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IMPROVING LEARNING MOTIVATION BY APPLYING USER-CENTRED DESIGN AND AUGMENTED REALITY ON 3D INTERACTIVE APPLICATION

Shumaya Resty Ramadhani[1*]; Fiona Stefani Limin[2]

Informatics Engineering[1,2]
Politeknik Caltex Riau
https://pcr.ac.id/
shumaya@pcr.ac.id[1*], fiona16ti@alumni.pcr.ac.id[2]

(*) Corresponding Author

Abstract— *Conventional methods in teaching are still prevalent in the educational field to present knowledge to students. This method is still relevant today; however, it needs technology to enhance the experience and support an intelligent education system. Witama Primary School is one of the schools that applies modern technologies in teaching processes to improve learning motivation, especially in natural science. Students need an interactive instrument or tool that attracts attention and boosts their learning motivation while studying solar systems using a smartphone. Therefore, to present a virtual solar system experience, this study aims to create an interactive 3D solar system using Augmented Reality (AR) on iOS mobile-based by implementing a user-centered design (UCD) method to understand requirements and expectations. UCD consists of four main stages, specifying the context of use, user and organizational requirements, product design solution, and evaluation design before developing the system to ensure the finery development process as the goal is to improve the student's focus and learning motivation. According to the User Experience Questionnaire results to thirty respondents, the obtained aspect of attractiveness is 2.222, the perspicuity aspect is 2.129, the efficiency aspect is 1.902, the dependability aspect is 1.689, the stimulation aspect is 2.222, and the novelty aspect is 1.727. Overall results showed that the interactive mobile app is in the good to excellent range. Moreover, the students and teachers find the product exciting and feel motivated to use the mobile app further.*

Keywords: *User-Centered Design, Augmented Reality, User Experience Questionnaire, Solar System, iOS Mobile.*

Intisari— *Metode konvensional pada pengajaran masih kerap dijumpai di dunia pendidikan untuk menyajikan ilmu kepada peserta didik. Metode ini masih relevan hingga saat ini, akan tetapi saat ini dibutuhkan teknologi pendukung untuk meningkatkan keinginan belajar serta mendukung sistem pendidikan yang berbasis teknologi. Sekolah Dasar Witama merupakan salah satu sekolah di Pekanbaru yang menerapkan pendidikan dengan pemanfaatan teknologi modern pada proses belajar mengajar. Hal ini dilakukan untuk meningkatkan motivasi belajar siswa khususnya pada ilmu pengetahuan alam. Siswa membutuhkan instrumen interaktif yang menarik perhatian dan meningkatkan fokus belajar saat belajar tata surya menggunakan smartphone. Oleh karena itu, untuk menyajikan pengalaman belajar tata surya secara virtual, penelitian ini bertujuan untuk membuat tata surya 3D interaktif menggunakan Augmented Reality (AR) berbasis mobile iOS dengan menerapkan metode user-centred design (UCD). UCD terdiri dari empat tahapan penting, yaitu menentukan konteks kegunaan, kebutuhan pengguna, membuat solusi desain dan juga evaluasi sebelum mengembangkan produk. Tujuannya adalah agar sistem yang dibentuk mampu meningkatkan motivasi belajar dan fokus siswa. Berdasarkan pengujian menggunakan User Experience Questionnaire kepada tiga puluh siswa, diperoleh aspek kemenarikan sebesar 2.222, aspek perspicuity sebesar 2.129, aspek efisiensi sebesar 1.902, aspek ketergantungan sebesar 1.689, aspek stimulasi sebesar 2.222, dan aspek kebaruan sebesar 1.727. Hasil keseluruhan menunjukkan bahwa aplikasi seluler interaktif berada dalam kisaran baik hingga sangat baik. Selain itu, para siswa dan guru setuju bahwa aplikasi mobile 3D ini menarik dan merasa termotivasi untuk menggunakan aplikasi lebih lanjut.*

Kata Kunci: *User-Centred Design, Augmented Reality, User Experience Questionnaire, Tata Surya, iOS Mobile.*

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INTRODUCTION

An attractive, engaging, and fun learning environment is compulsory to keep students' attention during the learning process. Discovering such an interactive, enjoyable, and unforgettable learning experience should be a concern in the educational system, especially for kids. Many technologies help establish a creative learning environment or intelligent education, and one of the latest promising approaches is Augmented Reality [1]. Augmented Reality (AR) is an interactive, creative, and innovative technology adaptable to various fields such as promotion for tourism [2]. AR usage in the tourism industry would become a potential alternative solution to deliver marketing materials that are engaging and in an informative format [3].

Another usage that is also beneficial is the implementation of online learning to enhance the teaching and learning process to become a new virtual experience and fun [4]. Interactive technology by applying AR has changed many people's activities; hence it impacts how users would experience the technology [5] [6].

It is time to adopt advanced technology to support and enhance the learning processes in the field of education. One of them is implementing augmented reality to improve academic learning. For educational purposes, AR helps encourage students to engage with the subjects. Science, in particular, may become fascinating when the teaching process applies AR technology to visualize particular topics such as astronomical knowledge. The solar system is one of the natural science lessons taught since elementary school. The topics introduced to students are the description and characteristics of various celestial bodies in the solar system [7].

Based on interviews with one of the elementary schools in Pekanbaru, SD Witama, the solar system topic includes the learning material for students in grade 6th. To understand the basic phenomena of astronomy and planetary motion, students require an ability to visualize events and objects. According to some research, AR environments are more suitable for learning astronomy than physical ones to create a creative learning process [8]. AR will complement reality with different sensory sensations [1] compared to imagination alone. In that case, it is safe to say that AR is one of the pioneer technologies in conveying information by combining text, images, videos, and 3-dimensional models, which students cannot obtain through books and other 2D multimedia images such as videos and props.

Problems arise when delivering material from the solar system to the students because sometimes they ask teachers how to describe each object in the solar system so they can visualize it. Most teachers still adopt a conventional way of delivering the topics, which is less appealing to learners, using textbooks only. By that, sixth-grade students are encouraged to learn from media such as interactive books, pictures, teaching aids, and videos. Additionally, to ensure students understand the materials thoroughly, teachers equip them with hands-on practice. While learning, students are suggested to demonstrate the process as a group by the teacher.

The process would be some students act as planets, and then the rest of the members surround the designated pupil as another planetary object. This fact is considered because studies about the solar system are still traditional because it still requires the support of other tools. Therefore, due to the lack of interactive learning media with digital technology, students must be encouraged to imagine themselves seeing a candid picture of the solar system process.

As the research concern is to develop software products that satisfy the user's interests and criteria, the active participation of the end-user in the process is necessary. In this case, the expected end-users, the Witama Primary School’s students, and the subject teachers need an interactive system as a stimulus to improve learning ability, especially the solar system. They could point out the problems and opinions to determine the needs and experiences expected to be achieved as the outcome of the product. By analyzing those lists of information, such features, the system's whole interface, and the indispensable depth of attractiveness can be set as goals of the software product.

User Centered Design (UCD) method is one of the practices that put the user's opinion and concern in the highlight and observe the experience of the system as the center of the software development [9]. Therefore, the researchers designed an interactive 3D solar system learning application using augmented reality technology to enrich the learning and teaching experience by practicing the UCD method.

METHODS AND MATERIALS

This research method is used in this study to get a broad knowledge of concepts and current technology up to applying UCD methods to seek an understanding of the stakeholder's needs. The aim is to improve learning motivation for the sixth-grade students in Witama Primary School in one of the Science topics. In general, there are four stages as it shows in **Error! Reference source not found.**, to accomplish the study's primary goal.

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1. Planning

Developing software products needs good planning processes, from understanding users' problems to testing the product acceptance [10]. An interactive learning system about the introduction of the solar system using Augmented Reality (AR) technology is introduced. The primary purpose of this research is to help students understand the concept of the solar system since the topic perhaps needs objects and visuals to make it more engaging than reading books only. This application is based on mobile iOS, utilizing AR to give an accurate impression. The application's target users are grade 6 students at Witama Elementary School under supervision from the respective teachers.

The development of this mobile application applies the User-Centered Design (UCD) method because the implementation process requires participation from the end-users to achieve the expected system. As the center and focus of the system, users could be actively involved in the designing process up to testing the system [11]. This step is necessary to discover the user's expectation of the system that precisely meets their requirements and interest.

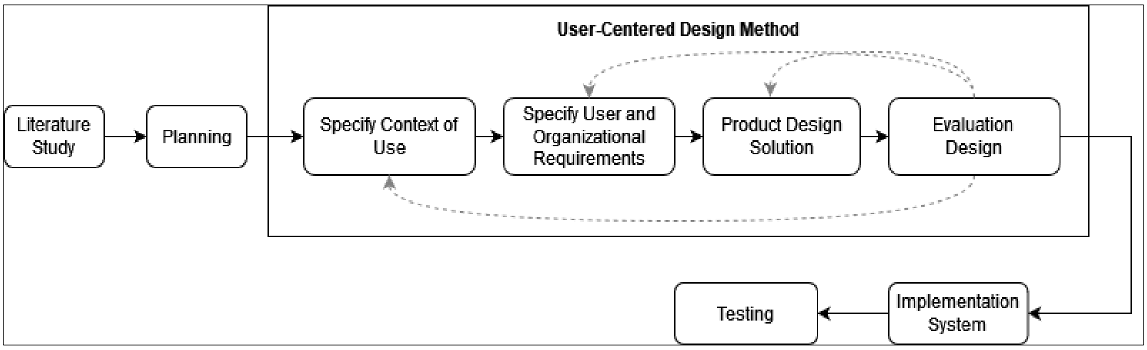

Figure 1. Research Methods

2. User-Centred Design

In software product development, developers should avoid associating personal views and preferences to avoid ambiguity and subjectivity in determining system requirements [9]. Developing an understandable software product by end-users to meet their interests and needs is also challenging for developers [12]. The end-users can participate in the designing system to evade subjectivity while developing a software product. The practice might take time and become an iterative process, but adequate to reduce time while creating the actual system and avert user rejection. The accurate implementation of UCD can ensure that the developed system design has achieved its goals. User-Centered Design is more than just collecting user requirements and turning them into functional requirements.

It also has to consider what kind of experience the user will have when using the system we create. Generally, there are four steps of UCD [13]:

1) Specify the Context of Use

Determining the user context is the initial process stage in the UCD method. This stage identifies who uses the application, the user's tasks, and how the user will use the application. The application is created for educational purposes to encourage learners to study solar systems in an interactive environment. The stakeholders of the system are students in Witama Primary School and the respective teachers.

2) Specify User and Organizational Requirements

This stage determines the needs of users who target application design. Several methods are used to draw users' stories and problems in more detail, such as focus group discussions, interviews, and questionnaires. In this study, we conduct surveys using questionnaires to understand problems students are facing. Additionally, a profound discussion method is carried out with the teachers to ensure the main objectives.

3) Product Design Solution

At this stage, the output of requirements evaluation serves as the design process input. Architecture, use case diagrams, user flows, prototypes of the systems and other diagrams might present as design output for this stage. Testing is also required to ensure the system achieves its goals.

4) Evaluation Design

The next step is evaluating the design results based on the students and teacher's specifications. The designs must meet the user's goals and expectations so that the assessing process of the system's usability becomes essential.

3. Augmented Reality

Augmented Reality is a technology designed to enhance the interactive experience of computer-generated objects as if the real-world objects that blend with the actual setting. The substance could be virtually projected into the real world through

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our smartphone's camera and provide the stakeholders new experience. The mobile app in this study is iOS-based and developed using native methods (swift). XCode by Apple is the tool that was used to develop the application combined with the ARKit for processing augmented reality. The ARKit is a framework from Apple. The object creation process uses the Blender application since it's free, open-source, and easy to use. Many communities around the world also support this tool. Therefore, the library availability and the ecosystems are guaranteed. The ARKit then merges the objects with motion tracking from Apple's devices, world tracking, scene understanding, and display conveniences to simplify the building process of AR.

Experiencing a new way of providing information as a benefit of applying AR, people discover a new form of interaction with the product and service [14]. People started using this technology approximately two decades ago to study anatomy [15]. As the fame and success continue, the improved technology is then being adapted into various educational settings, with a broad range of topics, user targets, academic backgrounds, interests, and more. Others used this technology as a business support system that provides virtually projected services like e-commerce and wedding organizing [16]. Among all benefits of using AR, the increase in learning gains and motivation of learners is the highest [17].

The previous research also indicates that AR reached the most usage in 2016 and is widely used, especially in the Asian continent. It also increases learning motivation by combining technologies and previous study methods [18]. Developing AR is simple and inexpensive since there are several free software products available such as 3DS Max, Blender, AR Toolkit, ARKit, FlarToolkit, d'Fusion, and Vuforia.

4. System Testing

The test methods in this study are black-box and User Experience Questionnaire (UEQ) testing methods to test the software products. Black-box testing is necessary to ensure the system output is relevant to the input given and that the application reaches its required functionality. There are distinct criteria for quality measurement of a software product : (1) incorrect function, (2) improper user interface that causes errors, (3) detection flaw in software performance, and (4) termination errors [19].

Considering the application's audience, which is around thirty of sixth-grade students, a simple evaluation method and easily interpreted is necessary. UEQ used in evaluating the 3D solar system application is one of the User Experience (UX) tests and is easy to implement. Due to its simplicity, UEQ is widely known and used in measuring processes in various fields, especially in software products focusing on user experience [20]. Measurement in UEQ has 26 component questions and seven stages of scale. There are six assessment categories in the UEQ method: attractiveness, perspicuity, efficiency, dependability, stimulation, and novelty. This UEQ measurement is available online and free to download. It is also available in Indonesian [21] hence students could understand the context better. To ensure better context understanding, the teachers will assist the students when filling out the UEQ survey.

RESULTS AND DISCUSSION

1. UCD Implementation

This section describes the details of UCD implementation that have been carried out on target users, in this case, grade 6 students and supervising teachers. All functions and designs are built based on UCD results. Moreover, the system also applies AR technology to increase interactivity and attractiveness. AR technology is made by utilizing Apple’s Augmented Reality Kit (ARKit) framework provided by Apple to create iOS-based applications. By implementing ARkit, this AR feature can take advantage of the camera and motion sensors on the smartphone device. This section also describes system testing results using black box testing and measures user satisfaction using the UEQ method.

1) Specify the Context of Use

The application users for the system are science teachers and sixth-grade elementary school students. The solar system is one of the topics in a science subject for sixth-grade students in Witama Primary School. The student learns by the book, and the teacher explains in more detail without using tools or materials. The student often finds the topic difficult because of the lack of imagination and visualization. Both teachers and students can use this application as one of the tools in the teaching and learning process of the solar system at any time.

2) Specify User and Organizational Requirements

First, we used the questionnaire method for the sixth graders to understand learners and dig into the issue. The teacher supervised the students while filling out the form to ensure proper interpretation of the questions. From the results, we found that 30 respondents answered that students require another support tool, preferably using gadgets they have in the form of the such interactive application, mobile-based, if possible, to learn about the solar system.

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The expected feature that students would like to have on the app is the visualization of the solar system so that they can observe and interact with the actual-like planets just using a smartphone. Additionally, when asked about the application's environment, most students agreed to develop this application as an iOS app instead of an android app. For a particular reason, most students in Witama Primary School use or have access to Apple products. Therefore, they are already familiar with its system. In conclusion, there are some critical points here from students:

a) Students need a simple set of menus and less complex navigation on the mobile app.
b) The users request an interactive activity in the application, 3D objects. full color but not over and distracting. Prefer dark colors that represent the natural environment of the solar system.
c) Using distinct colors for each menu
d) The product can display solar system artificial exploration in the real world. It would be better to make some improvements to enhance the experience.
e) Preferably an iOS based application

The second method to gather requirements was interviews and deep discussions with one of the sixth-grade science teachers in the school. According to the result, we analyzed that there are several requirements for 3D application in general by the teacher:

a) The need to present clear and concise information about the solar system so that students can achieve the insight and learning objectives through 3D simulations.
b) The information displayed, such as the understanding of the solar system, how the solar system and planets formed, the composition of the solar system, the names of planets, the period of planetary revolution, and the understanding of some celestial objects.
c) Add a set of quizzes to ensure understanding of the topics.
d) The product provides instructions for the use of an application.

3) Product Design Solution

This stage includes several designs, such as a use case diagram, activity diagram, structure menu, and product prototypes. According to the initial agreement, we created the system as an iOS-based mobile app using ARKit by Apple and Blender for planetary animation. The users use the smartphone's camera to display 3D planet objects on the screen and possibly interact with each object. **Error! Reference source not found.** depicts the use case diagram of the product.

This application has features where teachers and students can see the composition of the solar system in 3D by activating the phone's camera and pointing to an empty space. The implementation of augmented reality allows users to get 3D visualization of the planets' movement around the sun and also information about the solar system. To ensure learners understand the topics, they can also work on quizzes and see the scores. Additionally, users could see the instruction menu to help guide the application

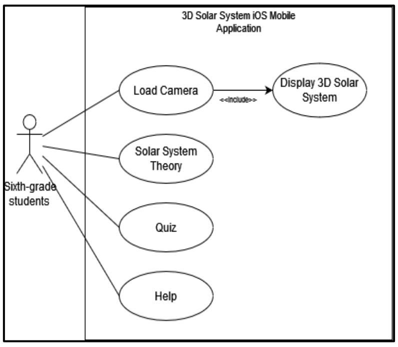

Figure 2. Use Case diagram

An activity diagram represents the flow of procedures as a support of the use case for this 3D AR solar system application. The main page of the solar system learning application will display several application menu options. There are options to start an augmented reality of the solar system, material information about the solar system, a quiz, and a help menu for instructions. Figure 3 depicts the menu structure of the mobile application. The users will have four main menus, as shown below.

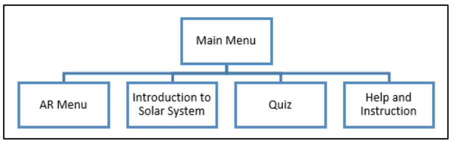

Figure 3. Menu structure

Figure 4 depicts the prototype of the expected mobile applications. The raw design is created after consulting with stakeholders, mostly with teachers.

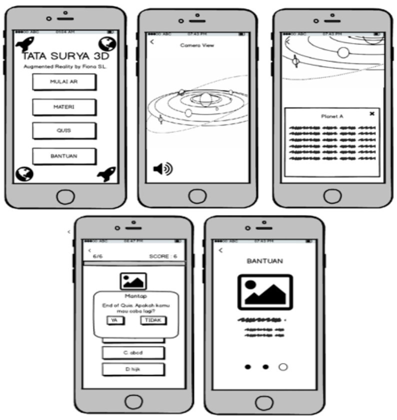

Figure 4. Prototypes of mobile app

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4) Evaluation Design

To carry out UX testing, the author uses two methods. First is an interview with a school teacher to whom we asked about requirements prior to app development. The second is the UEQ questionnaire tool, which contains several user questions regarding their experience toward the app [22] [23]. UEQ can help evaluate UCD results by ensuring the products meet user expectations and need to create significant improvements in the system to ensure an optimal user experience. Accordingly, for these products, the users have to use the application on their own to fulfill their needs. After that, all questionnaire participants, around 30 users, fill out the questionnaire.

2. System Implementation

The mobile application is developed according to the appliance of UCD processes during the research. Combining the requirements with augmented reality, we implemented all functions and designs to the mobile app to make it more compelling to the students. The following is the result of the iOS mobile app.

1) Main Menu

Figure 5 depicts the main menu page of the solar systems iOS app. Four menu options are available on-screen for users: starting using AR, the material of the solar system, quiz, and help.

Figure 5. Main page of mobile app

2) AR Menu

The application automatically requests permission to activate the camera on the mobile device when the users press this menu. The user can point the smartphone at an empty corner or wall if permission is allowed. Therefore, the app can display 3D AR objects on the screen. AR menu is essential to make this mobile app more appealing. Users can interact with the AR display by zooming in and out and tapping on the planet. It then appears to display a brief description of that planet. This iOS 3D app also comes with background music and animation according to its concept to make it enticing and lively.

Figure 6. AR menu of mobile app

The application showed a live 3D animation as shown in Figure 6. Every planet slowly moves around the sun, the moon rotates toward the earth, and each planet spins to its rhythm on its axes. All objects move according to each trajectory. Hence the rotation can be seen clearly on the screen and is more apprehensible to students.

3) Introduction of Solar System

This menu contains teaching content on the solar system. It has a complete list of planets based on the used reference and a thorough description when pressed. Figure 7 shows that the content consists of 8 objects, Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, and Neptune. The nebular theory is also included to add more insight into the concept.

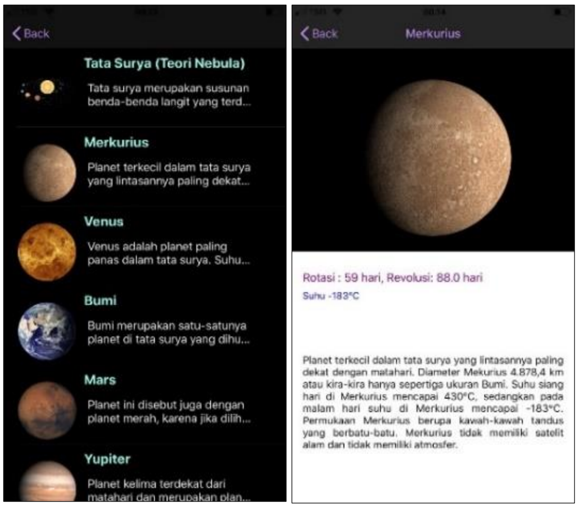

Figure 7. Description page of mobile app

Furthermore, this teaching content also encloses an animated video that displays the solar system's formation. The video was made using the blender application and exported as mp4. It is then

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embedded into the iOS mobile app to enrich its content besides text.

4) Quiz and Instruction Menu

The Quiz menu has around twenty questions related to the topic. It is randomized; hence the students will not get the same question list every time. The quiz used the objective test with four options available on the screen. Each correct answer gets five points and no reduction point when otherwise. The help menu displays a brief explanation of how to use this application. It contains images and list of instructions to ease the users, in this study, the sixth-grade students.

3. System Testing

Designing and implementing interactive features for educational purposes should be measured by how much the users are satisfied with the apps. In light of this, we used black-box and UEQ method testing for the solar system 3D iOS application. Blackbox testing is used to ensure the application being developed runs well. Meanwhile, to measure the user experience and its interactivity, the author uses the UEQ test method on this mobile system.

1) Black Box Testing

In developing the system, the black box testing method focuses on the system's functionality. There were test cases for the mobile app to check whether the application results followed the initial requirements and ensure its functionality worked perfectly. In this instance, the app successfully demonstrates the AR solar system 3D when the smartphone's rear camera is pointed at an empty wall or space. It is also able to display live animation with back sound. The application also describes the planet according to the user's choice when tapping each object. Furthermore, the quiz menu displays several questions in random order, successfully showing the correct answers and displaying the final score to the user.

2) UEQ Testing

The testing result illustrates that applying the UCD method to developing interactive 3D mobile apps generated positive values on six aspects of UEQ. The evaluation score of UEQ test is shown in Figure 8. According to UEQ results conducted on the teachers and groups of total thirty students, the average score obtained is around 1.98, which is considered "good" on the UEQ benchmark. In detail as shown in Figure 8, the attractiveness aspect of the application/product is approximately 2.222. The result of the perspicuity aspect is around 2.129. These results can be interpreted as the users also finding the mobile app understandable and easy to operate.

Furthermore, as depicted in **Error! Reference source not found.**, the efficiency and novelty aspects of this iOS mobile app are 1.902 and 1.727, respectively, which is considered excellent. Of all values, the 3D solar system app achieved the highest score of stimulation aspects and the above attractiveness, with a value of 2.227. On the other hand, the dependability aspect gets the lowest rank among all elements, about 1.689. However, it is still in a suitable category on the benchmark. In the UEQ test method, these benchmarks are a standard used to measure application performance.

Based on benchmark values in the UEQ method, this 3D mobile app's result is excellent overall, albeit slightly decreased on the dependability aspect. Therefore, according to this test method, the 3D iOS mobile app has a perfect stimulation scale for students. Students find the apps appealing and enjoyable for learning purposes, especially for a particular topic. Moreover, the teachers also feel motivated to use this product as interactive teaching material.

Additionally, according to discussions with teachers, they agreed that the AR mobile app developed well according to user requirements. Furthermore, adding back sound while the solar system rotates on the system as improvement is enticing and makes the apps engaging. By observing the students using the interactive mobile apps, the teacher notices the change in learning behaviour. Most students become more enthusiastic and excited than they usually show while learning without the help of technology. Their curiosity increased, especially when students had to interact with virtual objects on screen while using AR features to study the solar system.

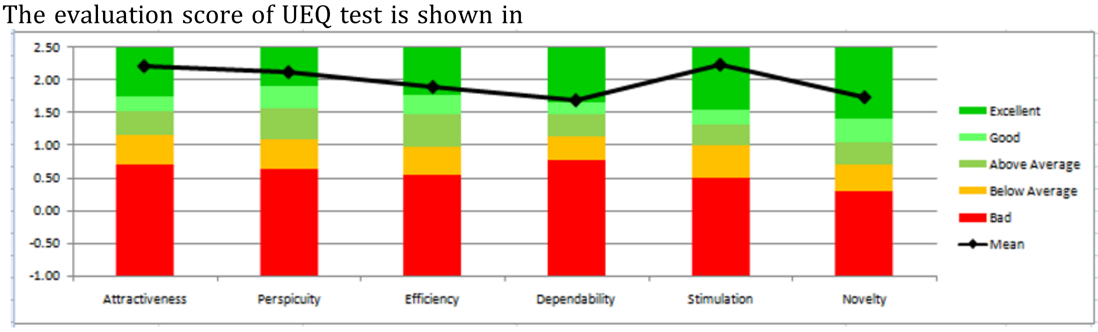

Figure 8. UEQ benchmark for 3D solar system app

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CONCLUSION

According to the test and the analyzed results of this software product, it is known that this study succeeded in applying the UCD method with a combination of AR technology in an iOS-based learning application. The developed mobile application increased the interest and motivation towards the content provided in the product of 6th-grade students at Witama Elementary School in learning Science, particularly the solar system topic. The stimulation scale on the UEQ test reached the highest among the others. This success is evidenced by UEQ testing with an excellent simulation scale above the 2.2 scale. This iOS-based solar system learning media application is considered helpful and successfully increases students' motivation by teachers as an alternative learning solution in natural sciences for schools that implement innovative education using technology, such as SD Witama. The overall UEQ test results also show the application's good user experience. In addition, the use of AR technology in delivering material about the solar system makes children become enthusiasts as they can interact with planets like natural objects. Therefore, it is safe to say that AR technology embedded in mobile applications provides a combination of attractiveness and effectiveness in education. To summarize, adopting the UI/UX method, such as the user-centered design method, in developing interactive applications is necessary. Applying UCD could elevate the guaranteed level of understanding of the requirements through the user's perspective and expectations of the system. This study shows that implementing UCD while developing applications for learning purposes and combining it with the latest technology is beneficial. Augmented reality for this specific case study could enhance learning motivation in students, as shown in evaluation results using the UEQ method. However, the system is only suitable for one specific topic in Science: the solar system. The audience would need feature improvements, content, and technology for future use.

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