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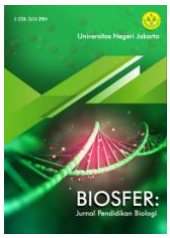

Developing a mobile augmented reality for facilitating socio-scientific issue-based biology learning

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ABSTRACT

This study is research and development using modified design and development research (D&DR) model through three main phases: 1) design; 2) development; and 3) evaluation with the aim of establishing an instructional product for teaching and learning. Augmented reality technology was used to develop a Mobile Augmented Reality of Respiratory System (MARRS) which was proposed for conducting socio-scientific issue-based biology learning on the topic of respiratory system. The MARRS was designed to visualize the context of smoking. More specifically, students were able to observe the structure and function of the respiratory system, simulation of smoking effects on lungs, and lung's disorder affected by smoking. Research findings show that there are three main aspects to be considered as the framework of the MARRS development: (1) the system design; (2) features; and (3) how to incorporate the MARRS into SSI-based biology learning. Once the MARRS was developed, it went through several round of validations by experts, practitioner, and users to evaluate its properness for teaching and learning. According to the validation criteria, the MARRS was categorized as very good in general. It can be concluded that the MARRS is proper to be implemented in teaching and learning of the respiratory system topic.

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INTRODUCTION

One of the main goal of the 2013 curriculum is to prepare Indonesian to have the ability to live as individuals and citizens who are able to contribute to the life of society, nation, state, and world civilization (Permendikbud, 2014). Therefore, learning in schools including biology is expected to be a tool so that students were not only able to master knowledge well, but also be able to apply what they've learned in school to the community and use the community as a learning resource. To support this, biology teachers should be able to plan biology learning which includes the objectives, content, and teaching materials as well as the methods used to support learning activities by considering the context of daily life that is relevant to students. However, in reality, science learning including biology, which has been happening, still tends to separate knowledge and real-life problems (Çimer, 2012; Nida, Rahayu, & Eilks, 2020).

To promote the implementation of the 2013 curriculum, it can be done by creating a learning experience where students are actively involved in the activities of understanding, evaluating, and making decisions related to real problems or issues in life. One of them is by involving them in a current social dilemma related to science to explain the relationship between science and its close relationship with society. Because of the central role of both the science and social dimensions in this dilemma, it is called Socio-scientific Issues (SSI) (Sadler, 2004). In recent years, SSI has become a major highlight in the science education because of its relevance to the ultimate goal of science education in the world including Indonesia, namely science literacy (Sadler & Zeidler, 2005). Therefore, SSI is very important in education to prepare citizen who have knowledge and skills when facing complex social and science-related problems.

SSI is different from other problems in science because it describes a problem that is contentious and ill-structures, which implies that SSI is an open subject to multiple perspectives and has no clear direct solution (Sadler & Donnelly, 2006). SSI often stems from dilemmas involving biotechnology such as genetic engineering, cloning, stem cells, genome projects, and Genetic Modified Foods (GMOs) and environmental issues such as local pollution problems, global climate change, land use, alternative fuels, and the introduction of exotic substances (biotic and abiotic) (Sadler, 2004; Sadler & Donnelly, 2006; Sadler & Zeidler, 2004, 2005). To date, science education researchers have made significant progress in using SSI as a context to make science learning more relevant to the lives of learners. Many studies have been conducted and use more varied SSI topics. For example, health issues related to covid-19 (Subiantoro, Handziko, & Wibowo, 2021), nuclear energy use and radiation pollution (Chang, Wu, & Hsu, 2013), and smoking issues (Bell & Lederman, 2002; Lee, 2007).

It is believed that smoking is one of the leading factor in the development of serious respiratory diseases worldwide, such as lung cancer and chronic obstructive pulmonary disease (COPD) (Lugg, Scott, Parekh, Naidu, & Thickett, 2022). Despite evidence showing that smoking has negative health impacts, approximately six million people worldwide die due to smoking-related diseases each year and about ten percent of them die from second-hand smoke exposure. The World Health Organisation (WHO) estimates that this number will rise to 8,3 million in 2030 (Strzelak, Ratajczak, Adamiec, & Feleszko, 2018). Indonesia as a developing country with the highest cigarette consumption made up of 40,3 percent current smokers (Holipah, Sulistomo, & Maharani, 2020). Based on a 2018 national survey, it was shown that 59,7 percent of current smokers initiates smoking before 19 years old and overall smoking prevalence among 10-18 years was increasing from 7,2 percent in 2013 to 9,1 percent in 2018. It was approximately 20 percent increase and far higher than Indonesian government target to reduce youth smoker into 5,4 percent in 2019 (Kemenkes RI, 2018; Holipah et al., 2020; CISDI, 2021). Other survey data has been reported by Global Youth Tobacco Survey (GYTS) in 2019, it showed much higher smoking prevalence among 13-17 years, which were 19,8 percent (WHO, 2020).

Indonesian government has been taking a role to control Indonesian cigarette consumption by some policies introduced, including defined tobacco products as excise items since 2007, established policies on smoking in open spaces, marketing tobacco products, selling tobacco products (Amalia, Cadogan, Suryo, & Filippidis, 2019; Holipah et al., 2020; Rasyid & Ahsan, 2020). However, evaluation study on these tobacco control policies showed the slow progress of change since the policies are still unclear and provides significant loopholes during stages of implementation (Astuti, Assunta, & Freeman, 2020). It is because smoking is actually also gives positive impacts to the state. Cigarettes contribute on macroeconomic as central government revenues (Rasyid & Ahsan, 2020). Economic costs of cigarettes use are important since it is used by policymakers for planing health services

provisions and other public expenditure (CISDI, 2021). Cigarette companies are also play an important role in the community welfare by providing employment (Rasyid & Ahsan, 2020). Furthermore, smoking is a cultural habit that has been growing since many decades ago in Indonesia. Therefore, an effective cigarettes consumption control requires to address all possibility of health, economic, social, and commerce domains of tobacco itself (Kosen, Thabrany, Kusumawardani, & Martini, 2017).

As a crucial issue related to science and many domains, smoking can be called as socio-scientific issue (SSI). SSI can be used as valuable context for teaching and learning science content. By using SSI as a learning platform can make science learning more relevant to students' lives, thus the learning process become more meaningful (Sadler, Barab, & Scott 2007). Moreover, many studies found that engaging students in SSI learning can improve their learning of science. Research done by Chang et al. (2013) indicated that SSI can enhance students' science knowledge. Besides science knowledge, research has investigated the potential of SSI learning in informal reasoning (Sadler & Zeidler, 2005), decision-making (Lee, 2007; Gutierez, 2015), socio-scientific reasoning (SSR) (Sadler, Klosterman, & Topcu, 2011; Chang, Hsu, Wu, & Tsai, 2018), reflective judgement (Subiantoro, Ariyanti, & Sulistyo, 2013), critical thinking (Pratiwi, Rahayu, & Fajaroh, 2016), scientific literacy (Arizen & Suhartini, 2020) and argumentation (Martini, Widodo, Qosyim, Mahdiannur, & Jatmiko, 2021). Therefore, how to design effective learning environments that facilitate students learning of SSI has become a main concern for research on SSI (Chang et al., 2018).

The advent of innovative technology today makes it possible for designers of learning environment to choose the best technology and bring it into the classroom to facilitate learning. Technology integration into classroom activity enables learning process to be more active, motivating, and meaningful for students. PowerPoint as one of the technology that commonly used in the classroom is still considered to be less effective since the students usually remain passive in the learning process (Singhal, Bagga, Goyal, & Saxena, 2012). According to O'Connor & Donovan (2018), passive learning implies that students only sit in the classroom without much engagement to the learning process, listen to lectures, take notes, and memorize it for the exam. In other words, students are passively consume information. Furthermore, PowerPoint is a simplification software, though simplification is important for learning, oversimplification can discourage and even derail critical thinking (Hill, Arford, Lubitow, & Smollin, 2012). Pictures, graphs, graphics addition to the slides may only overcrowd the information while present them in difference slide may prevent students from creating connections between slides. Consequently, an alternative technology is required to improve learning.

A promising technology to overcome that problem could be Augmented Reality (AR). AR is the fastest growing modern technology that allows user to interact with a combination of real and virtual worlds in real time (Azuma, 1997). This unique ability facilitates the development of process skills such as critical thinking, problem solving, and communicating utilized through interdependent collaborative exercises (Dunleavy, Dede, & Mitchell, 2008). AR also has the potential to enhance the learning experiences by transforming the learning environment into an attractive, interesting, and fun learning environment (Kiryakova, Angelova, & Yordanova, 2018). To support that, the designer of AR learning environments usually involves an AR system which not only provide the objects visualization feature but also other useful features. Feature modifications make it possible for the AR designer to improve the system and accomodate the learning needs. For example, GPS location and digital compass features for accomodating outdoor learning (Chiang, Yang, & Hwang, 2014).

As today, many studies have conducted to examine AR potential in many topics (Kalana, Junaini, & Fauzi, 2020), but relatively little has been done regarding how to incorporate this technology to an instructional design of learning. It always be a debate regarding whether it is the technology or the instructional method that matter to maximize the learning process (Bronack, 2011; Wu, Lee, Chang, & Liang, 2013; Chang, Hsu, & Wu, 2014). Furthermore, it is not the technology that is important for educational researchers (Bronack, 2011), but when and how innovative technology promotes the learning process by considering the interplay among technology design, instructional method, and learning context (Chang et al., 2014). More effective and efficient use of technology in learning settings can yield more benefit from its potential.

In the study by Aydin (2019), a survey was conducted to probe how pre-service science teachers integrate mobile AR into worksheets based on teaching strategies, namely expository, inductive, and inquiry strategies. Overall, it can be considered that technology does not contribute to learning, while

its integration is more important. Integrating mobile AR into expository or inductive strategy could reduce its potential in learning. Moreover, many studies have been conducted and concluded that a combination of AR and inquiry-based strategy is more powerful to promote learning. Some studies are from Chang et al. (2013), Chiang et al. (2014), Kamarainen, Metcalf, Grotzer, & Dede (2016), Chang, Chung, & Huang (2016), Ahmed, Umer, Nasir, Khan, & Ali (2017), Rezende, Albuquerque, & Ambrosio (2017), and Chang et al. (2018).

Smoking issue as described in the beginning can be used as learning context to conduct SSI instruction and it is relevant to high school biology curriculum on the topic of respiratory system. Respiratory system is the eleventh grade biology learning curriculum's topic that considered as difficult by students (Pahlifi & Fatharani, 2019; Myanda & Riezky, 2020). This indicates that students' knowledge about the topic is still low. One of the reason is because respiratory system involves complex mechanisms within the body that cannot observed directly by the students. Therefore, the common activity in the classroom is merely memorizing and reciting the concepts rather than learn them meaningfully. There is a necessity for making the respiratory system topic more contemporary, meaningful, and interesting for the students and relating it with daily life issues. Moreover, respiratory system topic must be supported by qualified instructional materials that provide rich visualization and actively engage students in the learning process.

Involving learners in SSI learning will not only isolate them on issues, but will also develop their knowledge and skills regarding science products and processes related to issues. In learning SSI-based respiration system materials, for example, students will engage in activities to understand the content or material of the respiration system that is relevant to the issue, process information (reasoning) regarding the issue, conduct moral and ethical considerations on the issue, create social debates or controversies by adopting positions on the issue, and make the best decision based on the issue (Sadler, Chambers, & Zeidler, 2004; Sadler & Zeidler, 2005). Good decisions on the issues raised must be constructed through considerations from various aspects, including moral, political, social, and economic through a process of reasoning (Sadler et al., 2007). The development of reasoning skills is one of the important learning outcomes in SSI and is included in the construction of higher-level thinking, including Socio-scientific Reasoning (SSR).

In this study, an innovative design of instructional materials is proposed to support inquiry-based activities by developing a Mobile Augmented Reality of Respiratory System (MARRS). We used AR technology to help students to experience inquiry process within the biology classroom on the topic of respiratory system. Smoking issue as an example of socio-scientific context was introduced to conduct SSI instruction, thus the issue visualization was also provided within the MARRS. The MARRS features were designed to focus on two outcome variables, which are conceptual knowledge and socio-scientific reasoning (SSR) as the important outcome in learning SSI. More spesifically, the research questions that will address the study are presented bellow.

1. How is the framework of the Mobile Augmented Reality of Respiratory System (MARRS) development?
2. Is the Mobile Augmented Reality of Respiratory System (MARRS) valid and practical?

METHODS

Research Design

This study is research and development using design and development research (D&DR) model through three main phases: 1) design; 2) development; and 3) evaluation with the aim of establishing an instructional product for teaching and learning (Richey & Klein, 2007). The instructional product was developed to support eleventh graders students of senior high school in terms of promoting their conceptual knowledge and SSR.

This study used the respiratory system topic which is included in biology curriculum for eleventh graders of senior high school. Referring to the Ministry of Education and Culture Regulation number 37 of 2018, the basic competencies that students should internalize from the topic of respiratory system are state in number 3.8 which is analysing the relationship between the structure of tissues that build the respiratory system organ in relation to the bioprocess and functional disorders that might occur within the human respiratory system. In pair with number 4.8 which is presenting the analysis results about the effect of air pollution on the abnormalities of respiratory system organs' structure and function based on the literature review (Permendikbud, 2018).

The MARRS was designed to visualize the context of smoking as an example of SSI which relevant to the topic of respiratory system. Engaging students in SSI instruction will not isolate students on the focused issue only, but they will also involve in activities that promote their knowledge about science's products and processes related to the issue. Consequently, the MARRS was also designed to support students to understand the scientific background about respiratory system. More specifically, students were able to observe the structure and function of the respiratory system, simulation of smoking effects on lungs, and lung's disorder affected by smoking. This will help students to acquire the basic competency number 3.8. Furthermore, according to Cao, Chen, Dong, Xie, & Liu (2020), tobacco particles within the smoke are the example of air pollutants that harm the human body that mainly reflected in respiratory system. This relevant with the basic competency number 4.8. In overall, the MARRS is relevant to academic discipline under the biology curriculum of Indonesia.

Population and Samples

Two experts, a practitioner (teacher), and twenty six of high school students were invited to review the MARRS in this study. The experts were divided into content expert and media expert. As the two experts were lectures from one of prestigious public university in Yogyakarta, Indonesia and had received the doctor degree, they were suitable for assessing the validity of MARRS regarding the aspects of content and media. The teacher invited in this study is from public high school in Sleman city, Yogyakarta, Indonesia and has worked for more that 20 years as a biology teacher thus, he was suitable for assessing the MARRS regarding the practicality in the formal classes. After validated by experts and practitioner, MARRS was reviewed by students from the same high school with the teacher in the limited trials.

Instrument

The data collection was using assessment questionnaires including content, media, practitioner, and students assessments. Content assessment questionnaire consists of 19 indicators about content feasibility and accuracy, content presentation, the relevance between fact and concept, and language aspects. Media assessment questionnaire consists of 21 indicators about software engineering, ease of use, media presentation, and interactivity aspects. Practitioner assessment questionnaire consists of 24 indicators about content, language, media, dan learning aspects. Students assessment questionnaire consists of 25 indicators about content presentation, MARRS display, features, MARRS operation, and benefit for learning aspects. All the assessment questionnaires were developed by using Likert scale of 1-5 (very good-very poor).

Procedure

During the design, need analysis was conducted on a practical problem—science teaching is still oriented toward content structure of the related academic disciplines. Furthermore, the pandemic of COVID-19 has significantly limited the process of teaching and learning and worsen the learning system. With the support of literature, findings pointed to the development of mobile application with AR technology as an alternative instructional material that engages students in SSI contextual learning with the ability to support the distance learning called Mobile Augmented Reality of Respiratory System (MARRS). Design decisions then made based on some consideration including SSI's learning phase and learning outcomes to be focused in this study. The development is proposed to produce MARRS that was valid, practical and effective. Finally, formative and summative evaluation was conducted. Formative evaluation occurred throughout the design and development of MARRS, while summative evaluation is conducted to investigate the impact of MARRS on learning including implementation and students assessment. These phases are summarized from Richey & Klein (2013). This paper will report the development process until the formative evaluation in the form of product validation and limited trial. The validation and limited trial was used to ensure the validity and practicality of the MARRS in relevant with the learning objectives and outcome variables to be focused: conceptual knowledge and socio-scientific reasoning (SSR) as the important outcomes in learning SSI.

Data Analysis Techniques

The qualitative data in the form of comments and suggestions were used to perform revision to the MARRS. While the score under the following scale: 1 = very poor; 2 = poor; 3 = moderate; 4 = good, and 5 = very good were then overally calculated to determine its category according to the criteria Table 1.

Tabel 1

MARRS Assessment Criteria.

No.	Score Range	Category
1.	$\bar{M}\text{i} + 1{,}5\ SD_i < \bar{X}$	Very Good
2.	$\bar{M}\text{i} + 0{,}5\ SD_i < \bar{X} \leq \bar{M}\text{i} + 1{,}5\ SD_i$	Good
3.	$\bar{M}\text{i} - 0{,}5\ SD_i < \bar{X} \leq \bar{M}\text{i} + 0{,}5\ SD_i$	Moderate
4.	$\bar{M}\text{i} - 1{,}5\ SD_i < \bar{X} \leq \bar{M}\text{i} - 0{,}5\ SD_i$	Poor
5.	$\bar{X} \leq \bar{M}\text{i} - 1{,}5\ SD_i$	Very Poor

(Sudijono, 2009)

Notes:
$\bar{X}$ = mean score
$\bar{M}$i = ideal mean score
SD_i = ideal standard deviation
$\bar{M}\text{i} = \frac{1}{21}$(highest score + lowest score)
$SD_i = \frac{21}{}$ (highest score – lowest score)

RESULTS AND DISCUSSION

Recently, how to design effective learning environments that facilitate students learning of SSI has become a main concern for research on SSI (Chang et al., 2018). And as of various current technological resources for education are available today, AR offer a promising potential to promote the SSI learning. The AR integration into SSI instruction in science education has not been done much. Therefore, the AR development needs an insightful consideration about its conceptual framework on the design, features, and how to incorporate it into SSI-based learning. The results are discussed in this section.

In this study, we aimed to develop a MARRS intended to support students engagement in SSI instruction within the topic of respiratory system by using the issue of smoking. To this end, several hardware and software were used to develop the MARRS. Softwares such as Blender 3D, Substance 3D painter, CorelDraw, Unity, and EasyAR were used to develop the system with the help of PC and android smartphone. We incorporated 3D models and animations to represent 2D respiratory system structure for facilitating SSI-based biology learning. The newly developed MARRS was then evaluated to ensure its validity and practicality. The framework of the MARRS development and the results of the evaluation are presented in this section.

The use of AR technology especially for education become more accessible as it no longer requires high-end electronics and sophisticated equipments. For instance, mobile devices open new opportunities for AR. According to Akçayır & Akçayır (2017), mobile devices are the most preffered AR technology used in education since they offer an ideal platform for AR application. Considering the advantages of mobile devices as they are very cost-effective, easy to use, support the portability, and encourage high interactivity (Akçayır & Akçayır, 2017), we decided to develop AR system using mobile devices as the delivery technology in the name of MARRS. We used the affordances of the mobile devices to situate students' understanding of respiratory system topic using the SSI context of smoking.

Visulizing the respiratory system structures in 3D instead of 2D is on the top of our currently planned stages. This will help students imagine the concepts in a more effective way (Marzouk, Attia, & Abdelbaki, 2013). There are two major types of image-based AR including marker-based AR and markerless AR. MARRS was designed by using a markerless AR system. Although marker-based AR system was mostly preferred in the educational AR studies (Sirakaya & Sirakaya, 2018), markerless AR is more benefits than marker-based AR (Abdineja, Ferrag, Qorbani, & Dalili, 2021). Since the virtual objects do not need to be anchored to any marker in the real world, this eliminates the user to print any distinctive shape, picture, or barcode (markers) to view the AR objects which can minimize the technical problems experienced about perceiving the marker.

The MARRS was developed in the form of android-based smartphone software as the preliminary survey revealed that most of students (>90%) use android smartphone. The centerpiece of the MARRS development was focused to provide opportunities for high school students to improve their conceptual knowledge and SSR related to the smoking issue as explained in the methods. Thus, these two outcome variables were also taken into consideration of the MARRS development. Figure 1 shows the final structure of the MARRS app. which consists of learning objectives, guidance, AR camera, students' worksheet, quiz, and glosarium menu.

Figure 1. The Structure of The MARRS App.

Within the MARRS, students will be guided by worksheet that can be downloaded directly from the app. This worksheet was designed based on SSI instruction phases. In this study, SSI instruction was conducted through six phases: 1) issue orientation and analysis; 2) clarifying the biology background of the issue; 3) resuming the socio-scientific dimension; 4) discussing and evaluating different points of view through role-playing activity; 5) reflection, and 6) evaluation (Feierabend & Eilks, 2010; Subiantoro et al., 2021). The six phases were split into two learning sessions/activities in the worksheet: "Activity 1: Structure and Function of The Respiratory System" and "Activity 2: The Impact of Air Pollutant (cigarette smoke) towards The Respiratory System". The first session includes two initial phases of SSI instruction in which students learned the essential biological background related to the issue. When the necessary foundational knowledge is mastered, the second session began. It incorporates the third and fourth phase of SSI instruction and aimed to teach students about both the societal dimension of debates and the inherent interplay between science and society. Figure 2 provides a snapshots of the students' worksheet.

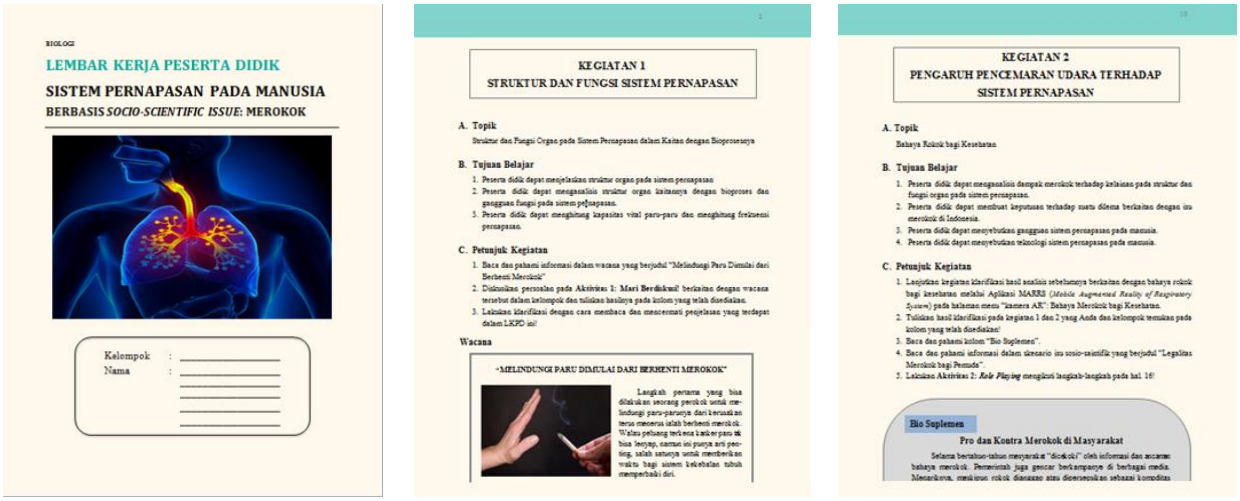
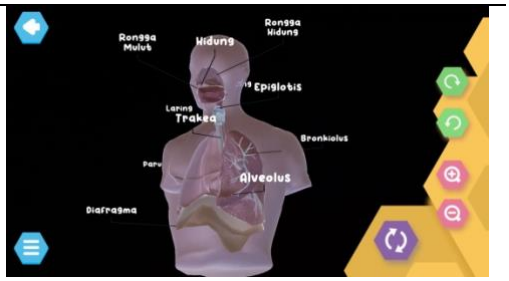
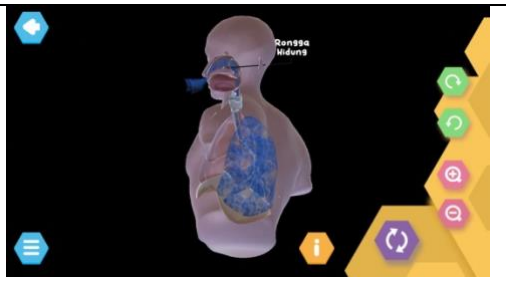
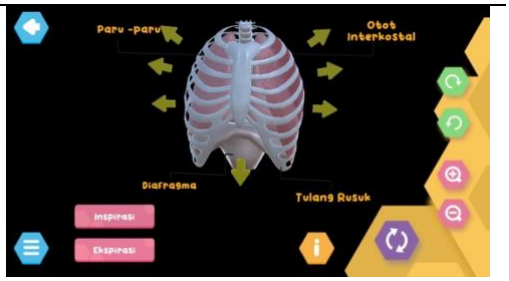
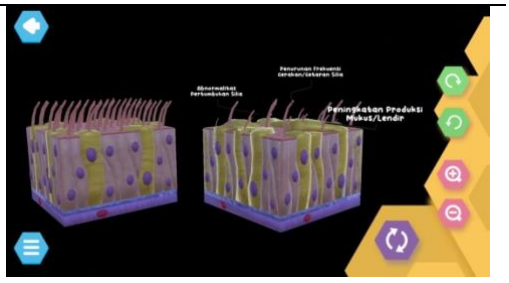


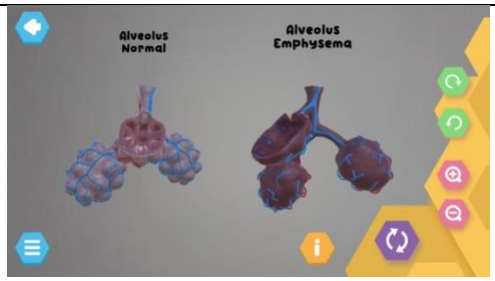
Figure 2. Snapshots of Students' Worksheet Activities

Before the learning sessions started, students were divided into six study groups where they need to collaborate to finish the sessions. In the "Activity 1: Structure and Function of The Respiratory System", students were introduced to the smoking issue with an article titled 'Protecting the Lungs by Quitting Smoking', this article was selected to provoke a preliminary discussion and identify the

students' level of knowledge about smoking and the potential consequences in relationship with structure and function of the respiratory system (Feierabend & Eilks, 2010). After that, students were asked to clarify their knowledge about scientific background related to the issue by exploring 3D objects with the AR camera. Table 2 shows the 3D objects for clarifying task.

Table 2
3D Objects for Clarifying Task.

3D Object	Objective	Scene
Structure and function of respiratory system	Visualize the structure and function of respiratory system by 3D models.	
Breathing air pathway	Visualize the breathing air pathway through the respiratory tract by ani-mation showing the movement of the air.	
Mechanism of inspirati-on and expiration	Visualize the mechanism of inspi-ration and expiration by animation showing the movement of lungs, ribs, external intecostasl muscles, and diaphragm.	
Cigarette smoke in the respiratory system	Visualize the lungs of smoker by animation showing the movement of cigarette smoke through the respi-ratory tract and the change in lungs color.	
Cigarette smoke effect on respiratory epitheli-um	Visualize cigarette smoke effect on respiratory epithelium by animation showing the difference between the normal and abnormal epithelium.	

Cigarette smoke effect on alveolus	Visualize cigarette smoke effect on alveolus by 3D models showing the difference between the normal and abnormal alveolus.	

In the AR camera, the 3D objects in Table 2 were split into two parts including structure and function of respiratory system and the harm of smoking for respiratory health which relevant to the students' worksheet. Structure and function of human respiratory system will show the visualization of structure and function, breathing air pathway, and mechanism of inspiration and expiration. While the harm of smoking will show the visualization of cigarette smoke in the respiratory system, it's effect on respiratory epithelium and alveolus. The clarification task in activity 1 is about the first part while the second part will be done in the beginning of activity 2. This divison is made regarding the learning time limitation since all the objects clarification task will not finish at one time of meeting. Figure 3 shows the sequence of the clarification task with the AR camera.

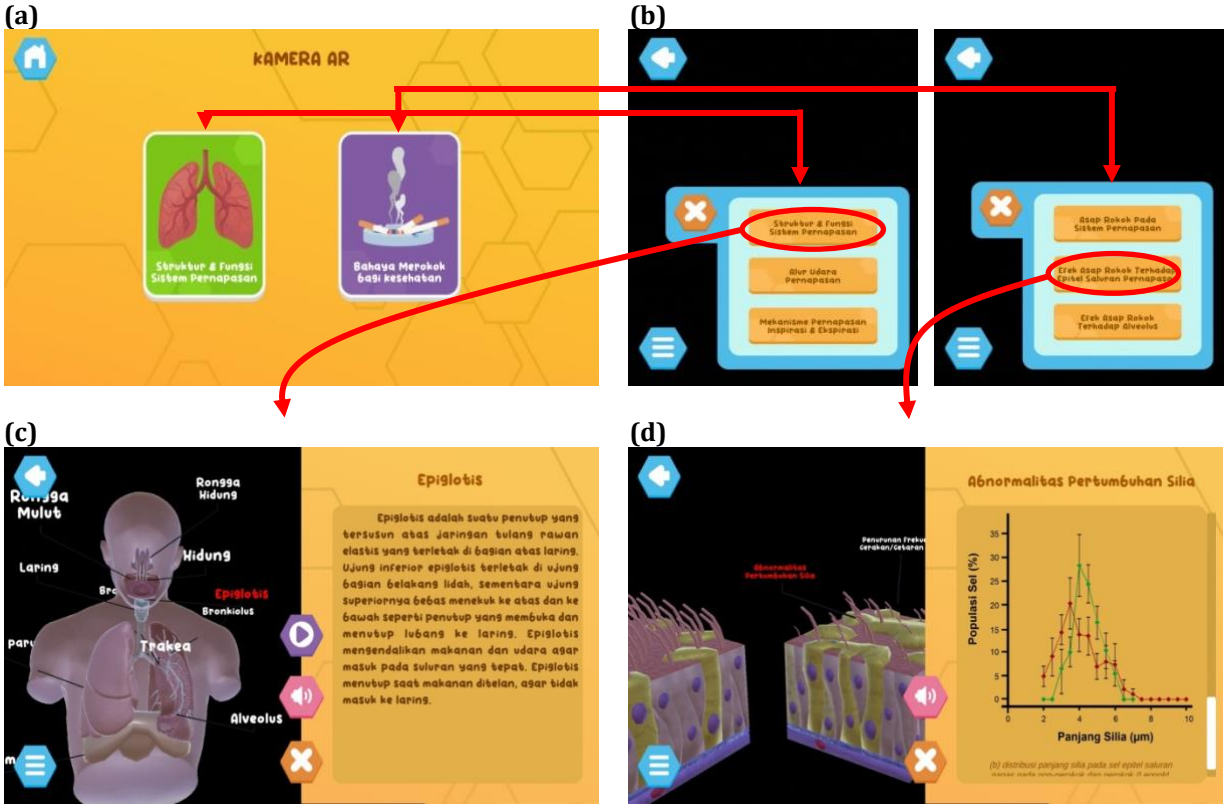


Figure 3. The Sequence of the Clarification Task with AR Camera

Navigation interface within the AR camera enables students to interact with simulated respiratory system objects in a 3D space. The interaction enables students to examine the respiratory system structures from different angles, view points, and magnification levels which can support their understanding of the relationship of each organ to its surrounding structures in a concrete way. This type of interaction can't be obtained through learning with static 2D images. Figure 4 shows the details of AR camera navigation interface. Moreover, each part the respiratory structures is clearly labeled. All the labels were designed to be interactive too, allowing students to touch the label for the explanations. When students touch the stucture label, the label color will change from white to red and show a pop up box with explanation about the related structure. The explanation can be learned in two ways, by reading text or listening to audio narrations. Play button was also added to connect students with Youtube (see Figure 3c). Figure 4 shows the details of AR camera navigation interface.

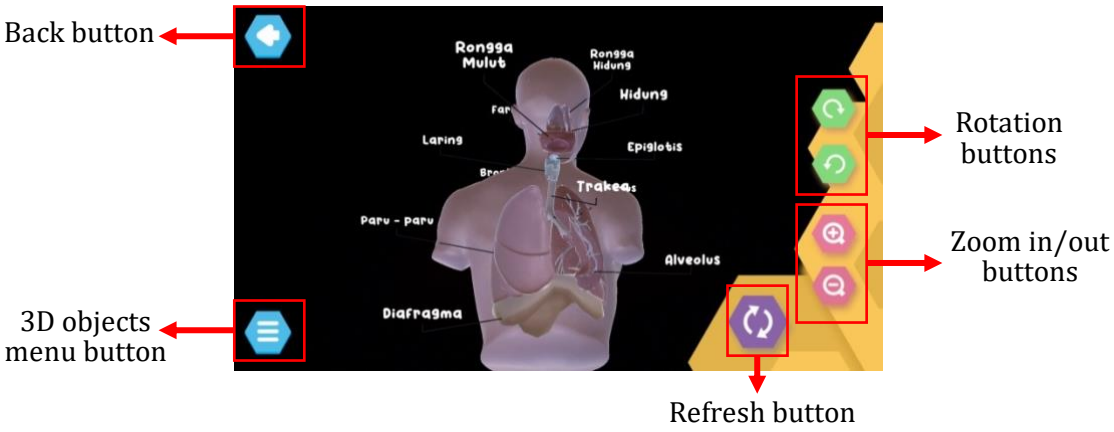


Figure 4. The Details of AR Camera Navigation Interface

The AR camera within MARRS not only provides static 3D objects but also 3D animations to enhance students knowledge. For example, the visualization of inspiration and expiration mechanism. The moving 3D models of the lungs with its surrounding structures including ribs, external intecostasl muscles, and diaphragm is used. The interactive button of insipration and expiration can be touched to stop the process and the hidden lables of the structures will appear in complemented with arrows showing what would happen if the inspiration or expiration occurs. In addition, the information button was used to provide the explanation. Figure 5 shows the 3D animation of inspiration and expiration mechanism.

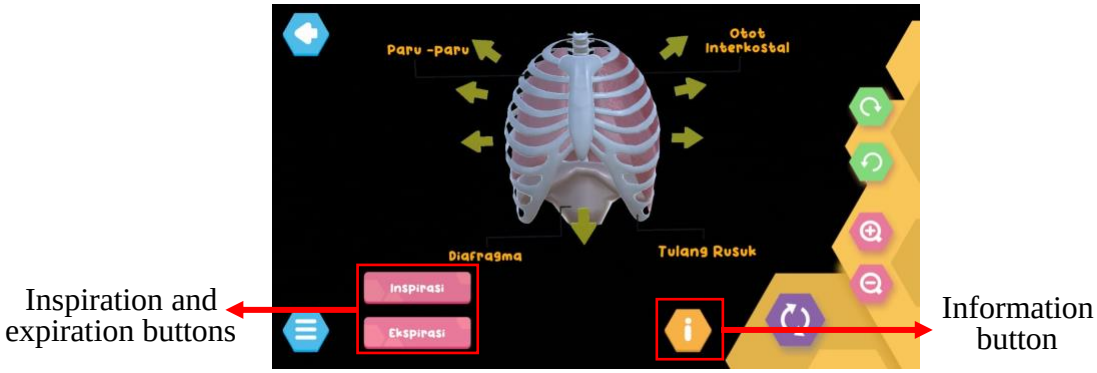
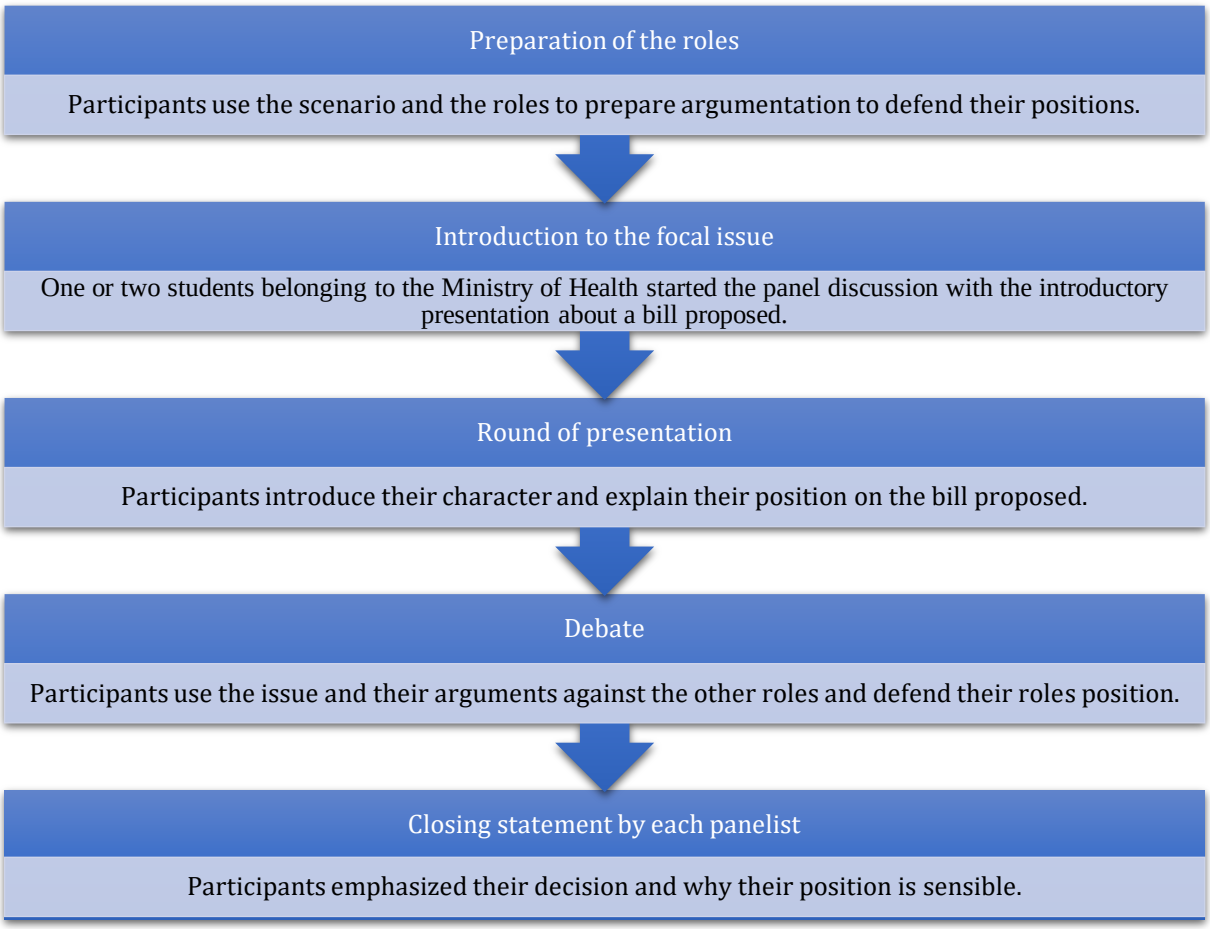


Figure 5. The 3D Animation of Inspiration and Expiration Mechanism

Overall, the learning experiences with the AR camera was specifically designed to support anatomical learning as the 3D models, animation, and videos are examples of multimedia that are often used to visualize anatomical structures (Hegarty, 2004; Nicholson, Chalk, Funnell, & Daniel, 2006; Küçük, Kapakin, & Yüksel, 2016). The navigation interface and all the interactive buttons was added with consideration to help students in performing inquiry-based learning more easily and increase their understanding about the scientific background of the issue. The pop up explanation text is mostly sourced from anatomy and physiology of human respiratory system books considering both the breadth and depth of content in adaptation to the high school biology curriculum. Some addition information in the form of diagram, chart, and table regarding the conflicting research results about smoking issue from some publications also presented in MARRS (see Figure 3d). This may promote students' interest in the learning process. The addition of these information is also made with consideration to develop their reasoning as a foundation for the next learning activity.

Furthermore, engaging students in SSI instruction is not only involves understanding the content knowledge behind the issue, negotiating in SSI requires students to adopt a position on the issue (Sadler et al., 2004). This entails students participation in dialogue, discussion, and debate (Parvathy, Mclain, Bijlani, Jayakrishnan, & Bhavani, 2016). Hence, reasoning skill is one of important outcome in learning SSI. In this study, we also focus on the develoment of MARRS to support Socio-scientific Reasoning (SSR). SSR is a theoretical construct associated with negotiation of SSI. This construct is important for decision-making in the context of SSI. The most significant practices are: 1)

recognising the inherent *complexity* of SSI; 2) examining issues from multiple *perspectives*; 3) appreciating that SSI are subject to ongoing *inquiry*; and 4) Exhibiting *skepticism* when presented potentially biased information (Sadler et al., 2007). To support all of these practices, the MARRS was also designed to provide a socio-scientific debate for the issue. This facilitates by the second session of the worksheet. The "Activity 2: The Impact of Air Pollutant (cigarette smoke) towards The Respiratory System" resumes the socio-scientific debate where students were asked to mimic societal or political decision-making (Feierabend & Eilks, 2010), this study used role-playing in the form of panel discussion which adopted and modified from Agell et al., (2015) and Sagmeister & Kapelari (2021). Figure 6 shows the stages of the role-based panel discussion.



Adopted and modified from Agell, Soria, Soria, & Carrio (2015) and Sagmeister & Kapelari (2021)

Figure 6. Stages of the Role-based Panel Discussion

Study groups were divided into six expert roles based on various potential stakeholders in society including minister of health, scientist, tobacco industry representative, minister of finance, tobacco farmer representative, and hawker representative that participated in the role-based panel discussion. The provocative scenario in this case is a bill proposing to completely ban smoking for someone aged 24 and under. It means that someone currently aged 24 and under will never be able to legally purchase, possess, and smoke cigarettes. The scenario is a fictitious constitutional act that deliberately created to enhance motivation. A similar act was done by Feierabend & Eilks (2010) in their research. Some basic scientific knowledge students gained from the first session will allow students to better understand the debate (Feierabend & Eilks, 2010).

After the MARRS has been developed, two experts, a practitioner (teacher), and twenty six of high school students are invited to review the product to ensure it's validity and practicality. The two experts involved including content expert and media expert. The content assessment was reviewed based on four aspects including content feasibility and accuracy, content presentation, the relevance between fact and concept, and language. Table 3 shows the result.

Tabel 3
Assessment Result by Content Expert.

Assessment Aspects	Score	Criteria
Content feasibility and accuracy	4.20	Very good
Content presentation	4.20	Very good
The relevance between fact and concept	4.50	Very good
Language	4.20	Very good
Average	**4.30**	**Very good**

The result shows that the content within MARRS is relevant to the high school biology curriculum competencies, presented clearly, provide a relevant fact of smoking issue to the concepts of respiratory system, and use communicative language that relevant to students age. Based on Table 3, the final average score of the four aspects according to content expert assessment is 4.3 and categorized as very good according to the criteria used (see methods). It can be concluded that the content within the MARRS is valid to be used as instructional materials for learning biology in the classroom. However, there are some suggestions from the content expert, so revision is needed. The suggestions are correcting some misstyping, adding some terms and correcting some terms' definition, and updating the references used to a maximum of the last 10 years. The media assessment was reviewed based on four aspects including software engineering, ease of use, media presentation, and interactivity Table 4.

Tabel 4
Assessment Result by Media Expert.

Assessment Aspects	Score	Criteria
Software engineering	5.00	Very good
Ease of use	4.40	Very good
Media presentation	4.70	Very good
Interactivity	4.60	Very good
Average	**4.70**	**Very good**

In terms of media, the MARRS software is compatible for android operating system and can be operated well. The software is easy to use and flexible to be used anytime and anywhere. The AR technology incorporated within MARRS can visualize difficult respiratory system concepts in a more real way. The user interface is very good and supported by interactive navigation to explore the objects. Based on Table 4, the final average score of the four aspects according to media expert assessment is 4.7 and categorized as very good according to the criteria used (see methods). It can be concluded that the MARRS is valid to be used as instructional materials for learning biology in terms of media. However, there is suggestion from the media expert to add 3D object that visualize airways during the breathing process. In the final product, the object has been added (see Table 2). Assessment by teacher as practitioner consisted of four aspects including content, language, media, dan learning. Table 5.

Tabel 5
Assessment Result by Practitioner

Assessment Aspects	Score	Criteria
Content	4.43	Very good
Language	5.00	Very good
Media	4.13	Very good
Learning	4.33	Very good
Average	**4.70**	**Very good**

According to the teacher, the MARRS as instructional materials is relevant to the high school biology curriculum competencies, communicative language that relevant to students age, easy to use and flexible to be used anytime and anywhere. Based on Table 5, the final average score of the four aspects according to practitioner assessment is 4.70 and categorized as very good according to the criteria used (see methods). It can be concluded that the MARRS is valid and practical to be used as

instructional materials for learning biology. However, there is suggestion from the teacher to change the text color to be more contrast to the background.

The MARRS that has been validated by experts was then reviewed by students in the limited trial. Assessment by students as users consisted of five aspects including content presentation, MARRS display, features, MARRS operation, and benefit for learning. Table 6.

Tabel 6
Assessment Result by Students.

Assessment Aspects	Score	Criteria
Content presentation	3.84	Good
MARRS display	4.06	Very good
Features	3.89	Good
MARRS operation	3.94	Good
Benefit for learning	3.77	Good
Average	**3.90**	**Good**

According to the students, content within the MARRS is presented clearly and make them easier to learn respiratory system topic. The MARRS display is interesting since the color coordination is very good. All the features provided within MARRS are supporting them to learn respiratory system topic. The application is easy to download and easy to use. Moreover, they fell that MARRS benefit them in terms of helping them to learn easier, making them more interested in learning, supporting active learning, facilitating learning anytime and anywhere, and acquiring more knowledge about respiratory system topic. Based on Table 6, the final average score of the four aspects according to content expert assessment is 3,9 and categorized as good according to the criteria used (see methods). It can be concluded that the MARRS is practical to be used as instructional materials for learning biology in the classroom.

Based on all the assessment results, it can be concluded that MARRS is valid and practical as instructional materials for facilitating SSI-based biology learning on the topic of respiratory system to promote students' conceptual knowledge and SSR.

CONCLUSION

According to the findings, there are three main aspects to be considered as the framework of MARRS development including the system design, features, and how to incorporate the MARRS into SSI-based learning. In consideration of these aspects, the MARRS has been successfully developed. Overall assessment results showed that MARRS is valid and practical as instructional materials for facilitating SSI-based biology learning on the topic of respiratory system to promote students' conceptual knowledge and SSR.

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