Developing an Android-Based Game for Chemistry Learners and its Usability Assessment

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Abstract—Nowadays, smartphones are not only used for communication purposes but also for gaming and studying. Gaming is trendy among adolescents in daily activity. The gamification of chemistry concepts, therefore, becomes very interesting and promising to enhance students' intention of learning and promoting ICT literacy among university students. In this article, we reported the development of an Android-based game on the concept of colloids. Volunteered students (N=100) from the Faculty of Education and Teacher Training took part in the implementation phase. Need assessment suggested that the concept colloids should be a specific topic to be developed as chosen by a significant number of respondents. The validity of the app in terms of the instructional design, software design, and the visual aspects scored above average (between 90 and 99 %). The developed app was found to be very easy to use, practical, and straightforward, with an overall usability score of 85.1%.

Keywords—Android game, colloids, chemistry, learning media.

1 Introduction

1.1 Learning media integration

The use of instructional media in learning has increased significantly in the last decade [1]. In the past, teachers relied only on conventional learning media such as blackboards and textbooks. Whereas digital media growing very fast [2], nowadays, integrating ICT and computer software to the learning process has become very popular among educators [3]. Besides, the rapid growth of both smartphone devices and its software offers numerous apps for students for independent learning. In this digital era, students have a great chance to get involved more intensely in online or computer-based educational apps, sometimes without the teacher's guidance. Therefore, integrating digital content into learning activities become crucial and essential [4].

However, educators all over the world and especially in Indonesia as a developing country, encounter some difficulties in engaging students in the classroom using computers or smartphones. Firstly, the internet infrastructure is the main reason for the teacher to be able to attract students to use ICT. Adequate internet access would help

teachers introducing technological based learning for the students. It will not be a problem for some schools in big cities like Jakarta, Bandung, and Surabaya, where internet infrastructure has settled. However, according to the annual report of Ministry of Education and Culture [5], there are more than 13000 public and private Senior High Schools all over Indonesia that most of them located in the suburb area having no adequate access to the internet. Secondly, the teachers are also struggling in developing proper learning media and mobile applications for their students due to a lack of development skills [6], [7]. Alternatively, teachers will usually download paid or free apps from the app market or app store. However, not all available apps on the market best fit some specific subjects like chemistry, physics, and mathematics. Lastly, another problem encountered by teachers is school regulation for students. Almost all high schools and secondary schools in Indonesia are prohibiting students from using smartphones in the school area [8], limiting students' interaction with electronic devices specially the smartphone due to concern of its use abusing.

In contrast, some private schools have been adopting quite promising solutions to integrating gadgets in learning activities by associating the tablet use to the schools' curricula. By controlling students' activities, the process of integrating technology into the classroom would give several benefits, including information and technological literacy enhancement[9]-[10], and independent learning skills improvement [11]. Considering that more youngsters are now intensively used smartphones beyond school time but for social media purposes, they also must be allowed to interact with smartphones for educational intention during school. Therefore, the best way to integrating mobile apps to the classroom is by associating the proper app for specific subject matters in the schools' curriculum so students would be more motivated and engaged in learning [12].

Even though some teachers might disagree with the use of the tablet in classrooms, many research findings indicated a positive effect on both students' learning outcomes[13] and engagement. [14] reported that from a total of 23 studies about the utilization of tablets in learning, more than half (16) studies had shown positive learning outcomes. [15], [16], for example, reported successful implementations and reviews regarding the use of smartphone engaged learning in the topics of science. Therefore, not surprisingly, in a developed country like Australia, The New South Wales government encouraged schools and college to integrate tablet use in the classrooms by designing the curriculum [17].

1.2 Educational games

Play is a voluntary activity accompanied by feelings, joy, and consciousness [18]. Play always coherent with the necessary capabilities of human beings to express their minds, thought, and ideas by doing certain activities that encourage brain activity. Play is a human beings' favorite way of learning, and it has a significant impact on skills, cognitive, and social. Although designing a good game for education is somewhat tricky, complicated, and time-consuming, but good games could help the teacher reach the students' learning outcomes in short [19].

Educational games have always been practical to attract people of any age [20]. They are also very reliable to engage students in the classroom. Playing games have always

associated with enhanced learning in student-centered based pedagogy. The games also encourage students collaborations [21], competencies, and skills [20], [22], and develop creative thinking skills. Games are practically useful as pedagogical tools because not only they can enliven teaching topics, but also very useful for dealing with problem-solving and core concepts.

Integrating games in learning activities are not something new; some previous studies reported the development and implementation of gaming into learning activities. For example, [23] developed an Android game for learning colloids, Atiek et al. [24] developed *"chemtective"* to learn chemistry through detective-problem solving. Wardani et al. [25] have also developed a chemistry board game called the alchemist board, which aimed at enhancing students' learning outcomes and critical thinking ability. [26] have successfully implemented social media and multimedia in learning to elevate students' creativity. Furthermore, we also have previously developed an augmented reality app for learning the concept of molecular geometry [27].

In this study, we developed a picture guessing game on the topic of colloids run on the Android system. The game allowed the users to guess the displayed pictures by taping the given characters below the image. The game has 30 levels. The level of the game determines the question difficulty meaning higher levels consist of more difficult questions.

2 Research Method

2.1 Development model

The app was developed based on (R&D) research method with the ADDIE model. The ADDIE model consisted of 5 fundamental stages, including analysis, design, development, implementation, and evaluation. At the analysis stage, we used seven questions regarding the need analysis of the app.

2.2 Usability test

The usability test was conducted to measure the ease of the app as an Android system app. The SUS was initially developed by Brooke [28] in 1996 to evaluate the system usability of a product or service consisted of ten questions based on a Likert scaling rule [29].

2.3 Validation of game contents and design

Before the implementation, the app was validated twice to ensure the content validity and design usability of the app. The validation is required to avoid concept misunderstanding among students, so the result of the research can be academically accepted. There were three aspects examined, including software design (7 indicators), visual communication (9 quality indicators), and instructional design (5 quality indicators).

3 Results and Discussions

3.1 Need analysis

Need assessment was conducted to acquire responses from students regarding smartphone usage in their daily activity; the study also aimed to reveal the attitude of students in using mobile applications in learning activities. The result of need analysis can guide the researcher in deciding the right app to develop based on users' experiences and preferences.

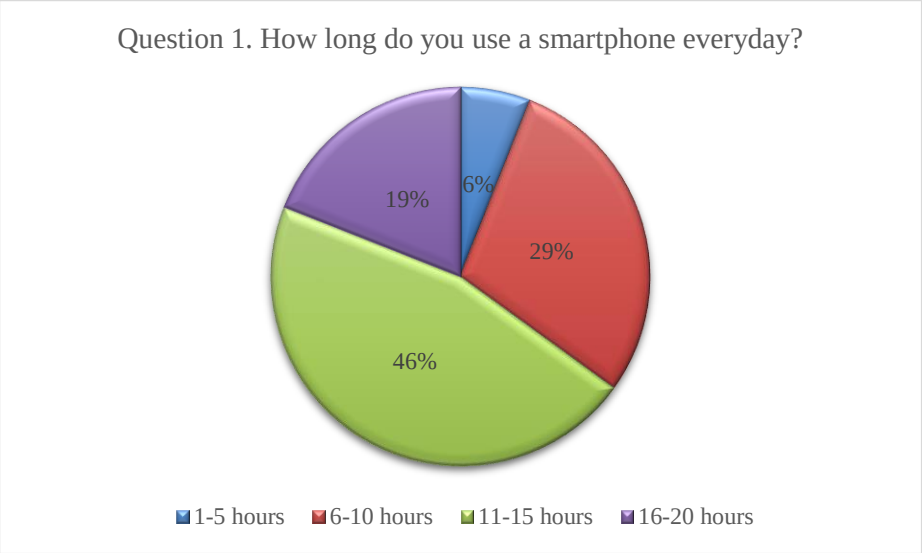

Fig. 1. Daily time allocation for smartphone use

Fig. 1. Shows that the vast majority of students used their smartphone for between 11 and 15 hours. While 19% of the respondents allocated over 15 hours using the smartphone, only 6% of students spend less than 5 hours a day. This data indicates the intensive interaction between students and the smartphone. [30] reported that most students allocated more than 8 hours a day using their smartphone either for educational or social media purposes. The second question aimed to emphasize students' behavior of using smartphones for game and chemistry learning.

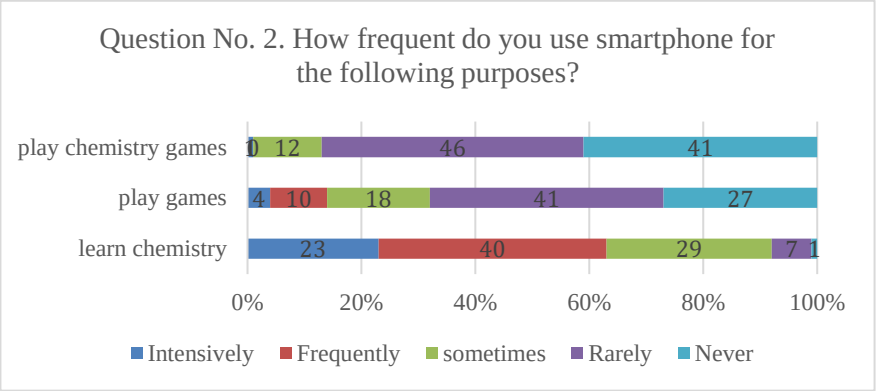

Fig. 2. Smartphone usage frequency for specific purposes

Fig. 2 depicted the attitude of students toward smartphone usage for chemistry-related games. Only 23 % of students intensively using their smartphones for chemistry learning purposes, while the majority of them are frequently utilized smartphones for learning chemistry. In terms of gaming, most of the students rarely played games or chemistry games. Only 12 % of students sometimes played chemistry educational games, and 18 % of students play games using their smartphones. Since most of the students did not involve in using chemistry-related games or apps, we were curious to know students' opinions about the chemistry-related game or app availability on google play or Appstore.

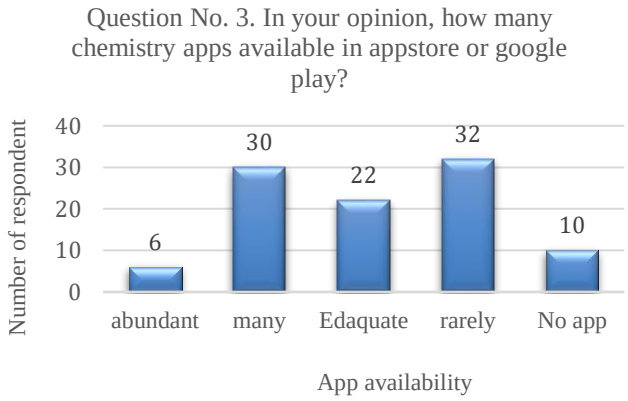

Fig. 3. Students'views toward chemistry app availability

Fig. 3 shows students' opinions toward chemistry-related app available on google play. From a hundred students, 32 of them argue that there are not so many apps available for learning chemistry, while most students still think of many apps available in the app market. This answer aligned with the previous question regarding students' ex-

periences in using chemistry applications, whether to learn chemistry or play the chemistry-related game. Almost half of the total students (41%) have never played a chemistry game app on their smartphones.

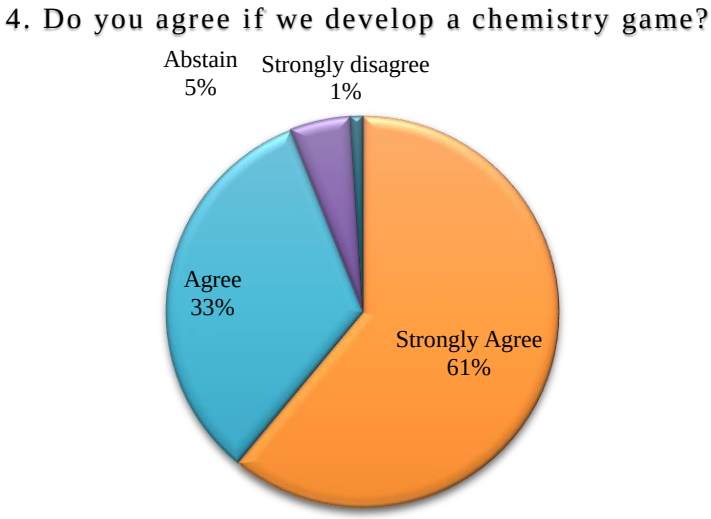

Fig. 4. Students' opinions regarding app development

We saw the great interest of students in the chemistry game app development since most of the students responded positively to the development plan of the chemistry app, as depicted by fig. 4. Students prefer a fun and joyful way of learning the serious matter like chemistry and physics, according to [31], joyful learning promotes fun, enthusiasm, and positive cognitive experience in the classroom.

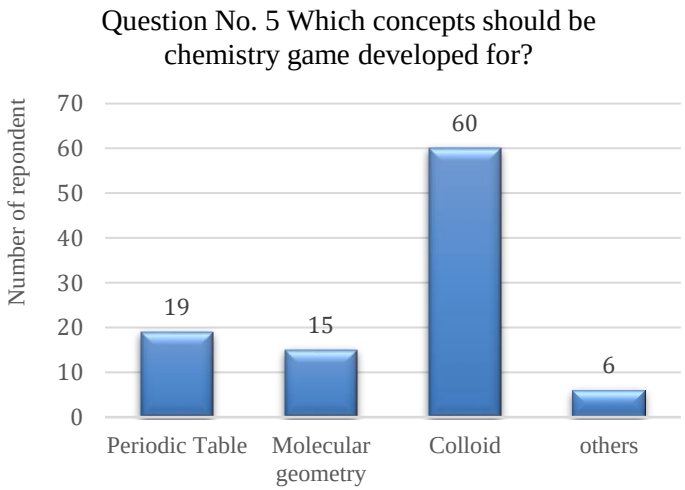

Fig. 5. The chemistry concepts selected by students for game development

Fig. 4 Depicted chemistry concepts as suggested by 100 students who took part in the need analysis of the Android game. According to the graph, more than half (60 students) students preferred colloid as a selected topic of the development of an Android game. Comparing to other concepts like the periodic table of elements, and molecular geometry, the idea of colloid is somewhat confusing for students in determining the dispersion system and defining the correct example for each dispersion system. In high school, students encounter difficulties in identifying the accurate dispersion system of colloid due to phase complexity.

3.2 Game development

We developed the game using the Android Studio, the graphic was designed using CorelDraw©, and the language of the content is Indonesian except for the first screen. Fig. 5 and Fig. 6 depicted some screenshots and the flowchart of the game, respectively. We prepared 40 questions to be integrated into the game, but only 30 items passed the quality assessment. Therefore, those 30 questions were employed as contents of the game. We intentionally switched contents between figures, texts, and abstract figures to avoid monotonously in displaying the concept of colloids, and we also focused on including only the following sub-concepts: the dispersion of colloids, examples, type of colloids, and colloidal properties like Brown motion, Tyndall effect, Electrophoresis and coagulation of colloids.

Fig. 6. Screenshots of the game

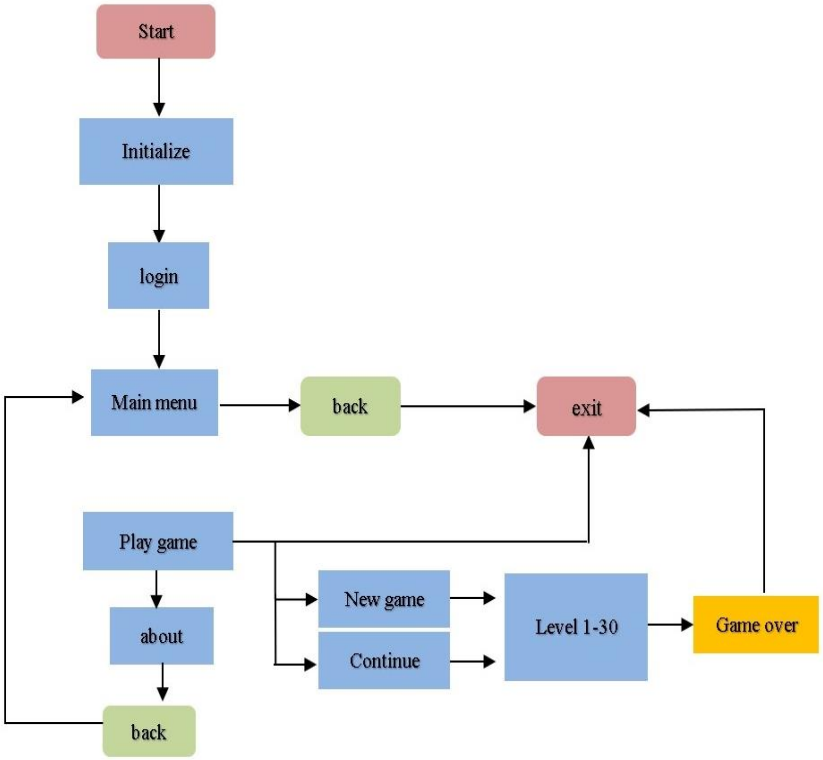

Fig. 7. The flowchart of the app

3.3 Media and content validity

The content and media validity assessment was conducted twice to ensure the correctness of contents inserted in the game. Furthermore, the questions also have been tested in a small group of students before the implementation; the test was necessarily conducted to evaluate whether the items are understandable, answerable, and properly designed. Content validity is a crucial aspect in quantitative educational research [32], which determines the correctness of content knowledge, as well as its coherency with the questions, appeared in the quiz [33].

Fig.8 shows that the software design was excellent, with a score of 99 out of 100. The graph also depicted an insignificant validity decline for both visual, communication, and educational design aspects of the app. In short, overall scores of validity indicated that the app was ready to be used in the implementation phase.

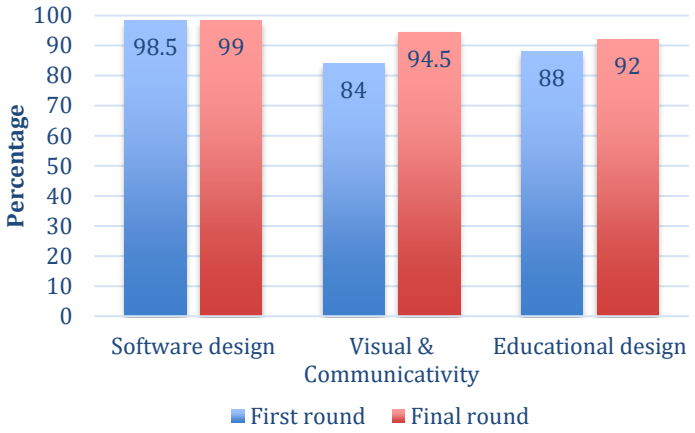

Fig. 8. Validity Scores of the App

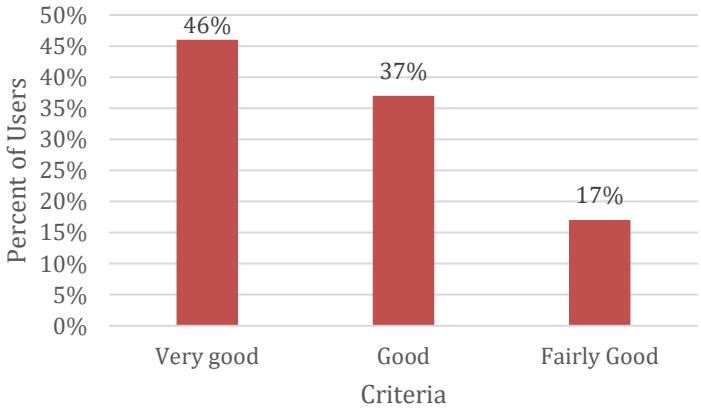

Fig. 9. System Usability Scores Given by 100 students

Fig.9 shows that almost a half of the students (46 %) found that the app is straightforward to use as learning tools, and the total score of usability was 85.1 %, which is marked as an excellent criterion. Usability of mobile app is a qualitative criterion that applies not only to the user interface of a product, but also to its functionality and specific context of the app use [34]. Based on the results, we strongly suggest educators engage students in the proper smartphone application to encourage them to learn independently and fast. Although some educators argued that smartphone use might cause a negative impact on students' academic performance [35]–[37], other researchers who successfully implemented the ICT integration to the classroom find the opposite results, Kaur et al. [38] argued that even there is a negative implication of smartphone use on students' performance at schools, smartphones controlled use can provide a positive contribution to student's ICT literacy. Not only because the smartphone is handy and

easy to operate, but in the digital era, smartphones have also been an excellent replacement for computers or laptops in terms of practicality and mobility. Learning through smartphone screens is much more interesting for young people nowadays[39] comparing to books, laptop computers, or any other resources available.

4 Conclusion

Although the smartphone has been responsible for students' academic performance decline all over the world, we believe that controlling the smartphone use with a proper app like a specific subject matter game could encourage students to learn better and independently. In this paper, we show that the particular app designed for the chemistry concept of colloids could attract students to learn chemistry, which indicated by the usability scores of the app, students' interest, and demand of the game (see need analysis).

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