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Development of Augmented Reality-Based Interactive “Element Card” Media on Electron Configuration Submaterial According to Niels Bohr

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Abstract

This study aims to obtain the feasibility of Augmented Reality-based Element Card interactive media on the electron configuration submaterial according to Bohr's theory. This research uses a 4D model which is only carried out until the development stage. This research was conducted at SMAN 1 Gedangan Sidoarjo on 30 students X IPA. This study used a validation sheet instrument, pretest and posttest questions, student response questionnaires, and student observation questionnaires. If the value of the validation result is ≥ 61% then it is considered valid, the practicality value is ≥ 61% then it is considered practical, and the effectiveness value if it is classified above 0.3 which includes medium or high then it is considered effective. The results of content and construct validation are 88% and 84% are included in the very valid category. Practicality was obtained from 94.86% and 97% of student responses and observations included in the very practical. The effectiveness is obtained from learning outcomes by calculating the N-Gain and Wilcoxon Signed Ranks Test, the value of Asymp. Sig (2 tailed) is 0.000 which is smaller than 0.05 so there is a difference in the students' pretest and posttest scores. This proves that the interactive media based on the Augmented Reality Element Card can be used for chemistry learning media.

Keywords: Augmented Reality, Interactive Media, Electron Configuration, Niels Bohr

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INTRODUCTION

Chemical material is divided into three levels of representation, namely macroscopic, symbolic, and submicroscopic. Phenomena that are directly observed include macroscopic representations. Chemical particles such as atoms, electrons, and molecules include submicroscopic representations. Symbolic, chemical calculations, pictorial signs, and chemical equations include symbolic. The three levels are related to the application during learning (Nopihargu, 2014). Learning is currently limited to macroscopic and symbolic levels which makes students learn submicroscopic only through illustrations in books. This is a factor in the difficulty of students understanding material related to the submicroscopic level. The difficulty of understanding concrete material and facts will affect the understanding of abstract material (Nopihargu, 2014).

One of the abstract concepts in chemistry is the electron configuration according to Bohr's theory. Abstract chemistry concepts cause students to understand less about the material being taught. This misunderstanding can lead to misconceptions in students. So to study chemistry, especially electron configuration based on the Bohr atomic model, we need a way that pays attention to pedagogic, content, and multimedia aspects that are in line with the applicable curriculum to avoid difficulties in understanding.

The curriculum is a plan of material that will be given to students. The previous curriculum was refined with 2013 curriculum (Purwanto, 2013). The 2013 curriculum is made for students more active in the learning process (Permendibud, 2013). In learning, textbooks are used to achieve learning objectives. However, textbooks also have a weakness, namely that there is potential that students have. Whereas the development from concrete to abstract that students have occurs during high school (Sirakaya, 2018).

Textbooks as learning media can help students understand abstract material with concrete illustrations. It is hoped that the potential of students can develop optimally. Learning media is used to facilitate communication while studying. Learning media is made in harmony with learning materials so that what the teacher teaches can be understood well by students (Yuliono, 2018).

Permendikbud Number 65 of 2013 said that learning must be done interactively, inspiring, challenging so that students can participate actively. So that learning media must be interactive so that students can interact and use the media directly. And learning with technology-based teaching media can be meaningful and attract students' attention (Sirakaya, 2018).

To help visualize abstract material such as the structure of an object or model, Augmented Reality can be used (Mustaqim,2016). Augmented Reality technology is an interactive technology that can support macroscopic, symbolic, and submicroscopic. Augmented Reality is a 3D object that can appear in the real world. As according to Rifa`i (2014) stated that Augmented Reality works in real time. The camera as the eye that sees the marker card will visualize the 3D object. The object can only be observed through a computer or smartphone camera. Abstract chemistry such as electron configuration can be illustrated realistically with this technology. Connecting the virtual world and reality can make learning effective (Kamelia, 2015). This learning media can be used in a hybrid learning model used by teachers during the COVID-19 pandemic. This model is effective according to the conditions agreed upon by the teacher and students (Sandi, 2012).

Based on the result's interviews and observations conducted by researchers at SMAN 1 Gedangan Sidoarjo with class X teachers, it shows that there are problems in learning that still use conventional learning methods such as lectures during the COVID-19 pandemic, and it is known that they have never used 3D objects as learning media. According to Utami, (2018) the review of learning media, including very good quality (SB). Based on student responses as limited test subjects, all students agreed that the learning media had good quality when used as a learning medium for Niels Bohr's Atomic Structure material.

Furthermore, Anwar, (2012), positive teacher response to multimedia. Based on student questionnaire data, it is known that the level of agreement with: (1) 85.31% for motivation in multimedia, (2) 84.7% for content in multimedia, (3) 86% navigation on multimedia, (4) 90.84 % multimedia and interactivity, and (5) 86.77% for multimedia display. Overall, students' responses to multimedia lie in agreed areas. Thus, the intertextual representation of school chemistry on the electron configuration sub-concept of the Bohr atomic model that has been developed in the developed multimedia form can be used.

Researchers will create Augmented Reality-based learning media so that 3D electron configuration submaterial objects according to Bohr's theory can be used in offline and online learning because markers can be visualized during online and offline learning. This media is easy to use because it is interactive and in the form of application media that can be accessed on each student's Android smartphone. Therefore, the researchers desire to develop an interactive learning media based on Augmented Reality Element Card on the electron configuration sub-material according to Bohr's theory.

METHOD

This research uses a 4D model. The 4D model consists of the stages of defining, designing, developing, and deploying (Ibrahim, 2014). Researchers limit it to the development stage. In the define stage, a preliminary analysis is carried out, namely analysis of problems, participants, assignments, materials, and learning objectives through interviews and literature studies. At the design stage, storyboard planning is carried out. in develop, at the development stage, interactive media based on android was developed, validated media, conducted media assessments by lecturers and chemistry teachers in schools and conducted limited trials on students. at the development stage, it was carried out to determine the practicality and effectiveness of interactive media for the Element Card application. At this stage, a limited trial was conducted in class. This research was conducted at SMAN 1 Gedangan Sidoarjo with a target of 30 students of class X science in January 2022.

To measure the feasibility of interactive media developed according to Plomp (2010) the research design is seen from the data validation, practicality, and effectiveness. The data that has been collected was analyzed quantitatively with data collection techniques from validation sheets, student observations, pretest-posttest learning outcomes, and response questionnaires. Validation data is calculated using a Likert Scale as shown in Table 1

Table 1. Likert Scale (Riduwan, 2015)

Value Scale	**Scale Value**
1	Very bad
2	Bad
3	Enough
4	Good
5	Very good

Then calculate the percent of the results using equation 1 and interpreted in Table 2 using equation 1 and interpreted in Table 2.

Equation 1. Likert Scale Calculation

$$P\ (\%) = \frac{\varepsilon\ score\ obtained}{\varepsilon\ score\ criteria}\ x\ 100\%$$

(Suyono, 2015)

Table 2. Interpretation of Validation Result Score (Riduwan, 2015)

Percentage (%)	**Category**
0 – 20	Very Valid
20,1 – 40	Invalid
40,1 – 60	Enough
60,1 – 80	Valid
80,1 – 100	Very Valid

From the interpretation results, the development of Element Card media is said to be feasible in terms of validity if the percentage is ≥ 61%. Practicality data obtained from observation questionnaires and student responses were calculated using the Guttman Scale in Table 3.

Table 3. Guttman Scale

Value	Answer
1	Yes
0	No

(Riduwan, 2015)

Then calculate the percent of the result using equation 2 and interpreted in Table 4

Equation 2. Likert Scale Calculation

$$P\ (\%) = \frac{\varepsilon\ score\ obtained}{\varepsilon\ score\ criteria}\ x\ 100\%$$

(Suyono, 2015)

Table 4. Practically Score Interpretation (Riduwan, 2015)

Percentage (%)	**Category**
0 – 20	Very Impractical
20,1 – 40	Impractical

Percentage (%)	Category
40,1 – 60	Enough
60,1 – 80	Practical
80,1- 100	Very Practical

From the interpretation results, the development of Element Card media is said to be feasible in terms of practicality if the percentage is ≥ 61%. Effectiveness data was obtained from the students' pretest and posttest scores which were calculated using one group pretest-posttest as in equation 3 below.

Equation 3. One Group Pretest-Postest

O1 X O2

Explanation:
O_1: Implementation of pretest before using interactive media
X: Treatment
O_2: Implementation of posttest after using interactive media

(Noor, 2010)

Students will complete if their pretest and posttest scores are at least 75 and then calculated by equation 4 and interpreted in table 5.

Equation 4. Study Results Score

$$\text{Student Scores} = \frac{\in B}{N} X\ 100$$

Explanation:
B = Number of correct answers
N = Many questions

(Riduwan, 2015)

Equation 5. N-Gain Value

$$\text{N-Gain} = \frac{postest\ score - pretest\ score}{100 - pretest\ score} \text{x } 100\%$$

(Hake, 1998)

Table 5. N-Gain Interpretation Value (Hake, 1998)

Nilai	Criteria
$G \geq 0{,}7$	High
$0{,}3 \leq G < 0{,}7$	Medium
$G < 0{,}3$	Low

Pretest and posttest scores are learning outcomes. The pretest and posttest scores increase if the N-gain value is in the medium or high category and this learning media is considered feasible in terms of effectiveness. Then the Wilcoxon test was conducted to determine the difference between the test scores before and the test scores after using this interactive media. If there is a significant difference, then the Element Card interactive media is declared effective.

RESULTS AND DISCUSSION

Define Stage

This phase is carried out in preparation for the development of interactive media, which is carried out through the following five steps.

Problem Analysis

Problem analysis was conducted to determine the existing problems by collecting data from field studies (interviews and student questionnaires) and literature studies. It is known that the method used in learning uses conventional methods, namely lectures, and uses book learning media and power points. So we need technology-based learning media that supports learning. According to Sirakaya (2018), the learning process supported by learning media integrated with technology makes learning meaningful and attracts students' attention.

Participant Analysis

The things reviewed in the participant analysis are the characteristics, abilities, and experiences of the students' learning process so far. This research was conducted on high school students aged 15-16 years because according to Sirakaya (2018) Mental development from concrete to abstract is experienced during high school. From the research, information was obtained that the economic background of each student has a smartphone to support student learning activities. However, 100% of students stated that the teacher had more teacher center during learning so that the technology they owned did not run optimally. 66.67% of students have difficulty understanding the material of electron configuration according to Bohr's theory because they do not understand the form of electron configuration. This fact follows the results of previous research by Novita (2019), which found research that animation media affected learning outcomes. According to the data, 100% of chemistry learning at X IPA 6 has not used 3D objects for electron configuration according to Bohr.

Task Analysis

Task analysis was conducted to determine the skills to be used in interactive media. Designing application content, 3D Objects, and element cards that can be used in physical or virtual forms. This is adjusted to the curriculum used by SMAN 1 Gedangan Sidoarjo. The media must be in accordance with the material to be taught so that the material taught by the teacher can be understood well by students. (Yuliono, 2018).

Material Analysis

Material analysis aims to identify the material to be included in the element card application. The material adapts to basic competencies in accordance with ministerial regulation number 37 of 2018 class X, namely 3.3 Analyzing similarities in the properties of elements in groups and their periodicity and 4.3 Determining the location of an element in the periodic table based on electron configurations (Permendikbud, 2018)

Learning Goals

The learning objectives are used as the basis for the preparation of the developed media. The electron configuration according to Niels Bohr's theory was chosen because it can be studied through animated 3D object illustrations. According to Nopihargu (2014), the advantage of the media developed is that it is more interactive because the learning media is integrated with augmented reality technology. So that it can support students to understand the material of electron configuration which is an abstract concept. In line with Ilyasa (2020), Augmented Reality technology can overcome students' difficulties in understanding abstract chemistry because students cannot see the material directly.

Design Stage

The interactive media design stage is the Element Card application, starting with making storyboards, preparing application content materials, and 3D objects that are integrated with Augmented Reality technology and markers used to scan 3D objects. The Element Card application is used on Android devices and can be used during offline and online learning so that this interactive media can be used in hybrid learning. The following is the appearance of the Element Card application that researchers have developed (Figure 1).

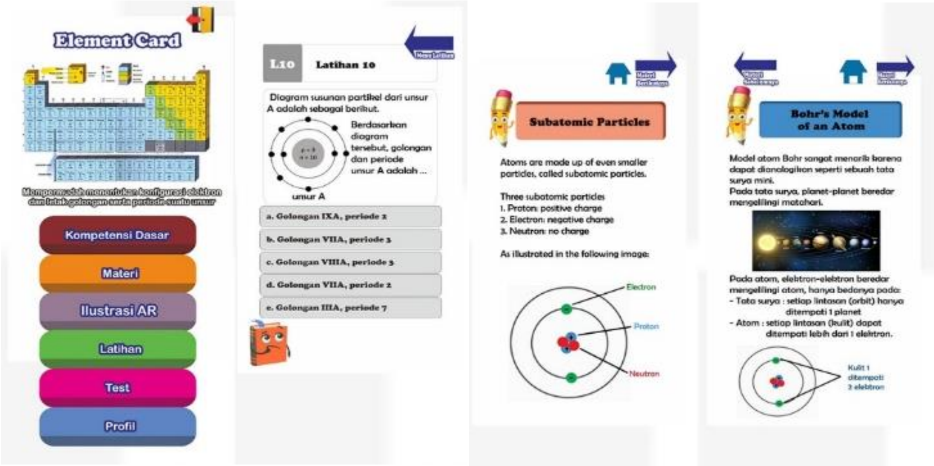

Figure 1. Element Card app view

The Element Card application contains basic competencies, teaching materials, 3D object display with augmented reality display, practice questions, pretest-posttest questions, and researcher profiles. Display of 3D objects displayed (Figure 2).

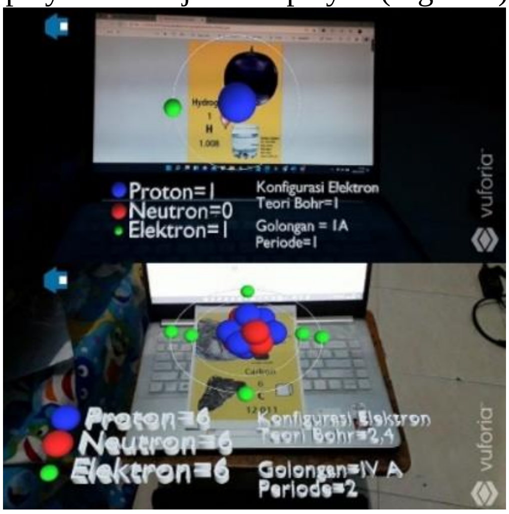

Figure 2. Display markers offline and online

Complete media files can be accessed at the following link: bit.ly/elementcard

Develop Stage

The development stage was carried out to test the validity of the Element Card media which is described in.

Validation

The Element Card was validated by two lecturers from the Chemistry Department, FMIPA State University of Surabaya and one chemistry teacher at SMAN 1 Gedangan Sidoarjo. The validation results were developed based on the Plomp (2010) validation which consisted of content validity and construct validity. This Interactive Media got several revisions before being tested.

Revision

Element Card was revised based on the revised data generated as follows:

Table 6. Validation Results

No.	Rated aspect	Percentage (%) and Criteria
1.	Content Validation	
	Material Coverage	93 (Very Valid)
	Material Accuracy	89 (Very Valid)
	Current	83 (Very Valid)

No.	Rated aspect	Percentage (%) and Criteria
	Skills	84 (Very Valid)
	Average	88 (Very Valid)
2.	Construct Validation	
	Characteristics related to chemistry	80 (Valid)
	Adapted to the Characteristics of Learners	83 (Very Valid)
	Has a guiding element	87 (Very Valid)
	Display color, graphic size, and animation	82 (Very Valid)
	Language Validation	87 (Very Valid)
	Average	84 (Very Valid)

Content validity shows that the electron configuration material according to Bohr's theory and practical skills on the media is said to be valid because it reaches an average of 88% so it is included in the very valid category. In line with Widarti's research (2018), students will easily understand the material if they have a good understanding.

Construct validity shows characteristics related to chemistry, adjustment of student characteristics, having guiding elements, appearance, and language in the media are categorized as very valid because they reach an average of 84%. The advantages of the media developed are interactive media that have been integrated with augmented reality technology. In line with Nopihargu (2014) states that it can help students understand abstract material at the submicroscopic level. This is proven to make it easier for students to understand the abstract concept of electron configuration according to Bohr.

The data obtained in Table 6 states that the validation of each aspect is very valid because an average of 88% and 84% are obtained. So that this media is considered feasible in terms of validity because of the percentage ≥ 61%.

Limited Trial

Limited trial was conducted at SMAN 1 Gedangan Sidoarjo on 30 students of class X IPA 6. This activity was carried out to obtain response data, observations, and students' pretest-posttest scores. The data is used to measure practicality and effectiveness.

Practical Interactive Media

Data on the practicality of the media were obtained after learning by taking student response data and the following data were obtained:

Table 7. Student Response Results

No	Rated aspect	Percentage (%) and Criteria
1	Ease of students in using the application	8167 (Very Practical)
2	Language in interactive media	98.89 (Very Practical)
3	The benefits of interactive media	100 (Very Practical)
4	Student interest in using Element Card as a learning medium	98.89 (Very Practical)
	Average	94.86 (Very Practical)

The data in Table 7 obtained a percentage with an average of 94.86% so that it is very practical when viewed from the student's response. Student responses were carried out to find out the advantages and disadvantages of developing Element Card interactive media. Learning media using augmented reality is a new thing according to students. In line with this research, Liono (2021) reported that AR technology can display 3D objects as a visualization of abstract concepts. And Ramadani (2020) which states that the responses of students and teachers to the Augmented Reality-based learning module that was developed also obtained high and very high categories with a percentage of 80.38% and 100%, so the module was said to be practical.

This activity also obtained data from observations made by three observers during the learning process. The data obtained are written in Table 8.

Table 8. Student Observation Results

No.	Aspects observed	Percentage (%) and Category
1	Having no trouble installing apps on Android devices	67 (Practical)
2	Can run applications without problems	100 (Very Practical)
3	No difficulty in configuring apps with media	100 (Very Practical)
4	Can scan markers on element cards without any problems	100 (Very Practical)
5	Can bring up 3D objects after scanning the marker on the card	100 (Very Practical)
6	Can drag and zoom 3D objects that appear	100 (Very Practical)
7	3D Stable object above available marker	100 (Very Practical)
8	Can display an animated image on the marker	100 (Very Practical)
9	Can use interactive media easily	100 (Very Practical)
10	Understand how to use interactive media with the help of Augmented Reality	100 (Very Practical)
11	It is clear that the information contained in the interactive media	100 (Very Practical)
12	Enthusiastic about using interactive media based on Augmented Reality	100 (Very Practical)
	Average	97 (Very Practical)

Data obtained in Table 8 states that the results of student observations are in the very practical category because they get an average of 97%. So that this interactive media development research is considered feasible in terms of practicality because it gets a percentage of 61%. These results are supported by Bau's research (2022) from the observation that teaching and learning activities after being given treatment are more effective than before being treated. Thus learning using augmented reality media is interesting and interactive so that learning feels fun and motivating while learning.

Effectiveness of Interactive Media

The effectiveness of interactive media is obtained from student learning outcomes data which was carried out with limited trials on students during the learning process using the Element Card media developed using a one group pretest-posttest design system as follows (Table 9).

Table 9. Student Learning Outcomes

	Medium Category	High Category
N-Gain Average	0.49	0.95
Student	7	23

Data in Table 9 states the average N-Gain value in the medium and high categories with the description of 23 students in the high category and 7 students in the medium category. The test results before using the Element Card contained 63% of students who did not complete the electron configuration sub material according to Bohr's theory with an average value of 53% based on a minimum completeness standard of 75. The test results after using the developed media were 93% of students completed the test with a significant increase in score an average of 93%. Then, the pretest and posttest data were analyzed again using the Wilcoxon Signed Ranks Test using the IBM SPSS Statistics 25 software. The results of the Wilcoxon Signed Ranks Test are shown in Table 10.

Table 10. Results of the Wilcoxon Signed Ranks Test

	Posttest-Pretest
Z	-4.808
Asymp. Sig. (2-tailed)	0.000

Wilcoxon test was conducted to determine whether there was a difference between the paired samples tested. Table 10 shows the Asymp.Sig (2 tailed) value of 0.000 which is smaller than 0.05, so the hypothesis is accepted and there are differences in students' pretest and posttest scores. Then it was concluded that class X students' influence in using the developed media and the interactive media Element Card using augmented reality was declared effective in terms of student learning outcomes. In line with Irwansyah's research (2018), which states that AR-based media with test results is considered feasible for learning resources with 70.83-92.50%. And supported by research by Kamelia (2015) which states that augmented reality provides interaction in reality. So that students learn more effectively.

CONCLUSION

The conclusion obtained is that the Element Card media is said to be very valid with the results of content validation of 88% and construct validation of 84%. Media Element Card is said to be practical with response results of 94.86% and student observations of 97%. Media Element Card is said to be effective because the Asymp.Sig (2 tailed) value of 0.000 is smaller than 0.05 so that there are differences in students' pretest and posttest scores. Therefore, Augmented Reality-based Element Card Media is concluded to be suitable for use as a chemistry learning media.

RECOMMENDATION

The development of interactive media based on Augmented Reality Element Card can be used during online learning, because the markers used to create 3D objects can be used without having to print them first.

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