Indonesian Society for Science Educators
Journal of Science Learning
journal homepage: ejournal.upi.edu/index.php/jslearning

Smartchem: An Android Application for Learning Multiple Representations of Acid-Base Chemistry

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ABSTRACT An android application named SmartChem was developed to explain multiple representations of acid-base chemistry. This paper is a description of an android-based media (SmartChem) through the stages of design, development, validation and revision, and finally, limited trials with pre-service science teachers. SmartChem is intended to aid students in understanding through media explanations of symbolic, macroscopic, and submicroscopic representations of acid-base material. The validity of the tool was assessed through the ratings of a panel of five expert judges using Aiken's validity index (Aiken's V). The results show that some parts of the SmartChem media needed to be revised, especially in linking submicroscopic level content with symbolism. From the trials of this application with trainee teachers, help in understanding multiple chemical representations of acids and bases was demonstrated; however, the low achievement group was more concerned with technical features, while the higher achieving group appreciated the content and learning experience.

Keywords SmartChem, Android application, Chemical multiple representation

1. INTRODUCTION

Human life these days is inseparable from the development of knowledge, information, and communication technology. The rapid growth of information and communication technology in the era of the industrial revolution 4.0 is inevitable and is impactful on all sectors of life (Umachandran, Jurcic, & Ferdinand-James, 2018). Industrial revolution 4.0 supports the development of information and communication technology that provides the opportunity to adopt and apply the latest information and communication technology in all sectors of life, including education (Liao, Loures, Venâncio, Brezinski, & Deschamps, 2018). Global demands encourage the education sector to continually adjust the technological developments for the efforts in improving the quality of education, mainly in adopting the use of technology for the education sector, especially in the learning process. Utilization of technology can be used as a supporting tool in understanding certain subjects, one of which is chemistry (Helsy & Andriyani, 2017).

Chemistry is a natural science branch that studies natural phenomena, especially those related to the structure, composition, properties, and changes in matter (Istijabatun, 2008). In addition to studying changes in matter, chemistry also explores the energy that accompanies these changes. In other words, chemistry is a science full of concepts, ranging from simple to more complex concepts, and from concrete to abstract concept.

The understanding in chemistry is tied directly with understanding the representation of macroscopic, submicroscopic, and symbolic levels, and the appropriate connections these three levels of representation have (Gkitzia, Salta, & Tzougraki, 2011). The macroscopic level is a chemical phenomenon that can truly be observed by the unaided eye, including students' experience every day (Treagust, Chittleborough, & Mamiala, 2003). The microscopic level is a chemical phenomenon that cannot be observed directly, such as electrons, molecules, and atoms. The symbolic level is a representation of chemical phenomena using a variety of media, including models, images, algebra, and

Received: 14 February 2020
Revised: 01 July 2020
Published: 31 July 2020

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computational forms. The inability to represent one level of representation can hinder the ability to solve chemical problems for other levels of representation (Kamkhou & Yuenyoung, 2019).

Most students find it difficult to master the concepts of chemistry. This is reinforced by research data that shows the difficulty of students understanding the concept of chemistry, mainly at the microscopic, and symbolic levels (Roche Allred & Bretz, 2019; Wu, Krajcik, & Soloway, 2001). This difficulty is caused by the characteristics of these levels that are invisible and abstract. Abstract chemical concepts will become a problem when these concepts are key concepts used to understand a certain occurring phenomenon. Analogy and the use of appropriate models are needed to understand the chemical concepts (Helsy & Andriyani, 2017; Sunyono & Meristin, 2018).

One effort that can be made to analogize an abstract concept to be more concrete is to use teaching media. Teaching media can improve the understanding of the three levels of chemical representation, especially at the symbolic and submicroscopic levels (Eliyawati, Rohman, & Kadarohman, 2018). One of the learning media that is in line with the development of the industrial revolution 4.0 era is the use of teaching media based on information and communication technology in the form of an android application (Andriani, 2016). Teaching media in the form of an android application can help students understand the learning materials and help teachers and parents present the learning materials (Mewengkang, Eunike, Liando, Ngodu, & Stefanus, 2019). Android application-based teaching media that can be used by students to understand the concepts of chemistry is SmartChem. This media is a multimedia device that can display text, images, animations, videos, and audio simultaneously in the form of an android application.

SmartChem, an android application-based media, is expected to help students visualize chemical processes. Multimedia can help students visualize concepts at the molecular level and stimulate memories of facts, concepts, or principles. This microscopic level of representation is also inseparable from the other two levels of understanding, namely the macroscopic level and the symbolic level (Ardac & Akaygun, 2004). Chemical understanding can be achieved by increasing the ability to explain and describe macroscopic, microscopic, and symbolic levels and the ability to connect between the three appropriately (Raviolo, 2001).

One topic of chemistry that must be understood through all three levels of representation is acid-base. There is a lot of research on teaching media that addresses the topic of acid-base, such as virtual laboratories (Ibrahim, Handoyo, & Ikhsan, 2017); Macromedia flashes (Ibrahim et al., 2017); worksheet development (Cahyani & Nasrudin, 2019); and android-based games (Kumar, 2013). However, no one has developed an Android-based learning media that discusses the three levels of chemical representation on the topic of acid-base. Therefore, it is necessary to create an android-based media, SmartChem, to explain the multiple representations of chemical understanding on the topic of acid-base. This SmartChem media was created to help pre-service science teachers understand multiple chemical representations at the macroscopic, submicroscopic, and symbolic levels on the topic of acid-base, mainly addressing the problem of understanding chemistry, especially for abstract concepts, and abstract concepts with concrete examples. This research will discuss the stages of developing android application-based SmartChem media, characteristics of Android application-based SmartChem media, and the validation and testing of Android application-based SmartChem media.

2. METHOD

This research is a descriptive research of the development of android-based SmartChem media to explain multiple chemical representations on the topic of acid-base. Descriptive research describes a situation, problem, phenomenon, service, and program systematically, and provide information about the living conditions of a community, or describe the attitudes towards a particular problem (Kumar, 2011). With this SmartChem media, it is expected that pre-service science teachers can understand multiple chemical representations on the topic of acid-base. Some stages in this research included (1) designing Android app-based SmartChem media; (2) developing Android app-based SmartChem media; (3) validating and Revising android app-based SmartChem media; and (4) limited trials to determine pre-service science teachers' responses towards the Android app-based SmartChem media.

The design of the android-based SmartChem media begins with concept analysis and making the storyboard. At the development stage of SmartChem media based on android applications, researchers made android applications using Dart programming language and supported by the Flutter framework using the Microsoft Visual Studio code editor. Five experts then validated SmartChem that was developed. These five experts have the same background in science with different specific expertise, which are material content experts, IT experts, and language experts. The validity was assessed by obtaining ratings by using Aiken's validity index (Aiken's V). Validated aspects of the SmartChem include display aesthetics, program analysis, learning applications, and SmartChem contents. After being validated, SmartChem media is revised and limited testing. There were 45 pre-service science teachers involved in the SmartChem media trial. The trial participants were pre-service science teachers in one science education majors in Indonesia.

The pre-service science teachers are final year students who have studied the content of the material. This trial was conducted to find out their response to the SmartChem media that was developed. Several questions were asked, especially regarding the content clarity of the multiple chemical representations of acid-base topics presented and the ease of use of this android-based media application.

3. RESULT AND DISCUSSION

3.1 Designing Android App-Based SmartChem Media

The designing stage of the android-based SmartChem media is done by analyzing acid-base concepts and creating acid-base storyboards. The first step is the analysis of the acid-base concept. The concept described must be understood and explained using words that are not necessarily similar to the description contained in the textbook. Analysis of the concepts that have been carried out always emphasizes macroscopic, submicroscopic, and symbolic representation levels on the acid-base topic. The results of the concept analysis are one concept included in the concept of apperception, and six concepts that are essential in acid-base material, including acid-base theory (Arrhenius, Brønsted-Lowry, and Lewis), acid nomenclature, basic nomenclature, the strength of acid-base, acid, and base. Each concept was analyzed of macroscopic, submicroscopic, and symbolic levels, and the connections of the three levels. The concepts examined can be used to make the media scripts in the form of storyboards. Storyboards that have been made are then developed into an android application-based media. The Figure 1 a-d are the example of a storyboard.

3.2 Developing Android App-Based SmartChem Media

The storyboard that has been made used as a basis for making animated videos. The prototype of this SmartChem application is a compilation of video animation that was inserted into the application. These compiled videos can be accessed through the android-based use. Therefore, the central aspect of developing this application is making animated videos. The animated video created explains the understanding of multiple chemical representations consisting of macroscopic, submicroscopic, and symbolic understanding of the acid-base topic. The following are the steps for making the animated video for SmartChem.

The first step in making animated videos is to create assets or objects that will be used in making animation, such as animated characters, molecular forms, electrical circuit forms, and other purposes. Asset creation is done using CorelDraw software. CorelDraw is a software for PC used to create vector shaped objects.

Then, the next step is making the animation itself. Macromedia Flash software is used to create the animation. After all, assets were created, the assets are

Figure 1a Storyboard of what is a base?

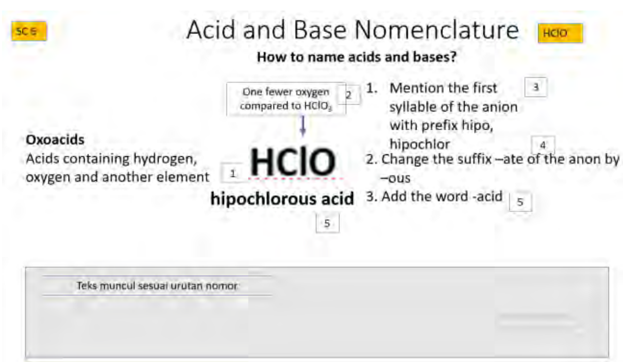

Figure 1b Storyboard of acid and base nomenclature

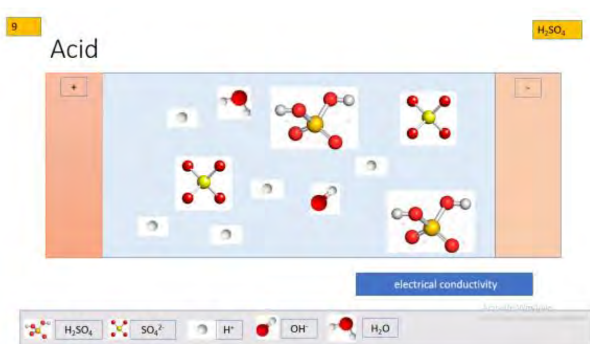

Figure 1c Storyboard of acid electrical conductivity

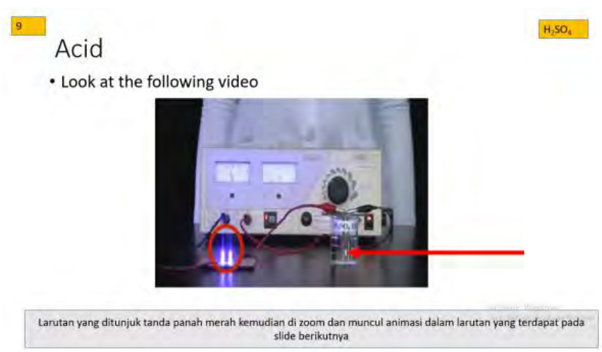

Figure 1d Story board video

Figures 1 Storyboard

entered into Flash to be designed and moved as desired. This animation movement used motion tween. Each scene is made into an animation and converted from the animation into a video format. This step takes quite a lot of time, because of the rendering process from animation to the video format. Because the rendering process is quite a demanding for the computer, the resulting file size is quite large. Therefore, the videos were compressed using a video editor called Wondershare Filmora. In this step, video compressing and text additions, such as titles and captions in the video were made. Afterward, the animated video is ready to be inserted into the application.

The application is created using the Dart programming language and is supported by the Flutter framework. The use of Flutter is different from making Android Native. The resulting application can only be run on the Android platform if Java/Kotlin Language, which is used as the basis for making Android, was used. But if you use Flutter, applications can be rendered into multiple platforms.

The development of the application was done using the Microsoft Visual Studio code editor. It starts with the development of the basis/prototype of the application, followed by the page and video controller system, until it ends with the display's finalization. After the application has reached the final stage, the application is compiled, and the build process is carried out. The process resulted in an installation file in the form of an "apk" (android application extension) that can be used to install applications.

3.3 Validating and Revising Android App-Based SmartChem Media

The android app-based SmartChem media need to be accomplished with the validation process. This stage is a primary concern that measures the extent to which the content of SmartChem matches three aspects of a qualified digital teaching media. Five validators gave their expert judgment on three aspects of the application: 1) Audio/visual aesthetic display, 2) program features, and 3) pedagogical features. The validity was assessed by obtaining ratings from a panel of five expert judges using Aiken's validity index (Aiken's V) (1985). The procedure for determining Aiken's V Index starts either with the rating of a single SmartChem aspect by n judges or the ratings of m aspects by a single judge. The validators were also asked to give recommendations and suggestions on parts that need to be improved and revised. The Aiken's V Index is computed using the formula

$$V = \frac{\sum S}{[n(c-1)]}$$

S stands for the difference between the judge's validity ratings of the item (r) and the lowest validity category (l). This rule provides $S = r - l$, and c states the highest

Table 1 Validation Score of SmartChem

Aspect	Judges' ratings					Aiken's V	
	A	B	C	D	E		
Audio/visual aesthetic display							
Type and size of font	5	4	5	5	5	0.95	Valid
Color composition	5	4	4	2	4	0.7	Invalid
Graphical clarity	5	4	4	5	4	0.85	Valid
Animation	5	4	4	5	4	0.85	Valid
Sounds	5	2	5	3	3	0.65	Invalid
Screen display	4	2	4	5	4	0.7	Invalid
Clarity of terms	5	5	5	5	4	0.95	Valid
Language usage	5	3	4	5	5	0.85	Valid
Characters placement	5	5	4	5	4	0.95	Valid
Interface flow	4	1	4	5	4	0.7	Invalid
Program features							
Complexity	5	5	4	4	2	0.75	Invalid
Algorithm design	5	3	5	5	4	0.85	Valid
Program interactivity	4	3	3	5	2	0.6	Invalid
Response to input	5	2	3	5	4	0.7	Invalid
Space efficiency	4	3	4	5	1	0.6	Invalid
The ease of program	4	3	5	5	5	0.85	Valid
Pedagogical features							
Learning material	5	1	5	4	4	0.7	Invalid
The appropriateness of content within animation	5	3	5	2	3	0.65	Invalid
The clarity of learning material	5	4	5	4	4	0.85	Valid
The clarity of examples	5	3	5	4	4	0.8	Valid
The clarity of exercise	4	2	4	3	3	0.55	Invalid

validity category. This study has magnitudes extending from 1 to 5 so that l = 1 and c = 4. The Aiken's V provides an index of raters affirmation that ranges from 0 to 1. The accepted value of Aiken's V Index is authorized on the exact binomial test represented by a table containing V's critical values by the number of judges and the number of ratings (Aiken, 1985; Dunn, 1999). The number of judges and ratings in this study designated 0.8 critical value. Aiken's V index of SmartChem is displayed in Table 1.

Table 1 shows that overall, the lowest Aiken's V Index is 0.55 obtained on the clarity of exercise, whereas the highest index is 0.95 achieved on the type and size of the font as well as clarity of terms. The table also shows that the SmartChem is valid in ten aspects, invalid at 11 aspects. Aiken's V index of each aspect is shown in Figure 2, Figure 3, and Figure 4.

Based on Figure 2, the lowest score V is obtained for sounds and interface flow in the aesthetic display aspect. The index of these two aspects is 0.65. Moreover, the validators recommend that several revisions need to be made. The revision included: 1) the quiz menu needs to be improved because it cannot be appropriately executed 2) The interface flow can be improved by adding guidelines for using apps in the beginning 3) some negligible sound effects need not be minimized 4) exploration of interface flow needs to be clarified 5) the speed of sounds should be uniform.

Figure 3 shows the average score for program features. Based on the figure, it can be seen that the V values range from 0.6 to 0.85. The highest score on this aspect is lower than the highest score on the aesthetic display. The highest score V Index is achieved for algorithm design and the ease of the program. The lowest V is acquired for the aspect of program interactivity and space efficiency, which is 0.6. Several recommendations were generated to improve the application performance: 1) some questions need to be added at the end of each material accomplished with feedback 2) program interaction with users need to be more dynamic.

Based on Figure 4, it is known that the SmartChem Aiken's V Index on pedagogical features ranges from 3.2 to - 4.4. The lowest V is obtained on the clarity of exercise, while the highest V is achieved on the learning material. Suggestions from the validators related to these two aspects include 1) Wider space is important to improve exercise performance 2) some questions measuring higher-order thinking skills (HOTS) need to be added into the exercise 3) questions on the exercise should be adjusted with the content within SmartChem.

The interface of SmartChem media that has been created and revised is as follows.

3.4 Limited Trials

A limited trial was conducted with 45 pre-service teachers majoring in science education. A questionnaire was administered to evaluate the feasibility of the developed SmartChem. Mainly, it assesses the pre-service teachers' perception regarding the mobile connectivity, learning materials, and mobile layout of the SmartChem, as well as to assess their experience after learning with this media. The result of the trial is presented in Table 2.

Table 2 The result of limited trials

No	Construct	Statement	SA (%)	A (%)	D (%)	SD (%)
1	Mobile Connectivity	The application is a convenient and effective time to consume	13.33	62.22	22.22	0
		The application is easy to connect	24.44	62.22	13.33	0
		The materials are accessible	22.22	64.44	13.33	0
2	Materials	The symbolic representations (chemical formula, chemical reaction, phase) are understable	33.33	64.44	2.22	0
		The submicroscopic representations (molecular representations) are understable	24.44	71.11	4.44	0
		The macroscopic representation (real phenomenon) are understable	35.56	64.44	0	0
		I can connect the symbolic, submicroscopic, and macroscopic level in learning acid-base	13.33	80.00	6.67	0
3	Mobile Layout	The appearance is attractive	17.78	57.78	17.78	6,67
		All text is clearly seen and readable	42.22	46.67	11.11	0
		All medias are support the materials comprehension	22.22	57.78	17.78	0
4	Learning Experience	Mobile learning can help to understand the concept	31.11	57.78	11.11	0
		Mobile learning can help to give meaningful learning	31.11	57.78	11.11	0
		Mobile learning can help to motivate students	33.33	60.00	6.67	0

SA = Strongly agree, A = Agree, D = Disagree, SD = Strongly disagree

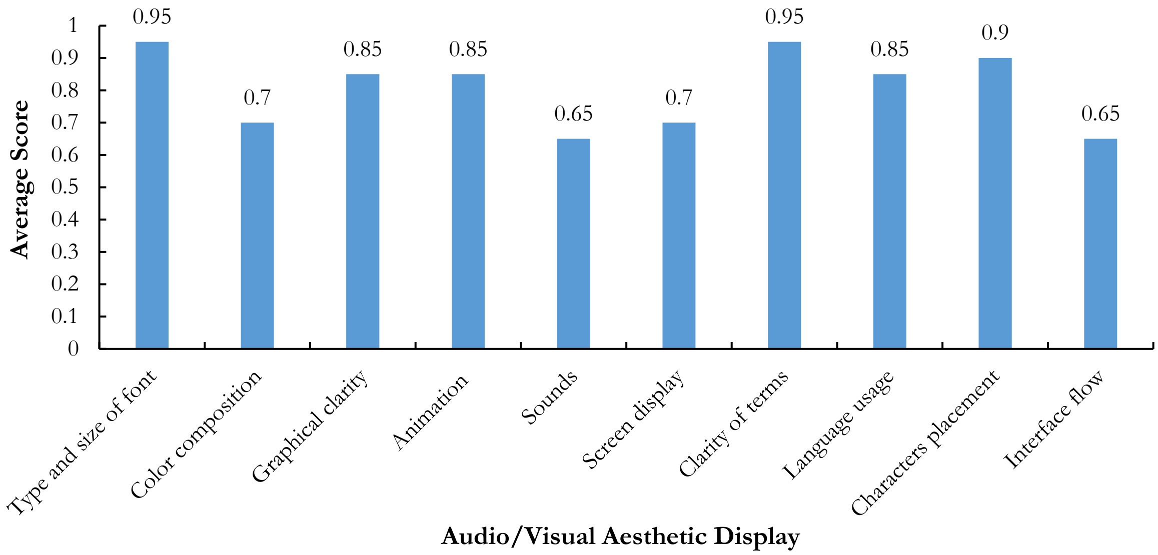

Figure 2 Average score on audio/visual aesthetic display

The results show that roughly around 62% of pre-service teachers agreed that the SmartChem is convenient and effective, easy to connect, and accessible (table 2). In regards to the learning materials provided SmartChem, 64.44% agreed that the symbolic and macroscopic representation is understandable. Whereas, around 71.11% of pre-service teachers agreed that submicroscopic is understandable. As many as 80% agreed, they could connect the content of symbolic, submicroscopic, and macroscopic levels in learning acid-base.

Most of the pre-service teachers also respond positively to the layout of the SmartChem, where 57.78% agreed that it is attractive and can support the comprehension of multiple representations of the acid-base topic. Additionally, 46.67% agreed that all the text is seen and readable. Furthermore, the pre-service teachers evaluate SmartChem after they experience learning with the media. As many as 57.78% agreed that SmartChem could help to understand the concept and give meaningful learning. Sixty percent of pre-service teachers noted to decide that SmarChem can help to motivate them in learning. Furthermore, around 30% of pre-service teachers strongly agreed that SmartChem assists positively on their learning.

The use of computer-based media is essential in

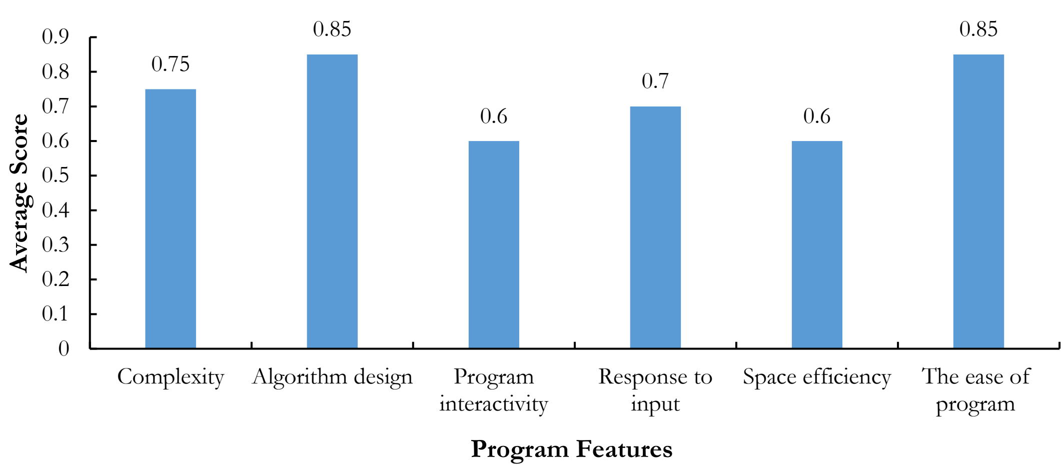

Figure 3 Average score on program features

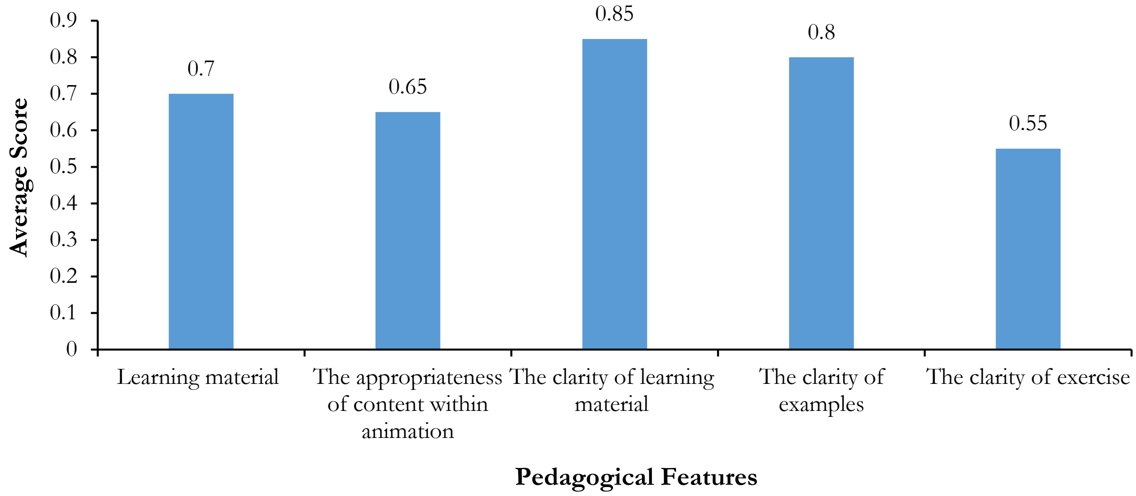

Figure 4 Average score on pedagogical features

enhancing the effectiveness of the learning process due to it can provide many components such as text image, graphics, animation, audio, and video, which complement each other and construct a powerful system (Rachmadtullah, Zulela, & Sumantri, 2018). Notably, in the chemistry course where the concepts of the abstract and submicroscopic level at the same time presented in certain topics (Calik & Ayas, 2005), such as in the acid and base. The results of this study show most of the pre-service teachers perceived positively to the use of SmartChem. It can be inferred that SmartChem is feasible to be employed as the media in learning multiple representations of acid-base.

Research conducted by Liu, Liao, & Pratt (2009) recognized that the ease of the media being used is in line with the usefulness of media itself, which consequently increases people's intention to use. The robust content presented is also correlated positively with a higher-level concentration of the user. Furthermore, the research by Owston, York, & Murtha (2013) noted a strong correlation between the students' perception of using blended learning and students' grades. Besides, the use of computers in learning is a powerful strategy to improve students' motivation (Leow & Neo, 2014; Lin, Chen, & Nien, 2014). Therefore, feasible SmartChem can be further performed to investigate the students' learning improvement and motivation in the chemistry course.

The pre-service science teacher who participated in a limited trial was the student who had enrolled in the general chemistry course. Based on the result of their academic performance on that course, 13 students had low achievement (group 1), 19 students had medium achievement (group 2), and 13 students had high achievement (group 3). Additionally, we analyzed students with different learning achievements in the general chemistry courses in response to the feasibility of the

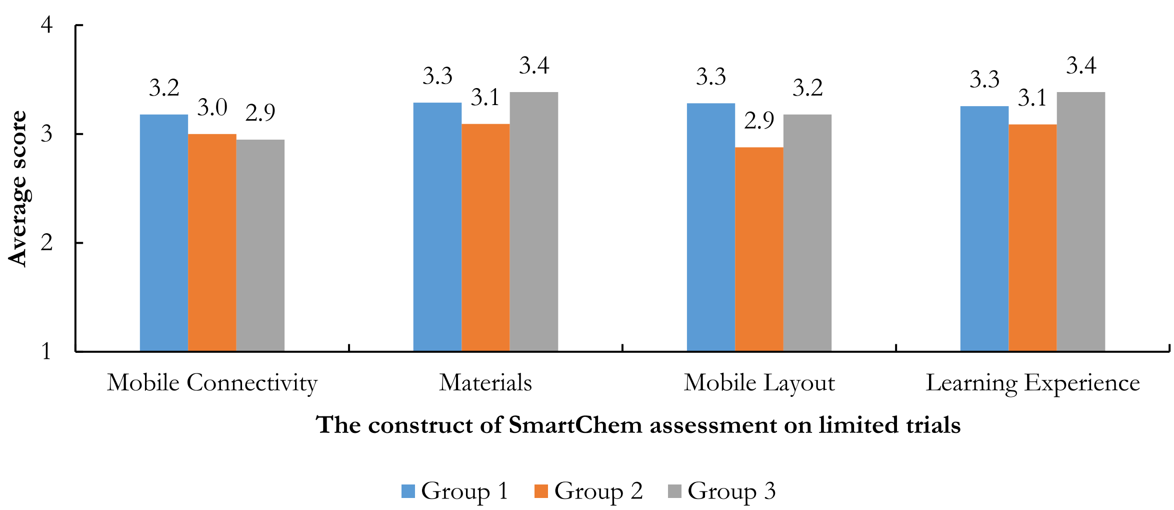

Figure 5 Pre-service teacher perception on SmartChem based on learning achievement on general chemistry course

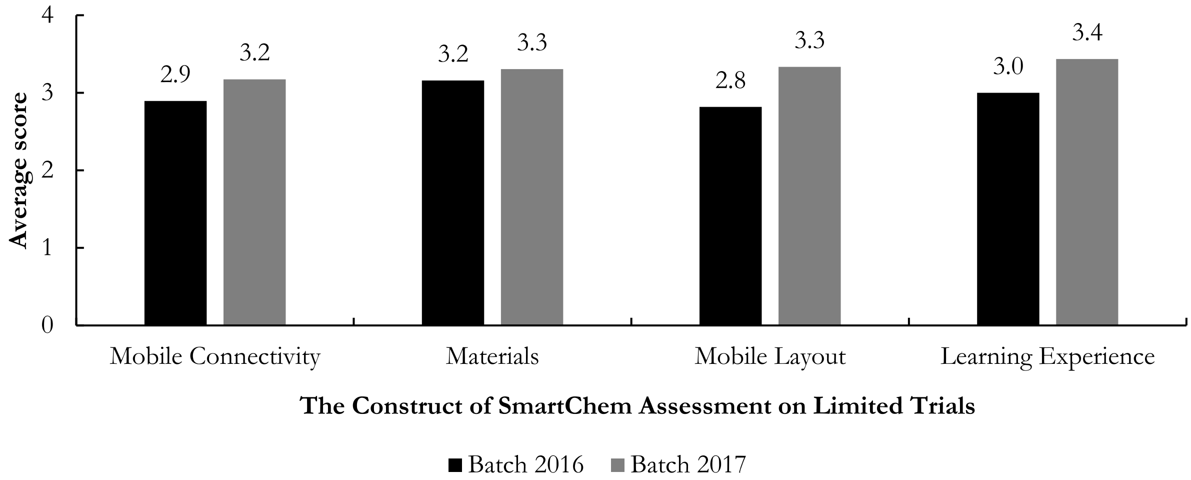

Figure 6 Pre-service teachers' perception on SmartChem based on academic year of study

SmarChem. The result is depicted in Figure 5.

Generally, the three groups assessed positively to the feasibility of the SmartChem, since the average score of each group at four constructs is more than two from four Likert-scale. Based on Figure 5, the group with low achievement in the general chemistry course gave a higher score in assessing the mobile connectivity and mobile layout of the SmartChem. Meanwhile, the group with high achievement gave a higher score for the learning material and learning experience with SmartChem.

The low achievement group was more concerned about the technical features such as the accessibility, effectiveness, and the attractiveness of the SmartChem in learning. They did not give a higher number to the content of the materials might because they were predicted to have less comprehension of the learning materials, especially the multiple representations in acid-base. Therefore, they also had a lower score than the high achievement group in learning experience using SmartChem.

Nevertheless, the high achiever group was more concerned with the content materials and learning experience. The students in this group had more comprehension of the materials, could compare the material with the reference, and could assess and give SmartChem with a higher score than other groups. Consequently, they also gave a higher score to the learning experience due to they perceived it is more meaningful learning compare with their previous experience.

We also analyze pre-service teachers' perceptions regarding the use of SmartChem based on the academic year. The students in the third year of academic study, which is batch 2017 consists of 23 students. Meanwhile, the students in the fourth year of academic study, which is batch 2016, consists of 22 students. The comparison between the two batches in assessing the feasibility of SmartChem is presented in Figure 6.

Students with more extended experience in college study gave lower scores to the feasibility of the SmartChem on all constructs. It might be caused they have experienced to have more complex material from the chemistry or other courses. They also might experience learning with more varied teaching media. Therefore, they have a broader view of assessing the SmartChem, and they scored lower instead of batch 2017.

4. CONCLUSION

Multiple understanding of the chemical representation of science students still lacks, especially in symbolic and submicroscopic understanding. One way to improve the understanding of multiple chemical representations of prospective science teacher students is by developing Android-based SmartChem media. Characteristics of SmartChem Media based on Android Applications that have been developed are media that can explain symbolic, macroscopic, and submicroscopic representations together to understand acid-base material. This SmartChem media is validated by five experts so that there are parts that need to be revised, especially in terms of linking submicroscopic level content with symbolic. The results of SmartChem media trials show this media can assist students in understanding multiple chemical representations on the topic of acid-base. The low achievement group was more concerned about the technical features such as the accessibility, effectiveness, and the attractiveness of the SmartChem in learning.

Nevertheless, the high achiever group was more concerned with the content materials and learning experience. The recommendation for this research is that SmartChem when testing electrical conductivity, pays more attention to the electrolysis process. Media Apps like this need to be developed for other topics, especially those related to scientific literacy and multiple chemical representations.

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