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Development of TAPUBA Puzzle as an Independent Learning Medium for the Periodic System of Elements

Muhammad Zamhari[1], ✉, Aslam Hanif [1], dan Pandu Ridzaniyanto[2]

[1]Pendidikan Kimia, Fakultas Ilmu Tarbiyah dan Keguruan, Universitas Islam Negeri Sunan Kalijaga, Gedung H.Moh.Dahlan lt.2 Kampus Gondokusuman Yogyakarta 55281, Indonesia
[2]Sekolah Menengah Atas Kolombo, Sleman, Yogyakarta, Indonesia

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Abstrak

Materi sistem periodik unsur merupakan materi kimia yang harus dipelajari secara mandiri. Namun, kurangnya media yang mendukung hal ini menjadi masalah. Penelitian ini bertujuan untuk mengembangkan TAPUBA *puzzle* sebagai media pembelajaran kimia mandiri tabel periodik unsur untuk siswa SMA. Penelitian ini bertujuan untuk mengembangkan TAPUBA *puzzle* sebagai media pembelajaran mandiri untuk belajar tabel periodik. Penelitian ini menggunakan metode *Research and Development* (R&D). Tahapannya adalah analisis, proses pengembangan, validasi produk, dan penilaian. Sebelum dinilai oleh empat guru kimia dan sepuluh siswa SMA kelas X program IPA dan matematika, TAPUBA *puzzle* divalidasi oleh ahli media dan ahli konsep. Seorang ahli instrumen memvalidasi instrumen yang digunakan. Hasil validasi oleh ahli media dan ahli konsep menunjukkan bahwa media tersebut valid ditinjau dari kinerja media dan materi sistem periodik unsur. Penilaian guru dan siswa menunjukkan bahwa media mencapai 89 dan 95% dalam kategori sangat baik. Hasil penelitian menunjukkan bahwa media ini layak digunakan dalam proses pembelajaran kimia pada materi sistem periodik unsur.

Abstract

The material for the periodic system of elements is a chemical material that should be studied independently. However, the lack of media that supports this is a problem. This study aims to develop the TAPUBA puzzle as an independent chemistry learning medium for the periodic table of elements for high school students. This study aims to develop the TAPUBA puzzle as an independent learning media to learn the periodic table. The research used Research and Development (R&D) methods. The stages were analysis, development process, product validation, and assessment. Before assessment by four chemistry teachers and ten high school students in class X science and mathematics program, the TAPUBA puzzle was validated by media and concept experts. An instrument expert validated the instruments used. The validation results by media experts and concept experts show that the media is valid in terms of the performance of the media and the material of the periodic system of elements. Teachers' and students' assessments showed that the media performed 89 and 95% in the excellent category. The results show that this media is suitable for use in the chemical learning process of the material on the periodic system of elements.

✉Alamat korespondensi:
E-mail: muhammad.zamhari@uin-suka.ac.id

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INTRODUCTION

The use of technology plays a vital role in the science learning process in the industrial revolution 4.0 era (Yu *et al.*, 2021; Yuliati & Saputra, 2019). The COVID-19 pandemic condition also compels the learning process to be carried out by distance learning (Schneider & Council, 2020). Thus, the role of technology in distance learning activities is inevitable (Almarzooq *et al.*, 2020). Science learning needs much interaction in the process that constrains the learning process is executed synchronously (Daniel, 2020; Marek *et al.*, 2021). However, not well-distributed internet signals in Indonesia and the low economic condition have become a massive obstacle to online learning (Herliandry *et al.*, 2020).

As a part of science, chemistry learning also faces a current condition. Chemistry is a subject that is closely related to the experiment, and the information is obtained from the laboratory (Hamidah *et al.*, 2018; Ural, 2016). One of the materials in chemistry learning is the periodic system of elements. Compared to other laboratory-based chemistry materials, the periodic system of elements uses more the memorization method (Setyawati, 2019). The periodic system of elements deals with the arrangement of chemical elements based on their properties and characteristics. This material is taught at the beginning of chemistry subject in high school. As the introduction of chemistry at senior high school, this material is vital to further chemistry learning (Rokhmah *et al.*, 2017). Also, this material is the starting point for students to learn chemistry. The initial impression obtained in studying chemistry psychologically affects the motivation of students to explore other chemistry materials (Rosa, 2012).

The periodic system of elements is material in high school chemistry that should be studied independently (Franco *et al.*, 2015). Besides being learned by memorizing, the arrangement of elements in the periodic table can be understood by their electron configuration. A specific pattern based on the number of electrons should make this material advantageous over other chemical materials in senior high school (Hoffman & Hennessy, 2018). Enrichment Diverse exercises should help students understand (Rathakrishnan *et al.,* 2018). Packaging The material for the periodic table of elements should be able to do more interesting (Hoffman & Hennessy, 2018).

An excellent initial impression should be given to make students enjoy studying chemistry. Many ways can be done to make a positive impression. The proper learning method will help students get a positive image of chemistry (Marheni & Suardana, 2017). However, it is difficult to do during the pandemic because of the many obstacles found in online learning (Turmuzi *et al.*, 2021). The use of alternative technologies is possible to overcome these problems (Herliandry *et al.*, 2020). The development of exciting learning media for the material of the periodic system of elements is executable.

Previous studies on periodic system learning media development have been executed, especially in Indonesia (Cahyana *et al.*, 2018; Hidayah *et al.*, 2017; Latifah & Lazulva, 2020). However, not much research supports fun learning. Most of the development carried out is non-interactive and one-way. The exercises available are like that available in the textbook. This condition keeps these media less challenging in independent learning activities (Ainley, 2006; Taber, 2015). Therefore, it is necessary to develop alternative learning media.

The puzzle for Android-based periodic system material is a powerful option. The puzzle is a game that is easy to find in everyday life. This is a fun game and can be played individually or in groups. It consists of pieces of pictures, boxes, letters, or numbers and is played by arranging the pieces to form a specific pattern precisely and quickly (Zamhari & Setiawati, 2017). Puzzle media has several advantages, such as attracting students' interest in learning. The puzzle pieces' arrangement can overcome space and time limitations (Herawati, 2012). To be able to complete the puzzle, the student is required to understand the material. Therefore, they will be motivated to learn better and focus on ending the game. Using visual media as a puzzle can help students learn more actively and be skilled in solving their problems (Pramudiani *et al.*, 2014). Android-based media is a potential option for learning the periodic system of elements (Kusumawardhani *et al.*, 2017; Wahyu, 2017). Android is the most widely used operating system compared to other operating systems used by 91.42% in Indonesia (Statcounter, 2021). The combination of fun learning and easy access to tools and applications will be a synergetic value for easy and fun learning.

This study aims to develop an application for the TAPUBA Puzzle Game (TAPUBA stands for Table Periodic Puzzle Berbasis Android). This study also investigates the quality and response of students to the developed application. The TAPUBA application is designed to have tiered challenges, from easy to more complicated stages. This step can make students curious and indirectly makes students challenged to learn more (Eyupoglu & Nietfeld, 2019). In addition, students will learn the periodic system of elements which is the primary material for studying chemistry.

METHODS

The research and development (R&D) method is employed in this research. This method aims to produce and assess the developed product (Sugiyono, 2010). The product developed in this research is the TAPUBA Puzzle containing a puzzle game on the material of the periodic table of elements (**Error! Reference source not found.**).

The analysis step was carried out before developing the media. The analysis carried out in this study was a needs analysis. The needs analysis aims to determine the problems in the chemistry learning process. This analysis is fundamental to ensure that the product developed is suitable for the media needs. It was done through an interview with students at the state secondary madrasah (MAN) 3 Bantul Class X Math and Science (MIA) program about chemistry subjects.

The instrument used to collect data from four chemistry teachers consisted of four aspects: learning characteristic aspect, game usability aspect, mobility aspect, and gameplay aspect. As for students, the instrument consists of the learning content aspect, game usability aspect, mobility aspect, and gameplay aspect. The instruments were developed based on a literature review of the criteria for good learning media. Prior to use, the instruments were validated by an instrument expert.

The material on the product was collected from the chemistry curriculum of senior high school in Indonesia on the material of the periodic table system. The game developed is a puzzle type. The game was made using the software *Construct2* and exported to *html5*. Then, the build process was carried out with the help of the PhoneGap application. The downloaded .apk file from the build process was transferred to an Android-based smartphone, and the installation was carried out.

Experts validated the product before the assessment stage. Two experts involved were media and concept experts. The media expert in this study was a lecturer who understood android-based learning media well. The media expert suggested developing puzzle products from the game's usability, mobility, and gameplay aspects. The material expert was a chemistry lecturer who understood chemistry well, especially the material of the periodic system of elements. The expert validated the media in the aspect of learning material content. This step is necessary to ensure the product developed has the appropriate scope of matter for the periodic system of elements.

Four senior high school chemistry teachers assessed the android module. The product was also tested on ten senior high school students, class X, majoring in Mathematics and Natural Sciences (MIA) in Yogyakarta. This stage was investigated to get feedback on the convenience and usefulness of the product. Teachers and students assessed the media with a table containing four categories.

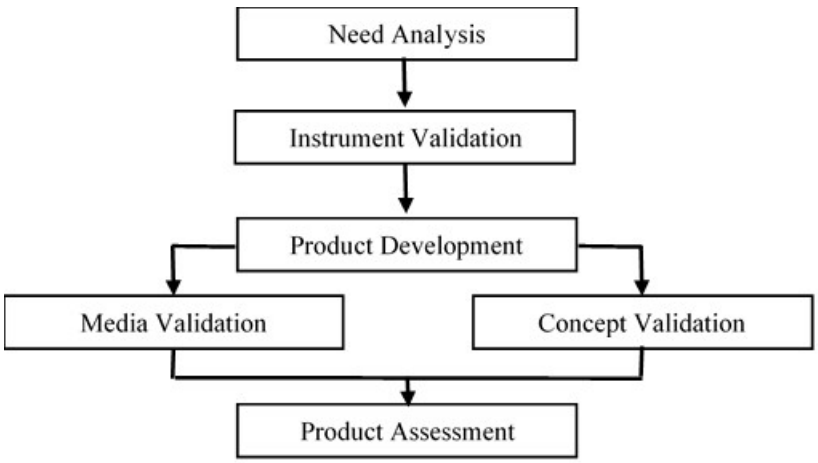

Figure 1. The method of TAPUBA puzzle development as a learning media for senior high school students

RESULTS AND DISCUSSION

Analysis

A needs analysis was conducted by interviewing students of class XI MIA 1 and MIA 2 MAN 3 Bantul. The results indicated that they have difficulty and boredom in learning chemistry. In addition, they also considered chemistry as one of the most complex subjects. The periodic system of the elements was one of the materials they found boring. This condition might be due to teachers' lack of various learning models in learning chemistry (Nastiti *et al.*, 2018). It made students find difficulty understanding chemistry to impact learning outcomes (Pegrum *et al.*, 2015). Learning media development to overcome these difficulties is expected to solve the problems (Hoffman & Hennessy, 2018).

Instrument validation

The instrument is an essential tool to measure the developed product. A good instrument can measure precisely (Danczak *et al.*, 2020). The development of the instrument was based on a theoretical study conducted on the criteria for applying good learning media (Table 1). The instrument developed was successfully validated by an instrument expert. The assessment instrument by the teacher includes an assessment of learning characteristics, game usability, mobility, and gameplay aspects. Then, the instrument by students contained aspects of game usability, mobility, gameplay, and the usability of learning media.

Assessment of learning content consisted of the suitability of TAPUBA media to learning materials contained in core competencies, basic competencies, and learning objectives; easy to learn independently; and the language is easy to understand. Assessment of game usability aspects covered game usability, including audio-visual presentation; efficient and attractive screen layout; consistency of navigation buttons, logical and minimalistic; ease and flexibility of game controls; good feedback; and providing help options. The mobility aspect of the media was studied by the speed of the game start and the game's accommodation to users. The gameplay of TAPUBA was investigated by the game objectives clarity; awards to players; control by the player; straightforward gameplay; consistency, and game not stagnating. At the same time, the usability aspect of learning media was assessed from the students' speed in using games; the ability to increase the knowledge when played; time flexibility; zero error of the game; and fun to play.

Product development

The product developed was the TAPUBA learning media which contains a puzzle game on the Android-based periodic table of elements. The media was developed using the software construct two from Scirra, exported to html5, and then built using the PhoneGap application. The application is in the form of .apk file. It can be used on a smartphone during the installation process. The application can be downloaded at the link https://bit.ly/3v9BwqN. The TAPUBA can be played either online or offline.

Table 1. Assessment instrument for TAPUBA puzzle as a learning media

Aspect	Teacher	Student	Criteria
Learning Characteristic	√	–	Conformity with Indonesia's national chemistry curriculum
			Conformity with learning objectives
			The ease of use independently
			The ease of language to understand
Game Usability	√	√	Audio-visual presentation supports the game
			Efficient screen layout and attractive appearance
			Consistent, logical, and minimalistic navigation buttons
			Control game easiness and flexibility
			The game provides feedback on user actions
			Help availability
Mobility	√	√	The game and play sessions can be started quickly
			The game accommodates users who needed
			Glitches/problems can be handled
Gameplay	√	√	The game presents a clear goal
			Awards for players are provided
			The ease of control by the player,
			Clear gameplay,
			The game is not stagnant
			The game is consistent
Usefulness	–	√	The game accelerates student understanding
			The game improves student knowledge
			Reusability of game
			Zero mistakes

Fun to use and user-friendly

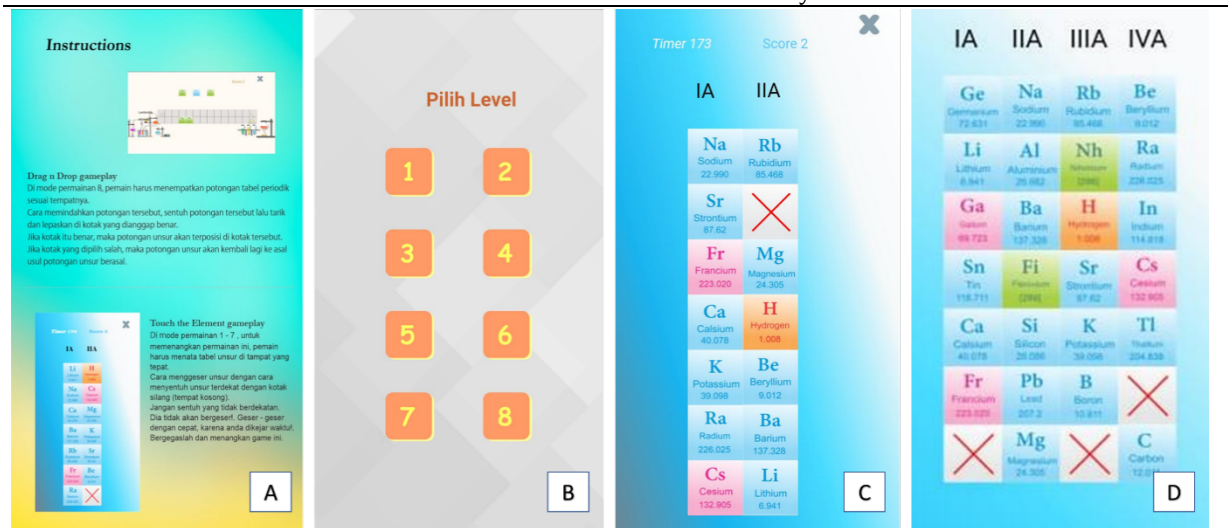

Figure 2. The performance of the TAPUBA puzzle of (A) media instruction, (B) available levels, (C) the example of the game at level 1, and (D) level 2

The developed media provides the instruction for use (Figure 2.A) and has eight levels of difficulties (Figure 2.B). The difference in the level of this game made students curious and chose a game with a higher level. This game is played by placing the pieces of the periodic table according to their place (Figure 2.C and Figure 2.D). The X symbol in the box is a space where the surrounding box containing elements can be shifted. The boxes of elements must be moved until an arrangement follows the group and periodicity.

The rules of this game require students to think about the position of the elements that should be and how to adjust the shifting process to provide appropriate elements arranged according to the group and periodic order. It is because the boxes around the X box can only do the shift. The lower level of the game has fewer elements with the help of X boxes (Figure 2.C) compared to the higher level (Figure 2.D). It is because arranging more elements requires more X-box assistance.

Each game at the same level is arranged randomly and provides different initial order if students start at the same level at other times. It compels the students not just to memorize previous games at the same level. Students must think critically about the steps that must be taken to produce an arrangement that matches the order of atomic numbers within a limited time. Determining the group and periodicity of the available atomic numbers forces students to calculate the correct group and periodicity quickly. Students also take advantage of the element symbol available in groups and periodic determinations. This combination increases students' memory of the position of an element and the logic of its placement (Rathakrishnan *et al.*, 2018).

Expert validation and product assessment

Before four chemistry teachers and ten students carried out the assessment, the media developed was validated by material experts and media experts. This step was taken to ensure that the product follows the periodic system of elements material and meets the criteria for appropriate learning media to be used in the learning process. Researchers followed up on the suggestions from concept and media experts to produce relevant learning media. The conclusion from this stage shows that the media is materially valid, and the resulting application is feasible to use.

The media that passed the material and media validation stage were then assessed by four chemistry teachers (Table 2). The assessment results obtained a total score of 57 from the ideal maximum score of 64. The ideal Percentage of the chemistry teachers' assessment performed 89.06% with an outstanding category. Further assessment by ten students received a total score of 152 from the ideal maximum score of 160 (Table 3). Its ideal Percentage was 95.00%, with excellent criteria. The excellent quality of the TAPUBA puzzle was obtained because researchers paid attention to aspects of chemistry in senior high school curricula and followed the quality aspects of good Android-based learning media in the development process. In addition, the validation of concept and media experts enhanced media quality. The results indicate that the TAPUBA puzzle learning media can be used in the chemistry learning process on the periodic system of elements. Further research on students in the learning process needs to be carried out to provide more benefits for the results of this media development.

Table 2. TAPUBA puzzle assessment by four chemistry teachers in senior high schools

Aspects	Total score	Ideal maximum score	Average score	Ideal percentage (%)	Category
Learning content	14	16	3.50	87.50	Very good
Game usability	13	16	3.25	81.25	Very good
Mobility	15	16	3.75	93.75	Very good
Game play	15	16	3.75	93.75	Very good
Total	57	64	3.56	89.06	Very good

Table 3. TAPUBA puzzle assessment by ten students in senior high schools class X in the program MIA

Aspects	Total score	Ideal maximum score	Average score	Ideal percentage (%)	Category
Game usability	39	40	3,90	97.50	Very good
Mobility	37	40	3,70	92.50	Very good
Game play	37	40	3,70	92.50	Very good
Media usability	37	40	3,90	97.50	Very good
Total	152	160	3,80	95.00	Very good

Table 4. A comparison of media development on periodic table material for senior high school student

Learning media type	Ideal Percentage		Category		Reference
	Teacher	Student	Teacher	Student	
TAPUBA	89.06	95.00	Very good	Very good	This work
Kotak Katik	-	83.33	-	Very good	(Hidayah et al., 2017)
Video Powtoon	-	88.35	-	Very good	(Latifah & Lazulva, 2020)
Android-based mobile learning	94.00	93.00	Very good	Very good	(Cahyana et al., 2018)

A comparison of this work with previous research shows in Indonesia that the media of this work obtained a better result (Table 4). Hidayah et al. (2017) successfully developed *Kimia Kotak Katik* as a learning media for the periodic system of elements. However, However, the physical form of media is not comfortable to carry and use anywhere. Latifah and Lazulva (2020) developed media for the periodic system of elements that is easier to use anytime and anywhere. However, the media is a one-way interaction. Android Based Mobile Learning by Cahyana et al. (2018) provides better scores for teachers and students. However, fewer and less challenging questions exercises give TAPUBA provides better advantages.

CONCLUSION

The TAPUBA puzzle has been successfully developed as an independent learning media for the periodic table of elements. The developed media was declared valid by the concept expert and media expert. Furthermore, product assessment by four chemistry teachers and ten students showed an excellent category with ideal percentages of 89.06% and 95.00%, respectively. These results indicate that the TAPUBA puzzle can be used in the chemistry learning process of Senior High School material on the periodic table. Further research is needed to do to provide more benefits of media use.

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