 51 males; age: M = 25.33, SD = 4.41). 43 students indicated computer science as their field of interest, 6 students indicated interest in software engineering, 3 students indicated interest in information technology, and 3 in electrical engineering (2 selected “other fields”).

Three questions assessed the students’ experience and interest in the field of logic circuits. 14 students were currently studying logic circuits, and 52 had studied the subject. 34 students indicated that they were interested in this topic. Students needed to give at least one positive answer to one of these items in order to continue answering the questionnaire.

On average, the students have been using smart phones for around 5 years (M = 4.96, SD = 2.195). Among 57 students, 51 were Android users.

5.2.2 Main difficulties in learning about logic circuits

21 students indicated that they have worked with Verilog or other HDLs while 36 indicated that – albeit having some experience in the field of logic circuits – they have not worked with any HDL before. The 21 students with experience in working with HDLs were asked to indicate the most difficult part when learning HDLs; 11 chose the concurrent coding style, 6 chose the debugging process and 4 chose dealing with compiling errors as most difficult part.

Out of 57 students, 61% indicated that they do not have enough time to practice on a technical subject like logic circuits. 39% indicated that they usually have enough time to practice on logic circuits or other technical subjects.

Among the 35 students who do not have enough time to practice, 43% are highly or very highly interested in practice on technical subjects like logic circuits via mobile devices. 40% of the students indicated medium interest, while only 17% indicated a low or very low level of interest.

When it comes to the 22 students who have enough time to practice, 45% are highly or very highly interested in using mobile devices to practice on technical subjects, 32% indicated a medium level of interest and 23% indicated a low or very low level of interest.

5.2.3 Preferable electronic devices to have more practice

When students were asked for the type of electronic devices that they are willing to use for more practice on a technical subject like logic circuits, 56% indicated a preference for laptops and 39% for desktops. As reasons, they mainly indicate that (i) they would like to use bigger screen size devices, (ii) they have never been urged to practice on a technical subject via mobile devices, and (iii) they do not know any m-learning applications in the area of logic circuits. In contrast, only 5% of the students mentioned that they would like to use small screen interfaces such as tablet PCs and mobile phones to practice on this technical subject.

5.2.4 Students’ knowledge and their interest in the field of logic circuits

Concerning the six technical questions, the participants reached about one correct answer (M = .98, SD = 1.60). However, a closer look into the data reveals that this score was closely linked to the interest in logic circuits: the 34 participants who indicated to be interested in logic circuits reached on average 1.44 correct answers (SD = 1.85), while the 23 participants who indicated not to be interested in logic circuits only reached .30 correct answers (SD = .77). This difference was significant, $F(1, 55) = 7.79$, $p = .007$ *partial* $\eta^2 = .124$ (see Fig. 2).

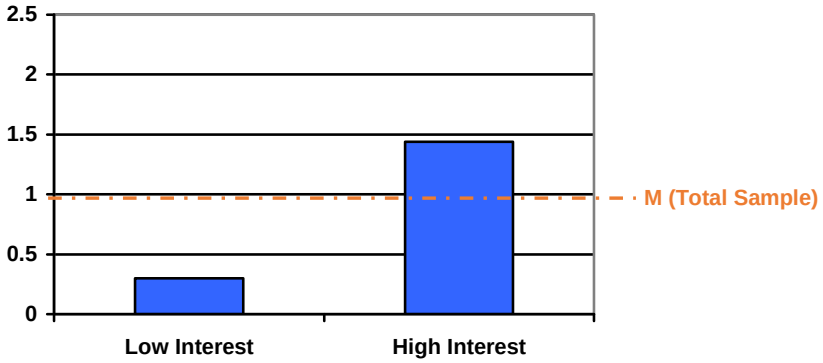

Figure 2. Number of correct answers to the 6 technical questions – separately shown for students with low and with high interest in logic circuits, respectively.

5.2.5 Using m-learning applications to practice

Out of 57 students, 60% indicated that they are interested in logic circuits and/or related fields, while 40% indicated no special interest in this subject. 59% of the students who are interested in logic circuits indicated a positive perception on practicing on graphical and code view of logic circuits via mobile devices. The advantages of m-learning applications are mainly seen in being interesting to use, helpful for faster learning, and flexible to use anytime and anywhere. However, 41% of the students who are interested in logic circuits indicated that m-learning applications which are integrating code and graphical view of logic circuits would not be useful for students.

In contrast, 78% of the students who are not interested in logic circuits did not express a positive attitude toward using mobile devices for practicing on graphical and code view of logic circuits; only 22% of the students who were not interested in logic circuits indicated a positive attitude towards using mobile devices for practicing on graphical and code view of logic circuits (see Fig. 3). A chi square test was performed and yielded a significant result, $X^2(1, N = 57) = 7.66$, $p = .006$; thus, the opinion towards mobile-based practicing on graphical and code view strongly depends on the interest for logic circuits.

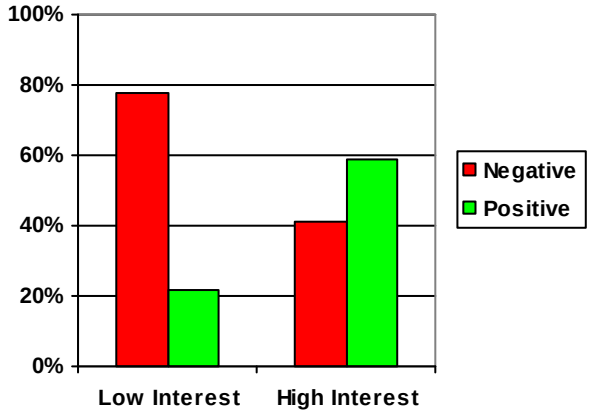

Figure 3. Percentage of students with a negative or positive attitude towards using mobile devices for practicing on graphical and code view of logic circuits – separately shown for students with low and with high interest in logic circuits, respectively.

In sum, in the students' perspective, the concurrent coding style is considered to be the most difficult part of learning HDLs. The results show that the majority of students does not have enough time to practice on technical subjects such as logic circuits, and among those students indicating a lack of time for practicing logic circuits the majority has a positive attitude toward using mobile devices for practicing on technical subjects. In addition, students interested in logic circuits performed better in the technical part and were affirmative about m-learning applications especially when both graphical and code view of logic circuits are represented.

6 DISCUSSION

In the present study, the participants were asked to express their opinion concerning e-learning technologies and their perceptions about improvements in learning about logic circuits through self-practicing with mobile devices. Furthermore, they were asked to identify types of electronic technologies and electronic devices that they usually use for teaching and practicing purposes.

Seven out of ten lecturers highlighted that more than forty percent of the students had difficulties with logic circuits and their implementation via HDL. Furthermore, most of them (nine out of ten) addressed that only one or two different examples are usually used to explain a specific problem. With this regard, we can conclude that additional instructional material – which can be provided via e-technologies – could facilitate, enrich and enhance the learning, teaching and practicing process for both lecturers and students. When students are given an opportunity to practice on more examples in an interactive environment, substantial improvement could be expected.

The lecturers indicated that e-technologies can provide simulation environments and give students an opportunity to interact with different parts of circuits and thus gain a better understanding of their functions. Half of the lecturers mentioned that they use e-learning applications such as computer and web-based applications to enable students to practice independently in the field of logic circuits. Furthermore, most of the lecturers (nine out of ten) generally disagreed with the usefulness of mobile devices in the learning process. However, when it comes to using m-learning applications that integrate code and a graphical view of logic circuits in order to allow for independent practice, more than half of the lecturers (six out of ten) agreed that it would be helpful for students. The advantage of m-learning applications are mainly traced back to being simple to use, giving immediate feedback anytime and anywhere, providing more interaction, and supporting students who prefer visualized information. In addition, providing and integrating different representations could be beneficial for students to make connections between the representations and to gain a better understanding of logic circuits on the whole.

All the students who participated in this study had knowledge and experience in the field of logic circuits. They are either currently studying the subject, previously studied the subject, or are interested in the field of logic circuits. A large number of students had experience in the field of logic circuits and had already worked with Verilog or other hardware programming languages. When asked to notify their difficulties in the field of logic circuits and HDLs, the concurrent coding style was frequently specified as the most difficult part of learning HDLs. Furthermore, a considerable number of students mentioned that they do not have enough time to practice on the subject. This group of students showed a positive attitude toward using mobile devices to practice on the subject. Furthermore, with respect to the students who are interested in the field of logic circuits, the results show a positive attitude towards practicing on graphical and code view of logic circuits via mobile devices.

On the other hand, the lecturers indicated that a substantial number of students have difficulties in logic circuits and their implementation using Verilog or VHDL. In addition, on average, lecturers present less than two examples to explain a particular problem. The results show that both lecturers and students had a positive opinion on the usefulness of m-learning applications integrating both code and graphical view of logic circuits.

Thus, on the basis of these results, we assume that an interactive m-learning application could substantially support self-practicing in the area of logic circuits and HDLs. An m-learning application which can enable them to practice on different examples of the topic without any limitations of time and place would be useful. In addition, integrating code and graphical view of logic circuits in order to explain concurrency in HDLs is supposed to foster learning outcomes.

7 CONCLUSION AND FUTURE WORK

In this paper we presented students' and lecturers' experiences and attitudes in the field of learning about logic circuits. Especially, their opinions concerning independent practice on the subject were examined. In the lecturers' view, m-learning applications would be helpful in the area of logic circuits because they can be simple to use, they can give immediate feedback, they can provide interaction and they can be beneficial for students who prefer learning with visualized information.

Although mobile devices can be helpful in practicing logic circuits, they have limitations which need to be considered during the design process of an m-learning application; especially, the small screen and keypad size have to be taken into account in order to support the teaching and learning process. Furthermore, the development and maintenance costs should not be underestimated.

In sum, the present study indicates that m-learning environments in the field of logic circuits are a promising approach and they are perceived as helpful by students who are interested in this topic. Furthermore, students who do not have enough time to practice on technical subjects expressed a positive attitude toward m-learning applications to improve self-paced practicing. When it comes to the integration of different representations of logic circuits, both lecturer and students indicated that m-learning applications would be helpful for students. Future work should focus on m-learning applications integrating different aspects of learning about logic circuits such as graphical and code view. A high level of dynamic phenomena should be considered in order to (i) facilitate understanding of the concurrent coding style of HDLs, (ii) motivate interested students to have more practice on different examples of a specific problem, and (iii) help those students who do not have enough time to practice technical subjects by providing an opportunity to learn and practice anytime and anywhere. Thereby, information should be delivered using different representations – specifically, graphical and code view of logic circuits – and special focus should be placed on interaction possibilities. Future research should assess the effectivity of different possibilities to foster the mental integration of different representations. In addition, the helpfulness of specific features of m-learning environments should be assessed.

REFERENCES

[1] M. M. Mano and M. D. Coletti, *Digital design*. New Jersey: Pearson Prentice Hall, 2012.

[2] A. A. Kumar, *Fundamental of Digital Circuits*. New Delhi: PHI Learning Private Limited, 2016.

[3] Z. Navabi. *Verilog Digital System Design.* New York: McGraw-Hill, 1999. doi: 10.1036/0071445641.

[4] K. Sandrasegaran and R. K. Appiah, “Engineering education: how can computers help?,” in *IEEE AFRICON 4th, 1996. AFRICON 1996.* Vol. 1, pp. 366-370, 1996.

[5] M.W. Tong, Z.K. Yang, Q.T. Liu, and X.N. Liu, “A novel content adaptation model under e-learning environment,” *36th ASEE/IEEE Frontiers in Education Conference*, pp. 1-5, 2010.

[6] P.L.P. Rau, Q. Gao, and L. M. Wu, “Using mobile communication technology in high school education: Motivation, pressure, and learning performance,” *Computers & Education*, vol.50, no.1, pp. 1-22, 2008.

[7] P. Zaharias and A. Poylymenakou, “Developing a usability evaluation method for e-learning applications: beyond functional usability,” *International Journal of Human-Computer Interaction*, vol. 25, pp. 75-98, 2009.

[8] C. E. Palazzi, “A mobile Serious Game for Computer Science Learning,” *12th Annual IEEE Consumer Communications and Networking Conference (CCNC)*, Las Vegas, NV, USA, pp. 351-354, 2015.

[9] F. Martin and J. Ertzberger, “Here and now mobile learning: An experimental study on the use of mobile technology,” *Computers & Education*, vol. 68, pp. 76-85, 2013.

[10] J. Potts, N. Moore, and S. Sukittanon, “Developing Mobile Learning Applications for Electrical Engineering Courses,” *Proceedings of IEEE, Southeastcon 2011,* pp. 293-296, 2011.

[11] M. Seraj and C. Y. Wong, “Impacts of Different Mobile User Interfaces on Students' Satisfaction for Learning Dijkstra's Shortest Path Algorithm,” *International Journal of Interactive Mobile Technologies (iJIM)*, vol.8, no.4, pp. 24-30, 2014.

[12] D.S.K. Seong, “Usability Guidelines for Designing Mobile Learning Portals,” *The 3rd International Conference on Mobile Technology, Application and Systems – Mobility,* pp. 1-8, 2006.

[13] A. I. Molina, M. A. Redondo, C. Lacave, and M. Ortega, “Assessing the effectiveness of new devices for accessing learning materials: An empirical analysis based on eye tracking and learner subjective perception,” *Computers in Human Behavior*, vol. 31, pp. 475-490, 2014.

[14] L. H. A. Salazar, T. Lacerda, J. V. Nunes, and C. G. von Wangenheim, “A systematic literature review on usability heuristics for mobile phones,” *International Journal of Mobile Human Computer Interaction (IJMHCI)*, vol.*5*, no.2, pp.50-61, 2013.

[15] D. Parsons and H. Ryu , "A framework for assessing the quality of mobile learning," In *Proceeding of International Conference for Process Improvement, Research and Education*, pp. 17-27, 2006.

[16] M. Seraj and C. Y. Wong, "Lecturers' and Students' Perception on Learning Dijkstra's Shortest Path Algorithm Through Mobile Devices," *International Journal of Interactive Mobile Technologies (iJIM)*, vol.8, no.3, pp. 19-24, 2014.

[17] C. R. Kothari, *Research methodology: Methods and techniques*. New Age International, 2004.