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Android-Based Digital Book Oriented to Multiple Chemical Representations on Terpenoid Learning Materials

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Abstract

This research aims to describe and analyze the application results of the developed digital book oriented to multiple chemical representations. The method employed in this research was the Design-Based Research (DBR) method with the ADDIE development model. The ADDIE development Model consisted of five stages to analyze, design, and develop a product. These stages covered the analysis of terpenoid material, the analysis of multiple representations of terpenoid material, and digital book design and development. The instrument used was a validation test questionnaire filled out by three validators. The result of this research is an Android-based digital book oriented to chemistry's multiple representations. The obtained $r_{observed}$ value was 0.83. Therefore, the developed digital book was declared valid and can be used as teaching material in the Natural Product Chemistry course.

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INTRODUCTION

The rapid digitalization of the 21st-century affects various aspects of life, including education. This influence is due to Information and Communication Technology (ICT) (Sari, 2018). Therefore, it is necessary to adjust the quality of education, especially the learning process (Anih, 2016). ICT can make the learning process enjoyable, influence the learning outcomes, and motivate the students (Yektyastuti & Ikhsan, 2016).

Learning with ICT can help students acquire 21st-century skills (Jumila, dkk., 2018). The use and utilization of ICT in the chemistry learning process can improve learning outcomes and students' learning outcomes (Chalimawati & Sartika, 2019). Also, ICT in chemistry learning can increase students' learning motivation (Alamsyah, 2017). because the chemistry material contains various types of concepts, one of which is abstract concepts. The teacher must make chemistry learning easy, fun, and enjoyable through ICT (Albeta, dkk., 2020).

Abstract concepts require the use of multiple levels of representation, namely macroscopic, submicroscopic, and symbolic level representations. The three levels of expression can help describe abstract concepts and help students understand concepts. However, students often misunderstand the concepts (Sari, dkk., 2018). In chemistry learning, these three levels of representation have not been appropriately implemented. Teachers usually use symbolic representation by skipping the macroscopic representation (Widyasari, dkk., 2018). It causes students to experience difficulties and even lead to misconceptions (Setiawan, dkk., 2016). Students' chemistry understanding is shown by their abilities to interconnect multiple representations. This interconnection ability occurs when students transfer and connect the three expression levels (Nilawati, dkk., 2016).

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Chemistry is often considered difficult to learn, especially in the concept of organic chemistry (O'Dwyer & Childs, 2017). It requires activities or media (Akkuzu & Uyulgan, 2016). One of the branches of organic chemistry is Natural Material Chemistry (NMC). One of the concepts in NMC is terpenoids. Students must determine the structure, biosynthetic pathways, reactions, and uses (Nugroho, 2017). The material can be represented in multiple chemical representations. However, NMC learning resources are still limited, either from journals or textbooks. Therefore, to understand the concept of terpenoids, students need teaching materials.

Based on a preliminary study on the sixth-semester undergraduate students of the Chemistry Education Study Program of UIN Sunan Gunung Djati Bandung in the academic year of 2019/2020, the researchers found several obstacles in the learning process. One of the problems was the availability of teaching materials and learning media. Multiple chemical representations have not accompanied the available teaching materials because the terpenoid concept is an abstract concept with concrete examples that have the characteristics of multiple chemical representations. In addition, the students often experienced difficulties in several terpenoid sub-material, such as structure determination and biosynthesis. Therefore, to overcome these problems, the students needed teaching materials to help them understand the concept of terpenoids.

The learning process within formal or non-formal schools cannot be separated from teaching materials to obtain the studied learning materials(Suyasa, dkk., 2018)(Suyasa et al., 2018). Books as teaching materials serve as multifunctional references that provide in-depth conceptual explanations to students (Day & Pienta, 2019). Teaching materials can make learning more meaningful and provide better learning outcomes (Lubis & Ikhsan, 2015).

The development of mobile learning eases the students to access learning materials and helps the learning process (Khumaidi & Sucahyo, 2018). Another advantage of mobile learning is that it can be used to replace textbooks into digital form or be called a mobile digital book (Saputra, dkk., 2018). Furthermore, the Android operating system on smartphones is increasingly popular because there are useful applications (Supeno, dkk., 2018). Therefore, the Android smartphone needs to be used as a learning medium because it has great potential in supporting the learning process (Perdana, dkk., 2019).

One of the teaching materials used in the learning process is a digital book or electronic book (Sargeant, 2015). Digital books can be used as a flexible learning resource that can be accessed independently or classically (Mawarni & Muhtadi, 2017). Digital books can convey various information in text, sound, images, animation, and video (Yayuk, dkk., 2017). Digital books allow students to explore digital books better (Dewi, 2015). Android-based digital books are needed to facilitate students because they are designed effectively and practically (Saputra, dkk., 2018).

A previous study has developed a digital book on chemical representations on equilibrium and acid-based materials which resulted in good results and met all three levels of chemical representation (Wijayanti dkk., 2015 ; Nur'aini dkk., 2015). However, there were constraints because the data was processed using a computer device that cannot be combined with the digital book's operating program. Other research on the development of digital books has been carried out on acid-base titration materials using the E-PUB program (Priyatni, dkk., 2020). However, the digital book was not yet oriented towards multiple chemical representations. Students need teaching materials oriented to multiple chemical representations to help them understand concepts (Setiawan dkk., 2016).

An android-based digital book oriented to multiple chemical representations on terpenoid material contains pictures, animations, and videos. The digital book is contained in an Android device to be accessed independently by students anytime and anywhere. It also contains evaluation questions with direct feedback (Perdana dkk., 2019). This research aims to describe and analyze the results of the validation test of the developed digital book oriented to multiple chemical representations on terpenoid materials.

Learning modules have been used on learning the isolation material of Jatropha Tintir's bark extract (*J. multifida L*) (Jumika, dkk., 2018). The chemistry supplement books have been developed using the concept of local content (Isti'anah, dkk., 2018). The chemistry supplement books have been developed using the concept of local content.

METHOD

The research method used in this research is the Design-Based Research (DBR) which aims to increase the impact, transfer and translate educational research, build theory and develop principles in the educational context (Penuel, 2019) using the ADDIE development model. The ADDIE development model consists of analysis, design, development, implementation, and evaluation (Alnajdi, 2018). However, this research only applied the stages up to the development stage. The stages of research can be seen in figure 1.

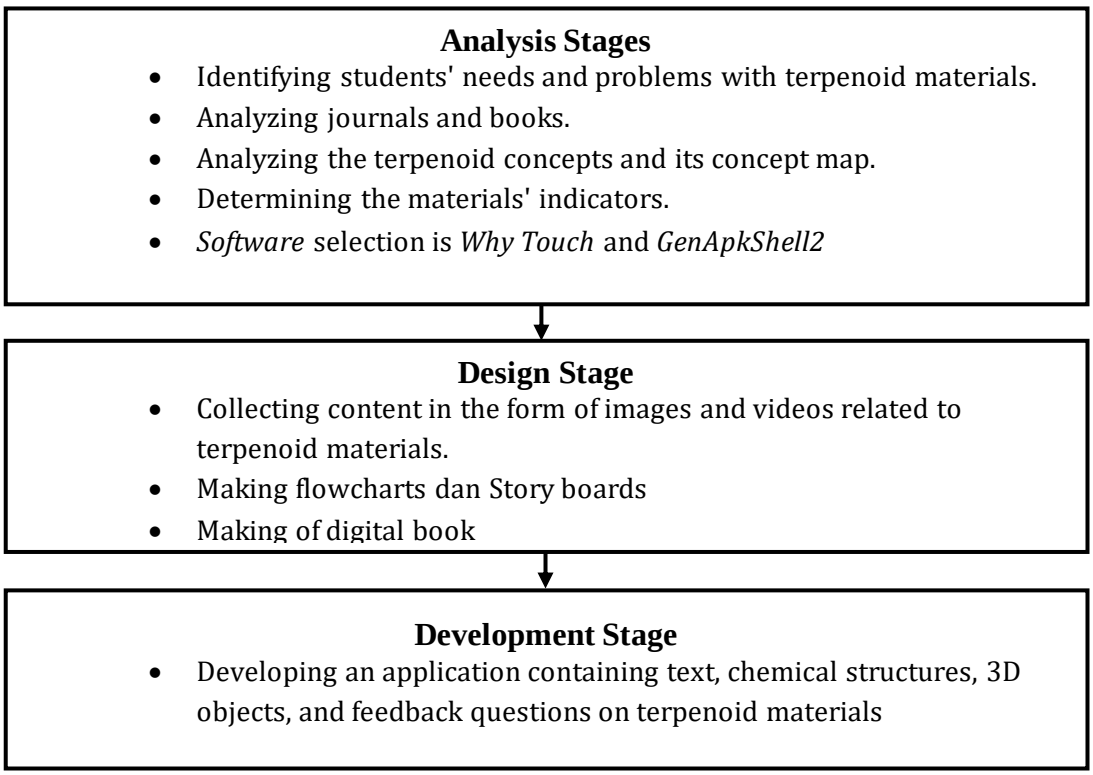


Figure 1. Research Procedure

The researchers collected the data after finishing the three stages of development. The data collection technique used in this research was a validation test questionnaire sheet. It contained descriptor statements regarding the learning aspects, multiple representation aspects, visual communication aspects, and software engineering aspects. Three expert lecturers filled it out as validators. The validation aimed to assess the digital book's content and structure with suggestions and comments as the benchmark for improvement and refinement.

After obtaining the validation test data, the data analysis technique was performed by comparing the feasibility value (r) with the $r_{critical}$ value. The mean value of the validation test is called $r_{observed}$ (Arikunto, 2019). The validity limit of the instrument was based on the error rate of 5% and the $r_{critical}$ value of 0.30. The $r_{observed}$ value was calculated using an interpretation equation, namely $r = \frac{x}{N \times n}$, where r is the validation value, x is the respondents' answers, N is the number of items, and n is the number of respondents. The product is valid if $r_{observed}$ value is greater than 0.30 (Sugiyono, 2010).

RESULTS AND DISCUSSION

This research produced a product in the form of an Android-based digital book on terpenoid material oriented to multiple chemical representations. The resulting digital book was made based on the need for teaching materials that can visualize three levels of chemical representation, namely macroscopic, submicroscopic, and symbolic levels. The digital book contained images, videos, and texts (Fauzi dkk., 2019). The digital book was chosen because it can be an independent learning tool containing material equipped with supporting pictures, videos, and evaluation questions with direct

feedback (Perdana dkk., 2019). The digital book contained 80 pages that discussed the definition of terpenoids, terpenoid classification, terpenoid characteristics, terpenoid biosynthesis, terpenoid uses, terpenoid sources, and terpenoid isolation.

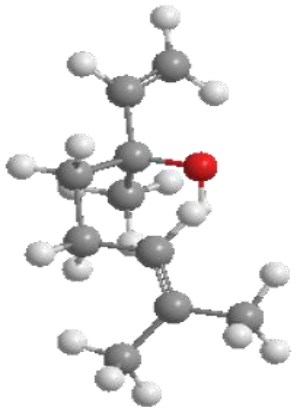
The Display of the Digital Book

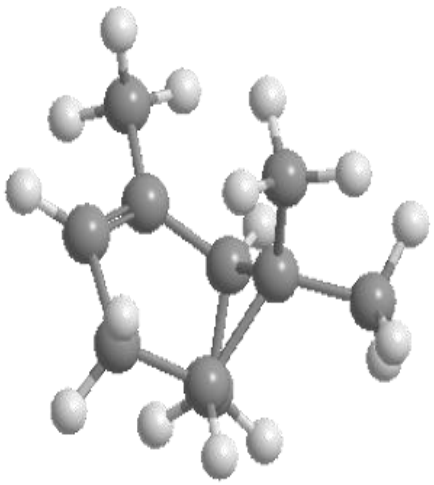
The description of the digital book's display can be seen in table 1.

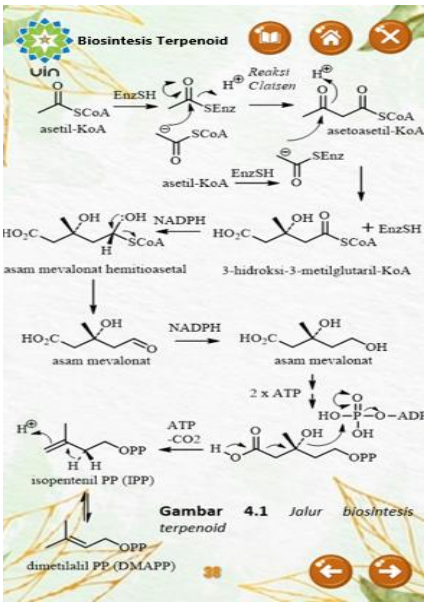
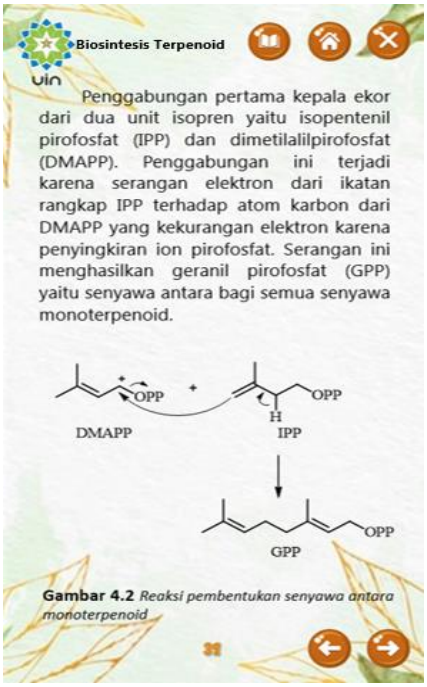
Table 1. The Description of the Digital Book's Display

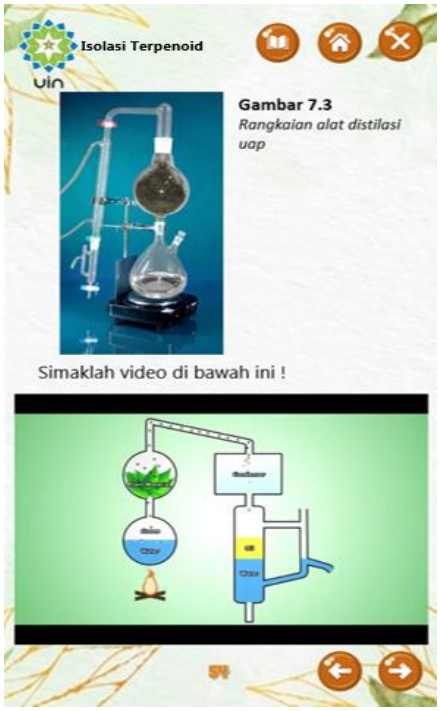
No.	Display	Description
1		The cover has buttons to start using the digital book. The button points to the main menu page to make it easier for users to operate and access the desired pages (Kuswanto, 2019).
2		The main menu page consists of several menu buttons to show the description, introduction, materials, exercises, help, and about pages. The description button will display a material description page and learning achievements on the terpenoid concept. The introduction button will display an introduction page to start learning the terpenoid concept. The material button will display the sub-material list page. The practice button will display a practice question page. The help button will display a brief guide, and the about button will display the profile of the author of the digital-book.

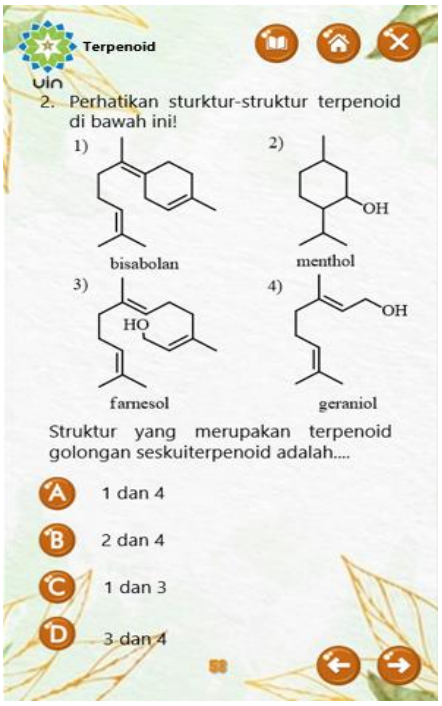
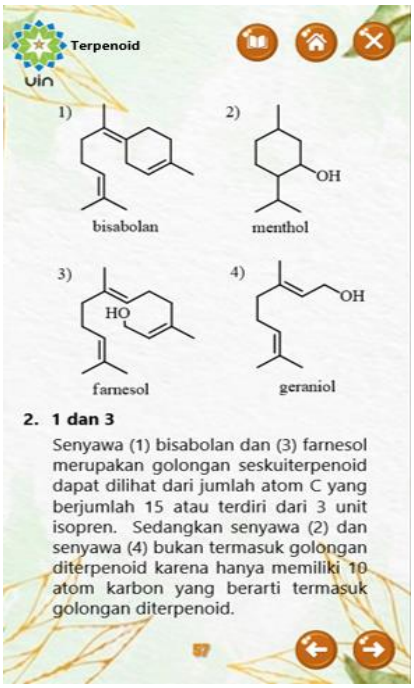
No.	Display	Description
3		The introduction page contains a video about the use and the benefits of terpenoids in everyday life to attract users' interest by linking the concept of terpenoids with their application in everyday life (Sari, D. S. & Sugiyarto, 2015). The page also contains the Qur'an verse of Ar-Ra'd: 3 regarding the signs of the greatness of God. Thus, it aims to provide religious values (Sarmedi, 2019).
4		The material page contains a table of contents for the terpenoids' sub-materials, namely the definition, classification, characteristics, biosynthesis, uses, sources, isolation, and references from digital books.

No.	Display	Description
5	 (a)  (b)	The digital book contains terpenoid materials equipped with multiple chemical representations, macroscopic, submicroscopic, and symbolic representations, to help students understand chemical concepts (Nurpratami dkk., 2015). On the material page, the first sub-material discusses the definition of terpenoids. Next, it discusses essential oils as terpenoid compounds (Heliawati, 2018). Finally, an image of lavender essential oil is presented as a macroscopic representation of the phenomenon (Figure 5a). Figure 5b presents the submicroscopic and symbolic representations of the essential oil. The submicroscopic representation of the lavender essential oil is presented with three-dimensional molecular images of the linalool compound. Furthermore, the symbolic representation is presented in the form of a symbol of the linalool compound ($C_{10}H_{18}O$). Linalool is a monoterpenoid compound found in the essential oils of several aromatic plants, one of which is lavender (Menezes dkk., 2014). By presenting the macroscopic, submicroscopic, and symbolic phenomena of essential oils, it is hoped that it can provide an in-depth understanding of the multiple interconnectednesses of the representations contained in essential oils.

No.	Display	Description
6	 (a)  α-pinene ($C_{10}H_{16}$) (b)	In the classification sub-material, the first part discussed is monoterpenoids. First, a text is presented to define the monoterpenoids as a terpenoid group with ten carbon atoms derived from 2 isoprene units joined head-tail. Next, the macroscopic phenomenon of monoterpenoids is presented by pine trees as the source of pinene compounds (Figure 6a). Figure 6b presents the submicroscopic and symbolic representations of monoterpenoid compounds. Monoterpenoid submicroscopic phenomena are presented with three-dimensional molecular images of pinene compounds. Furthermore, the symbolic phenomenon of monoterpenoids is presented in the form of a symbol for the pinene compound ($C_{10}H_{16}$). Pinene is a monoterpenoid compound resulting from a cyclization mechanism of the geranyl pyrophosphate (GPP) precursor (Heliawati, 2018). The presentation of macroscopic, submicroscopic, and symbolic phenomena of monoterpenoids is expected to provide an in-depth understanding of the multiple representations (Nilawati, dkk., 2016).

No.	Display	Description
7		The terpenoid biosynthesis page explains the precursor of terpenoid biosynthesis, namely the acetic acid molecule that forms mevalonic acid through the Claisen condensation reaction (Heliawati, 2018). The terpenoid biosynthesis page contains text explaining the formation of isoprene units and the reaction mechanism for isoprene unit formation. The formation of isoprene units comes from acetic acid, which undergoes several reactions to form mevalonic acid. The mevalonic acid reaction continues to form isopentenyl pyrophosphate (IPP), which can be isomerized into dimethylallyl pyrophosphate (DMAPP). IPP and DMAPP are the basic frameworks of an isoprene unit. The presentation of the terpenoid biosynthesis reaction aims to enable students to connect submicroscopic and symbolic representations.
8		The biosynthesis page discusses the reaction mechanism for the formation of monoterpenoid intermediate compounds, namely geranyl pyrophosphate (GPP). Monoterpenoid compounds are formed from the first fusion of two isoprene units. The digital book presents an explanatory text on the reaction for the formation of GPP and the mechanism of the electron attack reaction from the double bond of IPP to the carbon atom of DMAPP, which lacks electrons due to removing pyrophosphate ions to form GPP (Heliawati, 2018).

No.	Display	Description
9	 (a)  (b)	The Terpenoid Isolation page contains various oil isolation techniques, such as the press method, the distillation method, and the steam distillation method. It also presents a video of the working principle of the press and distillation method to obtain essential oils (Figure 9a). Another method that can be used to obtain essential oils is the steam distillation method (Dewi dkk., 2018). The steam distillation method tools are presented in the form of images and a video of how the steam distillation method works to obtain essential oils (Figure 9b). The video is chosen because it can be used as an additional learning medium to provide real experience in essential oil refining (Tasmalina dkk., 2018). The digital book presents content visualization in the form of text or images. The texts are accompanied by videos or animations so that users can understand the content (Irwansyah dkk., 2017).

No.	Display	Description
10		The evaluation page is in line with the characteristics of digital books so that students can learn independently or self-evaluate (Marselina & Muhtadi, 2019). The evaluation contains ten questions which consist of seven multiple-choice questions and three cloze questions. For example, figure 10 shows an evaluation question to determine the structure of compounds belonging to the sesquiterpenoid group. The question presents several structures of terpenoid compounds such as bisabolene, menthol, farnesol, and geraniol. Users are asked to determine the structure of compounds by choosing the options provided.
11		One of the advantages of digital books is that they can provide direct feedback (Mawarni & Muhtadi, 2017).). The Question Discussion page presents a discussion of the questions contained in the digital book. This page aims to provide explanations for each answer to the questions. This page can be accessed on each item of the question.

The developed digital book contains texts, images, and videos on terpenoid materials oriented to multiple chemical representations. The chemical representation is expected to help students understand the concept of terpenoids. Since it is based on Android, this digital book can be accessed via smartphone and can be accessed anytime and anywhere. However, the application needs to be redeveloped because it is still limited to certain Android versions.

Priyatni has developed a digital book on inquiry-based acid-base titration materials that is suitable to be used (Priyatni, dkk., 2020). The digital book was developed using E-PUB software and can be installed on android devices and laptops. However, the digital book was not oriented to

multiple chemical representations. Similar research has been carried out on developing electronic books based on chemical representations on chemical bonding materials (Nurmayanti, dkk., 2017) and basic chemical law materials (Andani & Yulian, 2018). The developed electronic books are suitable for use even though they are Android-based and require a computer device. The digital book produced in this research contains two aspects that have never been developed on terpenoid materials, namely android-based and multiple chemical representations.

The Validation Test Results of the Digital Book

Three validators had validated the product. The validation aimed to determine the quality of the digital-book and obtain suggestions and inputs from the validators. The aspects assessed were the learning process, learning materials, multiple representations, visual communication, and software engineering (Hidayatullah, dkk., 2019). The validation is performed by expert lecturers, namely multimedia expert and learning material experts. The results of the validation are presented in table 2.

Table 2. The Results of Validation

No.	Statements	$r_{observed}$	$r_{critical}$	Results
	Content Aspects			
1	The suitability of material with learning objectives	0.86	0.30	Valid
2	Easy to understand	0.86	0.30	Valid
3	The depth of the materials	0.80	0.30	Valid
4	The correctness of the material in terms of theory and concepts	0.93	0.30	Valid
5	The accuracy of the use of terms according to the scientific field	0.86	0.30	Valid
6	The suitability of the questions with the material	0.80	0.30	Valid
	Chemical Representation Aspects			
7	The macroscopic representations are presented correctly based on real life	0.93	0.30	Valid
8	The microscopic representations are presented correctly	0.86	0.30	Valid
9	The symbolic representations are presented correctly	0.86	0.30	Valid
	Book Display Aspects Digital			
10	Colours and illustrations	0.80	0.30	Valid
11	Visible visualization, both in size and shape	0.86	0.30	Valid
12	Representation of the actual object	0.80	0.30	Valid
13	Communicative, acceptable, and in line with the objectives	0.80	0.30	Valid
14	Creative, the visualization is presented uniquely and can attract attention	0.80	0.30	Valid
	Software Engineering Aspects			
15	Effective and efficient	0,80	0.30	Valid
16	Reliable	0.73	0.30	Valid
17	Compatibility (it can run on smartphones)	0.80	0.30	Valid
18	Reusability (it is easy to use and simple)	0.86	0.30	Valid
	Mean Score	0.83	0.30	Valid

Based on Table 2, the validation results on the aspects of material suitability with learning objectives obtained the highest $r_{observed}$ value of 0.93. The validators suggested connecting the concept of terpenoids with steroids because they have basic structural similarity. Terpenoids and steroids are classified into non-phenolic secondary metabolite compounds with the mevalonic acid biosynthetic pathway (Musman, 2017).

The test on the other criteria of the learning materials aspects obtained the value of $r_{observed}$ of 0.86. This value indicated that the digital book was feasible and had a high interpretation (Sugiyono, 2010). Furthermore, the materials contained in the digital book are in line with the self-contained principle, which means the arrangement of the material is complete (Arsanti, 2018).

The validation of multiple representation aspects consisted of the suitability of macroscopic, submicroscopic, and symbolic representations. The macroscopic representations in this digital book are presented in pictures of terpenoid macroscopic phenomena in real life. The submicroscopic representations are presented in three-dimensional molecular images of terpenoid compounds

whose relationships are presented in symbolic form. Table 2 shows the macroscopic representation aspect obtained the highest $r_{observed}$ value of 0.93. The validators suggested adding a sentence that slightly reviews the representation.

Other validation results on the chemical representation aspects obtained $r_{observed}$ value of 0..86. The result indicated that the chemical representations in the digital book are appropriate because the macroscopic representations contain real visible phenomena, the submicroscopic representations contain three-dimensional images, and the symbolic representations contain symbols of compounds (Fauzi, 2018). The result also shows that the multiple representations in the digital book are feasible and have a high interpretation (Sugiyono, 2010).

Table 2 displays the results of the validation on the display aspect. It obtained the highest $r_{observed}$ value of 0.86 on the visualization category. The $r_{observed}$ value on the other criteria was 0.80. The validators suggested adjusting the background image with the discussed material. The results indicated that the display of the digital book was feasible and had a high interpretation (Sugiyono, 2010). The display of teaching materials is an important aspect because it affects students' learning motivation (Setiawan dkk., 2016). Besides, the animated images or videos provided provide an impressive learning experience for students to improve their learning outcomes (Warkintin & Mulyadi, 2019).

The validation of software engineering aspects covered effectiveness and efficiency, reliability, compatibility, and ease of use. Based on Table 2, the ease of use aspect obtained the highest $r_{observed}$ value of 0.86, and the lowest $r_{observed}$ value was obtained by the reliability criteria (0.73). These results indicate that the digital book is easy to use and meet the criteria for human-computer interaction. Therefore, the software engineering aspect of digital books is feasible and has a high interpretation (Sugiyono, 2010).

Based on the validation results, the $r_{observed}$ value in each aspect is greater than the $r_{critical}$ value, with an average of 0.83. These results indicate that the digital book is valid (Sugiyono, 2010). Therefore, the developed digital book can be used as one of the teaching materials that can assist the students in finding concepts by connecting the three multiple chemical representations in the form of text, images, and videos in the Natural Materials Chemistry course.

CONCLUSION

In this research, an Android-based digital book oriented to multiple chemical representations has been successfully developed. It displays the phenomena of macroscopic, submicroscopic, and symbolic representation of terpenoid materials. In addition, this digital book is equipped with pictures, videos, evaluation questions, and direct feedback oriented to multiple chemical representations.

The validation obtained a r_{count} value of 0.83 with a high category. The result indicates that the Android-based digital book oriented to multiple chemical representations on terpenoid material can be used in Natural Material Chemistry. However, this research contains limitations because limited trials had not been performed to determine the quality of the developed digital book. Besides, the animations contained in the digital book are still limited. Therefore, the researchers recommend further research to improve the digital book.

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