

Development of Interactive Multimedia on Electron Configuration Concept

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Abstract:

Interactive multimedia has an important role in the learning process. The interactive multimedia presented the learning material in various forms and supported students' understanding of those who have different learning styles. To help students understand the topic and to facilitate students' learning style the PeT-EFig is developed. PeT-EFig (periodic table and electron configuration) as interactive multimedia which supported students' understanding of electron configuration concepts. The objectives of this study were a) to determine the feasibility of PeT-EFig, and b) to determine the response of chemistry teachers and students of PeT-EFig as interactive multimedia. The research method used is research and development (R&D) using the ADDIE model with five stages: analysis, design, and development stages. However, the research was only conducted up to the development stage due to time constraints. Based on the result, PeT-EFig is considered very suitable by the experts with 96 and 95% respectively. Likewise, teachers at SMA Muhammadiyah 1 Pontianak who teach chemistry subjects, stated that they strongly approved PeT-EFig as interactive multimedia on electron configuration 96%. Additionally, students also provided very positive feedback on the PeT-EFig through a small-scale trial involving 15 students with an average percentage of 87% for each aspect. Similarly, when a large-scale trial with 40 students, the final percentage score for each aspect was found to be 87%. The result indicated that the PeT-EFig could assist teachers in delivering the concepts and help students understand the electron configuration and atomic structure.

Keywords: Development; interactive multimedia; articulate storyline; electron configuration

Introduction

Learning chemistry requires knowledge of signs, symbols, diagrams, vocabulary, and many more, making the teaching and learning of chemistry challenging. This causes many students to face difficulties in learning chemistry (Emendu et al., 2020; Sibomana et al., 2020). Most students have a negative view of learning chemistry because it is a complex subject. The hierarchical and complex nature of learning chemistry makes the understanding of previous topics a prerequisite for learning subsequent topics. The intricate and interconnected concepts often lead students to face difficulties in learning (Siregar, 2021). Students' struggles with understanding chemistry concepts in chemistry lessons

result in students being unwilling to study it, leading to low learning achievements (Kausar et al., 2022). Students tend to resort to rote memorization, which limits them to presenting memorized content without a deeper understanding (Sibomana et al., 2020). In reality, chemistry is often perceived by the majority of students as a subject that is considered boring and difficult (Hsiung, 2018; Opatye & Ewim, 2022).

Several factors contribute to students' difficulties in learning chemistry, including a lack of understanding of chemistry concepts, limited interaction between teachers and students, an overwhelming amount of teaching material with insufficient variation in exercises, and a lack of diverse learning media (Timilsena et al., 2022). The difficulties faced by students in learning chemistry must be addressed by various parties involved in the chemistry learning process, and one of them is certainly the teachers. According to Marwanto (2021), as the learning process evolves, there is a consequence for teachers to enhance their role and competence by becoming leaders in class, facilitators, and mediators. As mediators, teachers must select and provide suitable learning media according to students' needs in increasing understanding of the concepts covered in the learning process (Chauke & Tabane, 2021; Niemi & Niu, 2021).

Learning media is a very useful part of every learning activity because interesting, creative, and innovative learning media attract students' attention and facilitate the teaching and learning process to support the achievement of learning objectives (Syahputra & Maksum, 2020). Learning media used to enhance the achievement of learning objectives are integrated with the use of information and communication technology in the learning process, aligning with the current technological advancements (Hikmah, 2019). Just as the 21st century marks the heyday of technology, it also contributes to the world of education by generating numerous innovations to support the learning process. 21st century learning, which focuses on students, necessitates the integration of technology into instructional media while aligning with the existing curriculum (Tarigan et al., 2021). Media integrated with information technology in the learning process aims to provide convenience for both teachers and students (Sudarsana et al., 2019). Learning media can serve as stimuli to stimulate students' interest or motivation to learn and facilitate the delivery of content. This is done to ensure that the material delivery process does not solely rely on the lecture method, static textbook usage, and the provision of memorization materials given by teachers during the learning process. However, the lack of interactivity and difficulties in visualizing abstract chemical concepts may lead to misconceptions about the material (Hsiung, 2018; Musengimana et al., 2021).

In the era of the industrial revolution, there were various media, and even a combination of several media could be combined into one device known as multimedia. Through multimedia navigation, an integrated combination of text, images, graphics, sound, video, animation, and simulation with the help of computers or the like is used to achieve learning objectives (Putri et al., 2022). The utilization of multimedia in a device can address students' boredom with learning and create an active and creative atmosphere (Syahputra & Maksum, 2020), eliciting feedback that encourages student learning (de Kleijn, 2023). This also helps teachers convey the learning concepts to students easily, and to reach the learning goals. The use of multimedia is an effort for teachers to present concepts in various forms to help students who have various types of learning styles, from visual, auditory, and kinesthetic, to be able to absorb information optimally according to their learning style (Janakiraman, 2023; Nabung, 2023).

Students who psychologically, have difficulty understanding chemistry due to its abstract nature can be aided by using interactive multimedia (Palma et al., 2021). Interactive multimedia in the learning process can be created using several software, namely articulate storyline 3, which produces various software output formats such as 5, mp4, swfhy, etc., serving as a self-learning tool for students (Mawaddah et al., 2022). Articulate storyline 3 has many features that present products as interactive multimedia

with practical value and be used anytime and anywhere for its users. Research by Septiana et al. (2022) and Ananda et al. (2023) shows that the application of interactive multimedia based on articulate storyline as a valid and practical medium has the potential to significantly influence motivation and be effective in improving student learning outcomes.

Therefore, the use of interactive multimedia in chemistry learning that does not involve practical work is considered very appropriate because students can interact with the learning concept through media (Harding et al., 2018). One of the chemistry topics that does not involve practical work is electron configuration. The electron configuration is a fundamental aspect of chemistry education. However, students still experience many difficulties, because the material on the concept of abstract entities requires understanding at a microscopic and symbolic level, so they have a great tendency to experience misconceptions (Sari et al., 2019). This is in line with the results of observations conducted during teaching assistance activities in the first semester of the academic year 2022/2023 at SMA Muhammadiyah 1 Pontianak, and direct interviews with students who expressed difficulties in the electron configuration concept, thereby facing challenges in the periodic system of elements. Teachers also express that the lecture method is less effective for students to understand the topic. Likewise, research by Afrianis & Ningsih (2022) and Adi & Azra (2023) with chemistry teachers, stated that the concept of the atomic structure was difficult to explain concretely due to its abstract nature. Hence, they use the lecture method and ask students to take notes on the key points presented in the learning. This gives the impression of "content transmission," where interaction between teachers and students is only one-way, making it difficult for students to understand the concepts explained in the learning material.

To address the difficulty of delivering the learning material, chemistry teachers at SMA Muhammadiyah 1 Pontianak use powerpoint as a learning media to attract I students' interest in chemistry learning. According to Lyu et al. (2023), powerpoint is a medium that is often used by teachers in classroom learning, but it is still limited and lacks variety so it is considered monotonous for students (Rahayu & Agustiana, 2023). Therefore, a learning media that can collaborate various information is needed to facilitate teachers in delivering learning material and enhance students' understanding and motivation related to learning material through the learning media used. Based on this, it is necessary to develop learning media for students in learning electron configuration concepts. The learning media commonly found for such instruction include textbooks, powerpoint presentations, and periodic tables (Suryelita et al., 2019). Therefore, the researchers developed instructional media that integrates various media to produce interactive multimedia. This multimedia is named Pet-EFig, which is a combination of the constituent words (periodic table and electron configuration). Through PeT-EFig, the researcher aims to determine the feasibility level and teacher response to PeT-EFig as interactive multimedia on the electron configuration concept. With the development of this interactive multimedia, it is hoped to produce learning media that helps students understand electron configuration-related concepts. Based on the needs analysis conducted by the researchers at SMA Muhammadiyah 1 Pontianak, it appears that students required interactive learning media. This was supported by the results of interviews with several students who expressed a preference for learning that includes videos and games, rather than solely relying on textbooks and powerpoint presentations. Teachers also stated that students need interactive learning media to better understand abstract concepts such as electron configuration.

Methods

This study belongs to the type of research and development. In the field of education, the application of these methods is used to produce, develop, and validate effective educational products for learning programs, both in hardware and software forms. Research and development with the ADDIE model as an instructional process involves the stages of analysis, design, development, implementation, and evaluation (Yu et al., 2021).

In this research, PeT-EFig was developed as an interactive multimedia with three stages of analysis, design, and development, due to time and cost constraints. In the analysis stage, the process involves analyzing the need for the development of learning media. This stage is conducted to identify problems and needs in the learning process through problem identification using literature studies and field investigations (observations) (Bachri et al., 2024). In this stage, performance and needs analysis are conducted through observations and interviews with teachers and students. The design stage is where the multimedia is designed, and learning devices are arranged. Designing multimedia begins by determining learning objectives, collecting references, designing storyboards for the multimedia to be developed, and preparing supporting elements and research instruments in the form of validity test questionnaires and response test questionnaires (Apriani et al., 2021; Sutiani et al., 2021). The development stage involves creating multimedia according to the design in the storyboard. In this stage, the research instruments, containing concept and media validation sheets and questionnaires for teacher and student response tests, are validated by two instrument validators. The validation of each statement in the instrument aimed to ensure the feasibility of the research instrument before use (Hadi et al., 2020). The results of instrument validation were calculated using the Gregory test (Divayana et al., 2020).

$$\text{Content Validity} = \frac{D}{A+B+C+D} \quad (1)$$

From the results of the content validity coefficient calculation, the obtained values were interpreted according to the agreement scale in Table 1.

Table 1. Agreement scale for the content validity coefficient

Validation category	Very low	Low	Medium	High	Very high
Validity score range	0.00-0.20	0.21-0.40	0.41-0.60	0.61-0.80	0.81-1.00

(Source: Divayana et al., 2020)

The validated research instrument was utilized in the content validity test of PeT-EFig for concepts and media suitability. The validity test is conducted by each validator who is an expert in their field. The validation process for concept suitability was conducted by a chemistry education program lecturer from the University of Muhammadiyah Pontianak and a chemistry teacher from MAN 1 Sintang. Meanwhile, the validation for the media suitability is conducted by a lecturer from the information system program at the University of Tanjungpura and a science teacher at a junior high school who also serves as a mentor for chemistry education students from the University of Tanjungpura in training for creating media based on articulate storyline 3.

The concept's validity was assessed based on the aspects of content, concept presentation, and language. Meanwhile, the validity of the media is evaluated based on UX and UI design aspects. The validity tests for concepts and media on each aspect were assessed per item using scores that refer to the Likert scale. The assessment involves scores of 1 (strongly disagree), 2 (disagree), 3 (neutral), 4 (agree), and 5 (strongly agree). The score calculation for concept or media suitability is determined by calculating the average percentage for each aspect. This is done by dividing the total score from the validator by the maximum score and multiplying it by 100%. The percentages for each aspect are then summed and divided by the number of aspects being assessed 3 aspects

for concepts and 2 aspects for media). The results are analyzed using a percentage scale from Table 2.

Table 2. The scale of validity test assessment

Validity Scale (%)	Category	Description
81 – 100	Very valid	No need for revision
61 – 80	Valid	Slight revision needed
41 – 60	Sufficiently valid	Moderate revision needed
21 – 40	Not valid	Major revision needed
1 – 20	Not valid at all	Cannot be used

(Source: Rati et al., 2022)

In addition to the assessment, some comments and suggestions serve as the basis for revising the PeT-EFig media as a research product. The media, which has been validated and revised based on comments and suggestions from the validators, was tested with teachers who teach chemistry. The response test is conducted by two respondents, namely chemistry teachers at SMA Muhammadiyah 1 Pontianak. This is done to determine the teachers' response to PeT-EFig in terms of content, media, and language. Each statement/evaluation item is rated on a Likert scale of 1 (strongly disagree), 2 (disagree), 3 (neutral), 4 (agree), and 5 (strongly agree). After testing the teacher's response, a small-scale trial was conducted involving 15 students from SMA Muhammadiyah 1 Pontianak. Subsequently, another large-scale trial was carried out involving 40 students from outside SMA Muhammadiyah 1 Pontianak. The students who responded to the GForm questionnaire were those who had already studied the material on electron configuration and atomic structure. The assessment scale for each statement utilizes a different Likert scale compared to the teachers' response scale, namely 1 (strongly disagree), 2 (disagree), 3 (agree), and 4 (strongly agree). The response test assessment is based on the percentage of the average score for each aspect. The obtained percentage is categorized according to Table 3.

Table 3. Scale for response test assessment

Response Scale (%)	Category
81 – 100	Excellent
61 – 80	Good
41 – 60	Average
21 – 40	Not good
1 – 20	Very poor

(Source: Rati et al., 2022)

Results and Discussion

The development of PeT-EFig as interactive multimedia on electron configuration aims to determine the level of feasibility of the developed multimedia and understand teachers' and students' responses to it.

Feasibility of PeT-EFig as Interactive Multimedia on Electron Configuration Topic

The feasibility of PeT-EFig as interactive multimedia is determined based on validation results through several stages of research. The analysis stage is the initial phase of the research aimed at identifying possible causes of gaps in the learning process to determine

the feasibility of the media through the development of instructional media (Apriani et al., 2021). Performance analysis and needs analysis in chemistry learning were conducted through observations and interviews. Observations are conducted by directly observing the learning process and analyzing the learning outcomes of students. The observation results indicate that the teaching method is predominantly lecture-based, and the learning outcomes of some students fall below the standard for basic concepts. Subsequently, interviews were conducted with teachers and students to gather more information based on the observation results. According to the interviews, teachers express difficulties in delivering concepts, especially basic topics that must be mastered by students who are new to chemistry, such as students in the 10th grade. Teachers consider the importance of instructional media for delivering abstract concepts, such as electron configuration, which requires analogies close to students' daily lives. Teachers face challenges in delivering concepts, and students, in turn, find it challenging to understand the concept. Some students express the desire for repeated explanations to facilitate understanding and show enthusiasm for video and game-based learning. The result of Haloho et al. (2023) reveals that educational game media can combine visual, auditory, and kinesthetic learning styles.

Learning material and students are the main considerations in selecting instructional media because the media are designed to focus on delivering information to students (student-centered). The use of various types of media such as images, text, animations, audio, and video will facilitate students' understanding of the presented concept. This is in line with Rahayu & Agustiana (2023), where the addition of images, text, animations, audio, and video combined to display multimedia-based information can facilitate students' understanding of the concept, aligning with the learning objectives by adapting to students' learning styles. One type of multimedia, namely interactive multimedia, allows users to control, combine, and manipulate various types of media and is equipped with control tools to create active interaction by the user (Cvetković, 2019). Articulate storyline 3 is a media tool that can combine several media types and is equipped with various interactive features to support the creation of interactive learning multimedia. According to Rahayu & Agustiana (2023), interactive multimedia learning is a learning program that can be controlled directly by students, because it can adapt to the characteristics and needs of students increasing motivation and learning outcomes.

The design of instructional media is created based on the analysis of performance and needs in learning electron configuration, aligned with the learning objectives KD 3.3 (explaining electron configuration and the pattern of outer electron configuration for each group in the periodic table) and KD 4.3 (determining the location of an element in the periodic table based on electron configuration). The design stage includes the creation of validity tests and response tests (Hurrahman et al., 2022). The media design, from storyboards, outlines the sequence of media with complete supporting elements (images, audio, video, etc.) to facilitate the creation of interactive multimedia (Putri et al., 2022). In the design or design stage, hardware/devices such as laptops and smartphones are required for creating storyboards for each slide or layer displayed in the media, including learning material, icons, backgrounds, and other supporting elements, using various software such as articulate storyline 3, microsoft word, canva, capcut, website 2 apk builder pro, web browsers, and javascript.

The development stage is where the designed media can be realized (Varisa & Fikri, 2022). The product based on articulate storyline 3 is named PeT-EFig (periodic table and electron configuration). PeT-EFig consists of several slides, each with multiple layers. The introduction slide provides an overview of PeT-EFig, followed by a log-in slide requiring users to enter their name and class before accessing the media. The home slide contains a menu list with learning objectives, introduction, glossary, concept, summary, evaluation, and information, where each menu presents content within a layer. PeT-EFig is a multimedia tool that can be used both online and offline on laptops, tablets, and

smartphones. Online usage can be accessed through a link, while offline usage involves HTML format on laptops and tablets as shown in Figure 1(a), and APK format on smartphones, as depicted by the application icon in Figure 1(b).

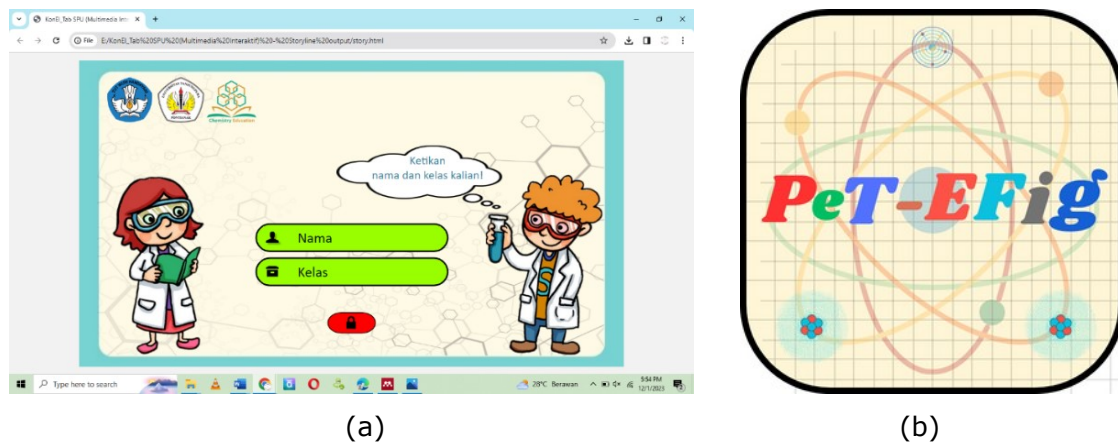


Figure 1. The display of PeT-EFig; (a) HTML format, (b) APK icon format

The development stage is followed by the validation process based on assessments from validators (Varisa & Fikri, 2022). The validation process uses a validation sheet that has been tested for validity with a content validity coefficient of 1, which means it is very valid. The validation process serves to test the feasibility/validity of the produced learning product/media before it is tested on users. Validation by validators considers several criteria in the aspects being tested to gather information or data needed to improve the multimedia's feasibility. The validation results are used for revision to correct errors and enhance the quality of the developed multimedia (PeT-EFig).

Results of concept validation

Concept validation assessment includes aspects of content feasibility, concept presentation, and language suitability with a total of 25 assessment items. The percentage results of material validation for PeT-EFig as the developed media can be seen in Figure 2.

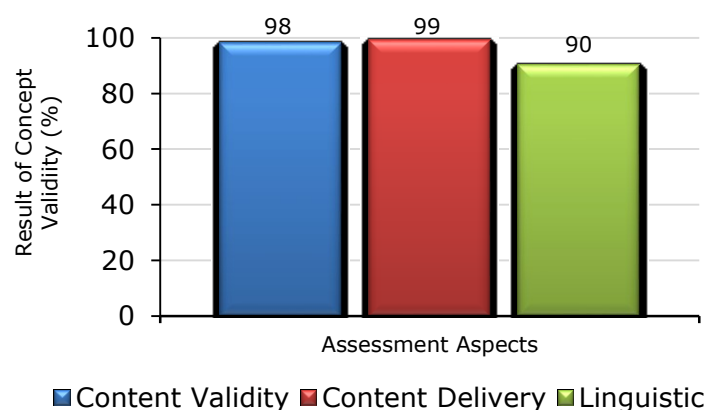


Figure 2. Concept validation result of PeT-EFig

The obtained assessment from concept validation results in an average material validity percentage of 96%. Thus, it can be categorized that PeT-EFig is highly suitable for use and tested without revisions for users. According to Hurrahman et al. (2022), comments and suggestions from validators serve as considerations for necessary revisions.

Based on Figure 2, the content feasibility aspect shows a percentage of 98%, indicating that the content or concepts in PeT-EFig are highly suitable for use. As per the compliance indicators with material competency standards, the material assessment items on the media align with the chemistry syllabus for grade X high school or equivalent in odd semesters. In the electron configuration concept, competency standard 3.3: explains electron configuration and patterns of outer electron configuration for each group in the periodic table; and competency standard 4.3: determines the position of an element in the periodic table based on electron configuration (Direktorat Pembinaan SMA, 2019). The concept follows the syllabus, aligning with the learning objectives covering electron configuration (configuration patterns based on Niels Bohr's atomic model and Quantum Mechanics atomic model) and the periodic table of elements (position of elements in the periodic system) (Rozaq & Kocimaheni, 2020). The concept is referenced from various sources to present reliable content with theories and facts. The validation results indicate that the concept in PeT-EFig is presented accurately, including chemical element symbols and data, visuals such as images and videos supporting concept understanding, as well as interestingly packaged quizzes and questions for each sub-topic to enhance students' curiosity.

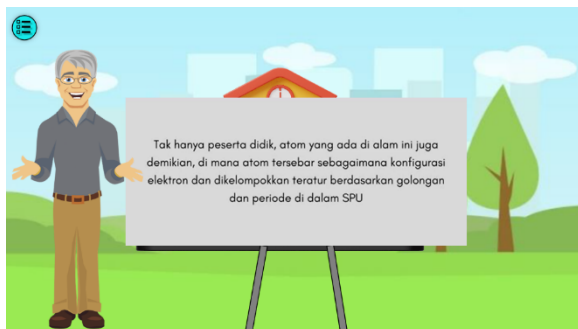
The concept presentation aspect has a rating percentage of 99%, categorized as highly suitable. This is based on the assessment of consistent and systematic concept presentation, including an introduction to the concept, explanatory videos, example questions, summaries, glossaries, and evaluations. PeT-EFig also employs a symbolic representation approach as a form of learning through knowledge in the form of abstract symbols such as symbols and formulas (Lorello & Lippi, 2023; Ünal et al., 2023). The periodic table contains symbols of 118 chemical elements, accompanied by electron configurations, energy levels, quantum number, and the location of elements in the periodic system, as well as images of these chemical elements.

The language aspect obtained a rating percentage lower than the other two aspects in concept validation, which is 90%, but still falls into the highly suitable category. This is indicated by the concept presented in PeT-EFig, which is in line with the Indonesian language spelling standard (EYD), utilizes effective and communicative sentences, and employs language suitable for the intellectual development of high school or equivalent students.

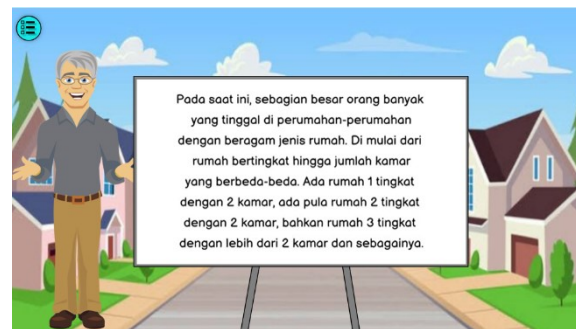
Considering the validation results across the three aspects, the concept in PeT-EFig is categorized as highly suitable, and the average concept validity score indicates high validity, allowing its use without revisions. However, the researcher cannot overlook the comments and suggestions from validators. As a result, the researcher still revises PeT-EFig based on the concept validator's suggestions, in Table 4.

Table 4. Revision of concept validity on PeT-EFig by concept validator

Before Revision	After Revision
Learning objectives are presented point by point with background music	Learning objectives are presented with text outlining the learning goals accompanied by audio that narrates the key points of the learning objectives.
The introduction to the topic is presented through a scrolling text containing an analogy of the electron configuration concept with the grouping of students at different school levels (elementary school, junior high school, senior high school).	The introduction section is transformed into scrolling text with audio narration, likening the electron configuration to a housing complex. Where the house is analogized as the atom's shell, rooms as orbitals, cost as energy levels, and people occupying the house as electrons.



In the media, the writing of electron configurations is presented with written example questions and explanatory videos.



Written example questions are removed from the media, as the videos used already demonstrate the writing of electron configurations for elements and ions.

Konfigurasi Elektron berdasarkan subkulit penulisan konfigurasi e-

Contoh Soal

Tentukan konfigurasi elektron atom di bawah ini berdasarkan teori mekanika kuantum!

(a) ${}_9\text{F}$
 (b) ${}_{34}\text{Se}$
 (c) ${}_{56}\text{Ba}$

Jawab :

(a) ${}_9\text{F} = 1s^2 2s^2 2p^5$
 (b) ${}_{34}\text{Se} = 1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^4$
 (c) ${}_{56}\text{Ba} = 1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^2 4d^{10} 5p^6 6s^2$

Sub-topic on the development of the Periodic System of Elements, in the grouping of elements, which is incomplete due to the absence of the Seaborg periodic system.

Konfigurasi Elektron berdasarkan subkulit penulisan konfigurasi e-

Contoh

Soal Latihan

Tentukan konfigurasi unsur dan ion-ion berikut:

1. a. ${}_{19}\text{K}$
 b. ${}_{25}\text{Mn}$
 c. ${}_{24}\text{Cr}$
 d. ${}_{24}\text{Cr}^{3+}$

2. a. ${}_{19}\text{K}^+$
 b. ${}_{25}\text{Mn}^{2+}$
 c. ${}_{24}\text{Cr}^{3+}$
 d. ${}_{24}\text{Cr}^{2+}$

The Seaborg periodic system is added to the SPU development, explaining that Glenn Seaborg added several chemical elements to the periodic table and named them the actinide series.

Perkembangan Sistem Periodik Unsur

Unsur-unsur yang ada di bumi, dikelompokkan berdasarkan kemiripan sifatnya. Pengelompokkan unsur menjadi golongan dan periode oleh ahli kimia, yang terus berkembang dari waktu ke waktu hingga terbentuknya sistem periodik unsur modern.

- ❖ Logam dan nonlogam
- ❖ Tabel periodik Lavoisier
- ❖ Triade Dobereiner
- ❖ Oktaf Newlands
- ❖ Lothar Meyer
- ❖ Sistem periodik Mandeleev
- ❖ Sistem periodik modern

Perkembangan Sistem Periodik Unsur

Unsur-unsur yang ada di bumi, dikelompokkan berdasarkan kemiripan sifatnya. Berikut pengelompokkan unsur-unsur kimia oleh para ilmuwan yang terus berkembang dari waktu ke waktu, yaitu:

- ❖ Logam dan nonlogam
- ❖ Tabel periodik Lavoisier
- ❖ Triade Dobereiner
- ❖ Oktaf Newlands
- ❖ Lothar Meyer
- ❖ Sistem periodik Mandeleev
- ❖ Sistem periodik modern
- ❖ **Sistem periodik Seaborg**

Memasuki tahun 1930-an, Glenn Seaborg menambahkan beberapa unsur kimia dalam tabel periodik unsur dan menamainya deret aktinida yang terpisah dari bagian utama tabel. Unsur-unsur tersebut merupakan unsur berat yang membentuk rangkaian transisi.

The revision of the concept in PeT-EFig was conducted to improve the content, presentation, and language of the concept. Concept revision for learning objectives included audio, replacing the music with a reading of the learning objectives. Similarly, for the concept introduction, an audio reading of analogy text was added to enliven the learning atmosphere and support auditory students. According to Kurniawan & Hartono (2020), learning style is the way individuals obtain information and interact with the learning environment, and auditory learning emphasizes hearing. Therefore, audio-learning interactions are more engaging than music background. A similar approach was taken in the concept introduction, with the addition of audio reading of analogy text as a

stimulus in the learning process. The analogy was changed from a school to a residential setting because the analogy of student levels in the school hierarchy as electron configurations is more suitable for the analogy of element placement in the periodic table than electron configurations. Additionally, the sub-material layer of the SPU development included the Seaborg periodic table to complement the development of the periodic table.

Result of Media Validation

Media validation involved 15 assessment items covering UX Design and UI Design aspects. The results of the media validation are presented in Figure 3.

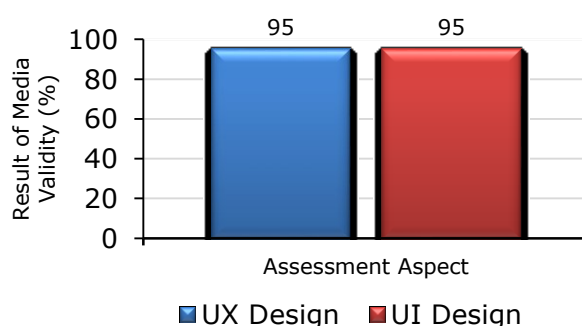


Figure 3. Media validation result of PeT-EFig

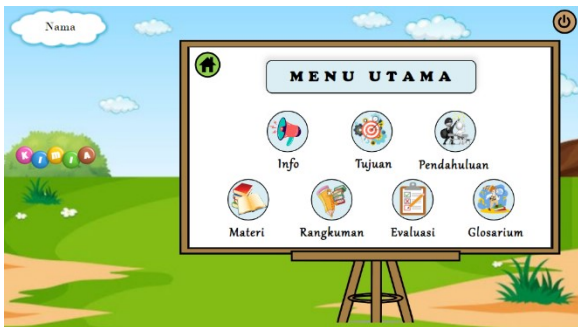
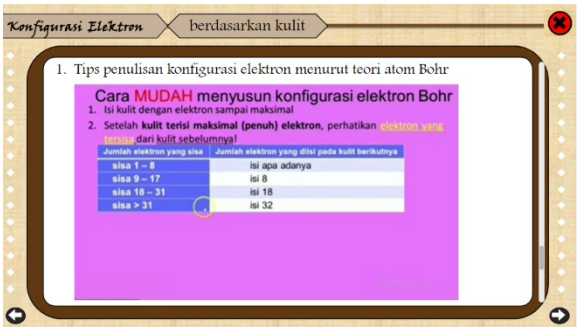
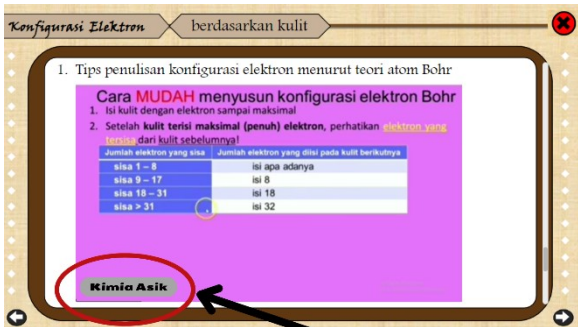
Based on Figure 3, which shows the graph of media validation results for PeT-EFig, the obtained percentages are equivalent for both aspects, UX and UI design, each with a percentage of 95%. Consequently, the average percentage of media validation is also 95%, categorized as highly valid. UX design (user experience design) and UI design (user interface design) aspects are crucial in software and software development. UX design is an aspect that focuses on the user's perceptions and perspectives that occur during, before, and after the use of a product or media. Meanwhile, UI design concentrates on the visual appearance of a system to create an appealing product or media (Divayana et al., 2020; Hernández-Campos et al., 2022).

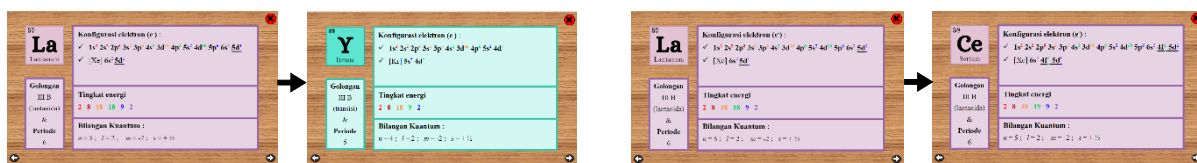
In terms of UX design, for the reliability indicator, PeT-EFig proves to be a reliable interactive multimedia. This indicates that PeT-EFig can be operated at various times and conditions without experiencing system errors or failures. Reliability in software is often understood as the software product's reliability in various usage conditions. Additionally, the very valid category is also achieved for the reusable and compatible indicators, indicating that the media can be used repeatedly and across various platforms/devices (Wilson et al., 2023). PeT-EFig is designed to be reusable through laptops, tablets, and smartphones. However, the usable indicator with lower percentage and a categorized rating of acceptable, unlike other assessment items that are highly valid. Usability, according to Kausar et al. (2022) refers to the degree of ease during the use process to achieve specified goals with efficacy and satisfaction in the context in which the system or method is used. This is because some buttons in PeT-EFig are not labeled, and the appearance of buttons in some slides with animations is quite slow. Therefore, revisions were made to the buttons, especially the home, menu, close, back, and next buttons, to be displayed on all main slides without animation.

Concerning UI design, is an assessment focusing on the visual design of media, including text, graphics, images, animations, audio, and video. The results of the UI design aspect's validation are categorized as highly valid, indicating that the visual design of the media is good and attractive. According to the research by Rahayu & Agustiana (2023), an engaging appearance in educational media can motivate students to use the learning media more effectively. In this study, there are many navigations contained within buttons, so

researchers had to check the button's compatibility with media navigation. This is to prevent navigation errors that could lead users to experience navigation problems. Through media validation, validators also provided suggestions and comments as considerations for the researcher in revising the PeT-EFig media, as shown in Table 5.

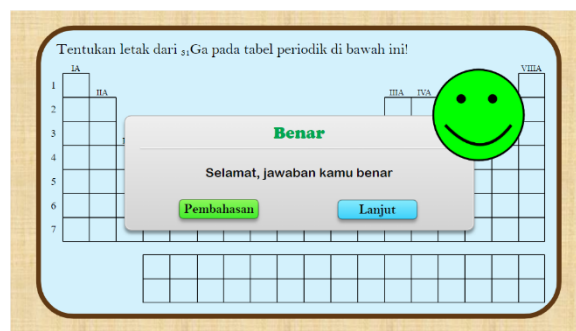
Table 5. Revision of media validity on PeT-EFig by media validator

Before Revision	After Revision
The menu display starts with objectives, introduction, and glossary on the first row, while the second row contains the material, summary, evaluation, and information menus.	The sequence of the menu list is changed to information, objectives, introduction (first row), material, summary, evaluation, and glossary (second row). This is done considering that the instructions in the information menu are important for the ease of media use. Similarly, the glossary was relocated to the last menu. Additionally, each menu's content is accompanied by audio stating the selected menu's name.
	
Explanation videos for the electron configuration sub-topic based on shells are not displayed with watermarks from the video source.	Videos quoted from YouTube are added with watermarks containing the YouTube channel name or account owner.
	
In the periodic table for the lanthanide elements, the 'next' button does not follow the navigation as it should. This is because the 'next' button on the 57La layer takes the user to the 39Y layer.	After the revision, as in the numbering sequence for element 57La, the next button for the lanthanide layer leads to layer 58Ce.



In the quiz for the sub-topic of the SPU table, the hotspot quiz type for questions number 4 and 5 does not function properly because the submit uses the "by player button" mode. Therefore, the last button (next icon) is considered by the system in the media as the user's answer, resulting in the user's answer being marked incorrect by the media.

After revision, the submit mode was changed to 'on double click,' so when clicking twice on the part considered as an answer, the media would recognize it as the user's response. Through this mode, users are given three chances to find the correct answer.



Revisions to the media, based on comments and suggestions from the validator in Table 5, include changes to the menu list display where the position of icons is altered, giving priority to placing the info icon as a button directing users to the guide on how to use the media (Yu et al., 2021). This was done to ensure that users understand how to use the media and the functions of each icon in the guide layer, making it easier for users to navigate the media. Additionally, for the content display, videos from various sources, including YouTube, as the most dominant video platform on the internet, one of which is Indonesia (Chen & Dermawan, 2020; Ertemel & Ammoura, 2021). Videos from YouTube added to the multimedia were watermarked to preserve the authenticity of the videos. This ensures that the addition of videos in multimedia is not considered illegal and can protect the intellectual property of the video owners. Videos play a role in introducing information that is easy to improve students' abilities through the presentation of structured information that can be repeated (replay) and is easily distributed and accessed via mobile devices such as smartphones (Pei & Wu, 2019; Paksi & Harmianto, 2022). This is in line with the opinions of students during interviews who hoped for ease of use and access to learning media.

PeT-EFig was developed using the articulate storyline 3 application. According to Sindu et al. (2020), articulate storyline 3 is an application with authoring tools to create interactive learning media with a combination of text, images, graphics, audio, animations, and videos to offer convenience in creating learning objects in the form of simulations, quizzes, drag-drop interactions, recording layers and others, to become an interactive and innovative learning media that is web-based (html5) or in the form of application files to be run on various devices such as laptops, tablets and smartphones. Not only that, articulate storyline 3 is also equipped with interactive objects that make it easier for media creators to create media. In the PeT-EFig, an SPU (periodic system of elements) table is created which displays 118 chemical elements with additional state effects as shown in Figure 4. Where when one of the chemical elements in the SPU table is clicked, will see the

effect state, and then an image of that chemical element will be displayed, along with electron configuration, group number, and period to quantum numbers and energy levels of chemical elements.

SISTEM PERIODIK UNSUR

1 IA	2 IIA											13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA
1 H												B	C	N	O	F	Ne
2 Li	Be																
3 Na	Mg	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8 VIIIB	9 VIIIB	10 VIIIB	11 IB	12 IIB	Al	Si	P	S	Cl	Ar
4 K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
5 Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
6 Cs	Ba	57-71 Lantanida	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
7 Fr	Ra	89-103 Aktinida	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Nh	Fl	Mc	Lv	Ts	Og
		La Ce Pr Nd Pm Sm Eu Gd Tb Dy Ho Er Tm Yb Lu Ac Th Pa U Np Pu Am Cm Bk Cf Es Fm Md No Lr															

Keterangan

Figure 4. Periodic table with state effect

The state effects serve to enhance the interactivity of objects on both the layer and slide in articulate storyline 3. Additionally, articulate storyline 3 includes a feature for creating games. According to Haloho et al. (2023), If games are used in learning media, they will support students in being interested and active, encouraging them to spend more time learning. This is because, in articulate storyline 3, the slide menu has a quizzing feature that enables the creation of quizzes using graded question slides. This allows the selection of quizzes in various forms such as true/false, multiple choice, multiple responses, fill in the blank, word bank, matching drag and drop, matching drop and drag, sequence drag and drop, numeric, and hotspot. Through these slides, the results of quiz completion can be presented, allowing students to understand their mistakes and the correct answers.

In PeT-EFig, various types of quizzes are presented in each subtopic. In the SPU subtopic, a discrepancy was found by the validator in a hotspot-type quiz. This quiz asked the user to locate a chemical element on the SPU. However, the correct answer was still marked as incorrect by the system in the media. Therefore, a revision was made, and an error was found in the improper use of the submit mode. The use of the "by player button" submit mode made the system consider the user's last keystroke as the quiz answer. To address this, the submit mode was replaced with the "on click/on double click/on right click" feature. Not only that, graded question slides can also be used as an evaluation form that students can complete through multimedia. In articulate storyline 3, the graded question slide can display the results of the evaluation with the use of triggers. According to Sindu et al. (2020), triggers, as a feature for combining slides/layers, can execute animated actions, such as a quiz, displaying the evaluation results along with the user's answer mistakes in PDF format. Therefore, various features such as interactive objects and characters can be utilized in the content display, and quizzing slides can be used in creating quizzes/evaluations in interactive learning media.

Based on the results of content and media validation, PeT-EFig developed through Articulate Storyline 3 can be categorized as interactive multimedia. It meets several criteria: a combination of various media types such as text, audio, video, animation, and images; user control features to operate the multimedia; equipped with quizzes that provide direct answers (answer keys and question discussions) to users as feedback from multimedia; and it can be used independently, as it is equipped with usage instructions (Rati et al., 2022). Not only that, in PeT-EFig, users can also directly see the completion results and receive recognition for evaluation completion in the form of an award certificate.

Teacher Responses Test

Interactive learning media that has been deemed suitable based on validation results by experts/validators and has undergone several revisions as a form of improvement in response to suggestions and feedback, continued with a trial on the teacher as a respondent (Putri et al., 2022; Septiana et al., 2022). PeT-EFig, as multimedia that has been validated and categorized as very valid or highly suitable for use, can proceed to the testing phase. According to Rati, et al. (2022), testing is conducted to gauge user responses to the developed multimedia. The product testing is carried out by two chemistry teachers through assessments using a teacher's response questionnaire covering aspects such as content, language, and media. The percentage results of teachers' responses to PeT-EFig for each aspect are presented in Figure 5.

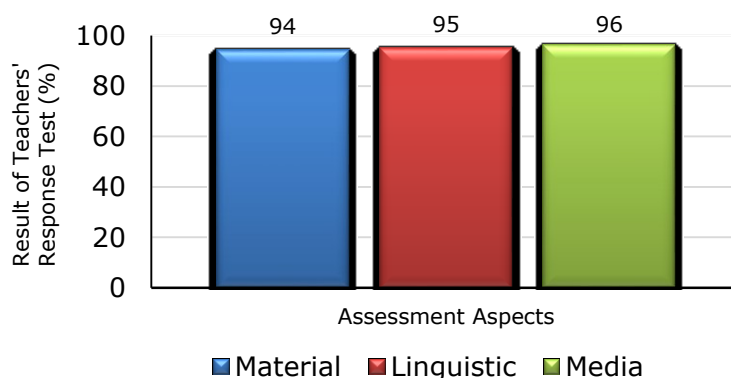


Figure 5. Results of teachers' responses to PeT-EFig

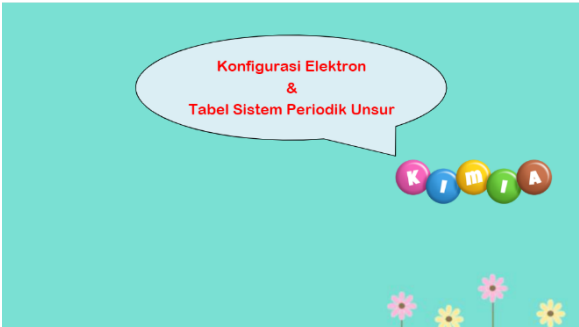
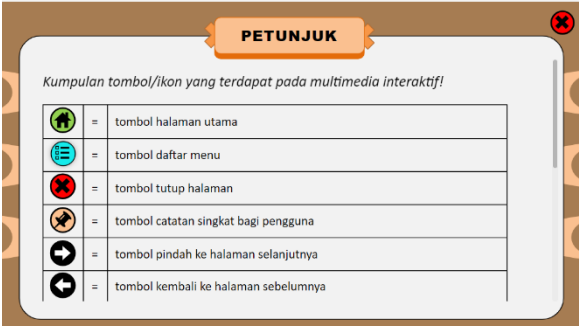
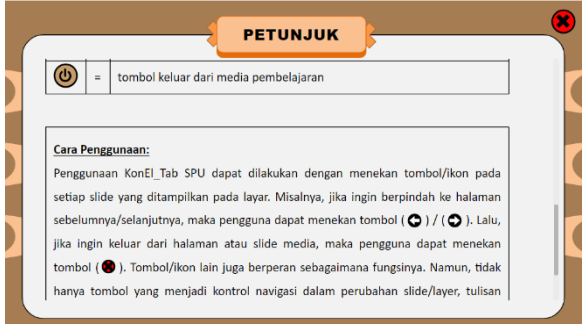
As per the results of the teachers' response test to PeT-EFig for each aspect of content, language, and media with scores of 94, 95, and 96%, respectively, the average score of the teachers' response test is 95%. In all three aspects of the PeT-EFig responses test by teachers, positive responses were obtained. Teachers also approve of the use of PeT-EFig as a chemistry learning media for students, specifically for the electron configuration topic.

Based on the results of the trial process, teachers strongly agree that PeT-EFig can be used by students for independent and group learning. Independent learning was considered more difficult for most students, compared to group learning because group learning can share information. However, with independent learning, students can manage their learning time like at home and adjust their level of ability to understand the learning material. This is in line with the research findings of Putri et al. (2022) and Septiana et al. (2022), regarding interactive learning media based on an articulate storyline which is stated to be very suitable for use to support teaching and learning activities in the classroom and as independent learning for students so that learning time is more efficient. Similarly, the research by Sindu et al. (2020), states that interactive multimedia effectively enhances students' learning enthusiasm and assists them in independent learning. This is supported by the findings of Ananda et al. (2023) and Rahayu & Agustiana (2023), stating that interactive multimedia provides users with the freedom to control all activities in the program through the navigation buttons provided, allowing students to experience collaborative learning even when studying independently.

PeT-EFig, deemed highly suitable by experts/validators and highly approved by teachers as a learning media based on response test results, can be used by students as a chemistry learning tool for the electron configuration topic. Although teachers strongly support the use of PeT-EFig as interactive multimedia for electron configuration content,

they also provided some suggestions for the PeT-EFig multimedia, as shown in Table 6, making it a subject for additional revisions by the researcher.

Table 6. Revisions to PeT-EFig Based on Students' Response Test

Before Revision	After Revision
The media introduction displays a welcome greeting in PeT-EFig with a display of text greetings in bright red color one by one 	The simultaneous display of an introduction, as a welcome greeting on PeT-EFig with different colored text displayed simultaneously. 
In the info menu, only images of the buttons/icons and their functions are displayed. 	In the info layer, for the instructions, not only the display of a collection of icons as buttons and their functions is presented. However, a brief guide on how to use PeT-EFig is also added. 

The welcome greeting intro display in the PeT-EFig media has been shortened, with text appearing simultaneously. This adjustment was made because the media already includes a first intro before the 'login' slide, which is quite lengthy, so the second intro does not need to take up additional time. The addition of usage instructions in the info menu layer aims to enhance usability in this media. Usability, as an indicator showing user-friendliness, can be improved by making users who have not used this media or media based on articulate storyline 3 not feel any difficulty. This can be achieved by adding usage instructions with the help of the scrolling panel feature in articulate storyline 3.

Articulate storyline 3 can also be utilized by teachers for the creation of interactive learning multimedia as it can enhance innovation and creativity in designing interactive and communicative learning. Through interactive multimedia, teachers can provide a solution to improve the quality of learning and an alternative to the limitations of teaching opportunities for teachers (Riana, 2022). Independent interactive multimedia provides ease of use and completeness of content, allowing users to utilize it without the need for guidance from others. In practice, interactive multimedia in learning needs to be designed to be independent so that students can study more freely.

Student Response Test

PeT-EFig was also trialed with students, as users of instructional media are not only teachers. Therefore, small-scale trials and large-scale trials were conducted involving high school students who had studied electron configuration material. This response test was carried out through a questionnaire on a google form containing 6 statements, consisting of four aspects: media appearance, content, software, and benefits

The results of the small-scale student response test

The small-scale trial involving 15 students from SMA Muhammadiyah 1 Pontianak yielded the results shown in Figure 6.

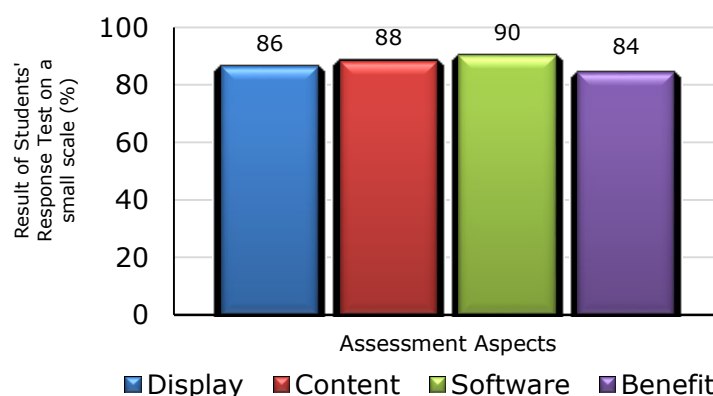


Figure 6. Results of students' responses test on a small scale to PeT-EFig

Based on Figure 6, the average percentage obtained from the small-scale student response test is 87%, categorized as excellent. This indicates that not only teachers but also students responded positively to PeT-EFig across various aspects such as media appearance, content, software, and benefits, with respective scores of 86%, 88%, 90%, and 84%. The students' responses in the small-scale trial indicate that in terms of media appearance, they were interested and could see the overall content of PeT-EFig. Furthermore, students found it easy to understand electron configuration and atomic structure presented in PeT-EFig, based on the content aspect.

The software aspect, which scored higher than other aspects, indicates that students could easily use PeT-EFig. This is because most students have electronic devices such as smartphones that are commonly used in daily life, as well as in the current learning process which often involves the use of portable devices like mobile phones, laptops, and tablets (Tolstoukhova et al., 2019). Contrary to the software aspect, the benefit aspect obtained a slightly lower percentage of 84%, yet still categorized as excellent. This demonstrates that students can understand and are interested in learning electron configuration and atomic structure through PeT-EFig. This aligns with the findings of Puspitarini & Hanif (2019), suggesting that instructional media can enhance students' learning motivation. According to the research by Wanodya (2021), utilizing technology as an instructional medium can motivate students, thereby improving their learning outcomes or achievements.

The results of the large-scale student response test

The large-scale student response test was conducted following the excellent response received from the small-scale trial (Siregar et al., 2019). The percentage results of the small-scale response test, indicating excellent outcomes, were followed by a larger-scale student response test involving 40 high school students outside of SMA Muhammadiyah 1

Pontianak who had studied electron configuration and atomic structure. The percentage results of the large-scale response test are shown in Figure 7.

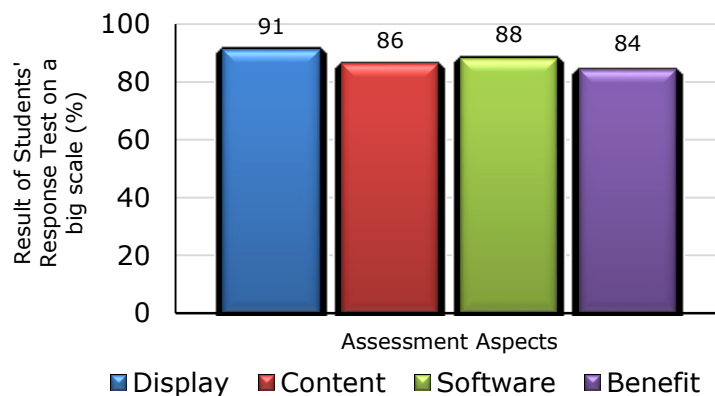


Figure 7. Results of students' responses test on a big scale to PeT-EFig

Based on Figure 7, the percentage results for each aspect in the large-scale trial, namely appearance, content, software, and benefits, were 91, 86, 88, and 84% respectively. The average percentage for the large-scale trial is 87%, indicating an excellent category. This value is equivalent to the small-scale response test. In the large-scale response test, the appearance aspect emerged with the highest percentage. This indicates that students are interested in the appearance of PeT-EFig, supported by a clear and visually appealing interface. According to Wanodya (2021), an attractive media appearance influences students' learning interests. The variety of appearances in PeT-EFig, which can incorporate various media types such as text, graphics, animations, audio, and video, as well as allowing users to interact actively with the media, contributes to this high level of interest.

The response from students in the large-scale trial regarding the content aspect is categorized as excellent. This is supported by the presentation of key points from the material in various formats, accompanied by explanatory videos and diverse question-based games (quizzes) up to problem-solving discussions. According to the findings of Lutfi et al. (2021), students perceive chemistry learning through games as instructional media that can provide learning motivation, entertainment, and a sense of enjoyment during the learning process.

The software aspect in the large-scale trial also received an excellent response because it can be utilized across various devices, including smartphones. According to Riyan (2021), smartphone-based learning media have good feasibility for use as a variation of instructional media. As an interactive multimedia, PeT-EFig can be easily used by students. Similarly, the benefit aspect obtained a highly suitable criterion because PeT-EFig presents easily understandable material, thus categorizing it as interactive multimedia. In line with the views of Diyana et al. (2019), interactive multimedia can help students understand concepts deeply, thereby optimizing student-centered learning and enabling students to practice independently outside the classroom by adjusting the place and time, accommodating teachers as users.

PeT-EFig, as a multimedia learning tool, has been deemed highly suitable or very valid by both content and media validators and has been highly approved by teachers as instructional media. Moreover, it has been very positively responded to by students during the trial process in presenting electron configuration material alongside various other features, as illustrated in Figure 8.

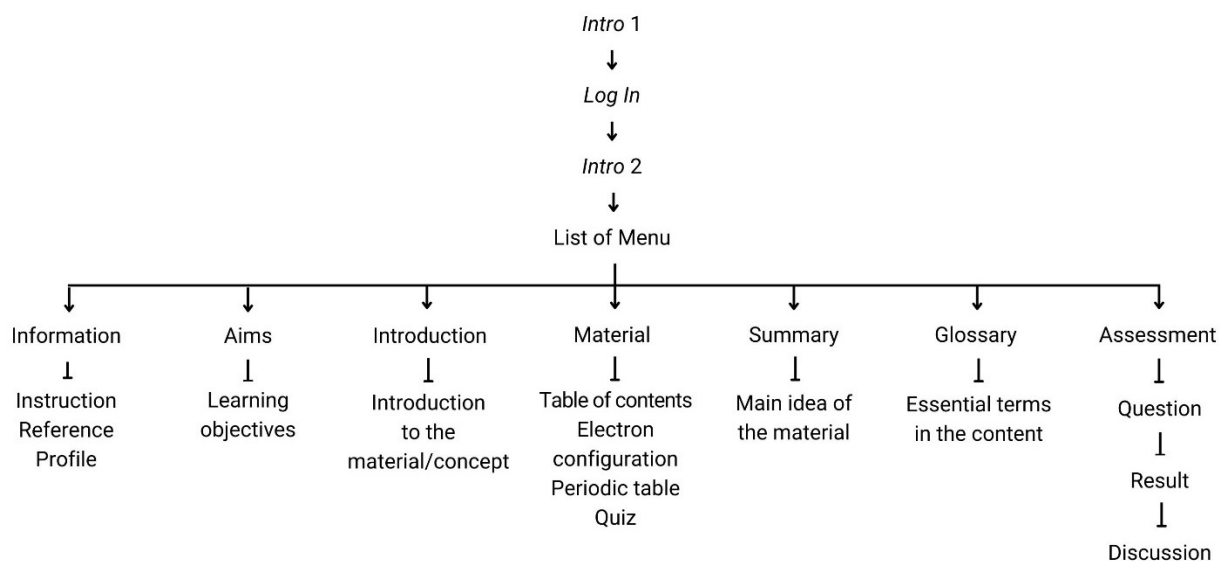


Figure 8. The content structure of PeT-EFig media

The revised PeT-EFig as the final product can be distributed to students through the web, Articulate Online, LMS CD, and Word as a publishing format provided by Articulate Storyline 3. The distribution of the published results of PeT-EFig can be done using several formats. According to Mawaddah et al. (2022), the results can be published on the personal web, word processing, CD/EXE format, SCORM/LMS, or can be turned into a URL to be accessible via smartphones, anticipating students who do not have laptops. However, this requires online access and internet connectivity. In this research and development, publishing in web format in the form of HTML can be distributed to students offline. For smartphone usage, the published results are converted into the APK format with the help of the website 2 APK Builder Pro. For online use, a URL link can be used, making it accessible through various electronic devices such as computers, laptops, and smartphones.

Conclusion

Based on the research results supported by theoretical studies and similar research by other researchers, it can be concluded that the learning media in the form of PeT-EFig can be categorized as highly suitable as interactive multimedia based on articulate storyline 3 for the electron configuration concept. In addition, chemistry subject teachers who were respondents to the research strongly agreed that PeT-EFig is a multimedia tool in learning, which can be considered interactive multimedia and is very suitable for chemistry learning, especially on the electron configuration concept. The students who participated showed very positive responses towards the PeT-EFig. Students who enjoy learning media that includes videos and games can utilize PeT-EFig, which is also equipped with text, images, graphics, animations, and audio to comprehend electron configuration and atomic structure materials. Observing the results of the research on interactive multimedia, some recommendations can be given from this study, such as the use of learning media in the form of interactive multimedia to support the teaching and learning process. The creation of interactive multimedia for learning can be made using articulate storyline 3. This is because it is a program similar to powerpoint, with similar workings and usage. Thus, it becomes easier for teachers in the process of creating learning media, especially multimedia, and enhance students' interest in the learning process.

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We would like to thank the experts who validate the feasibility of the PeT-EFig. We also want to thank the headmaster and chemistry teachers of SMA Muhammadiyah 1 Pontianak for providing the opportunity for researchers to conduct research and response tests and provide responses to the learning multimedia product (PeT-EFig).

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