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# Development And Validation of the “Flipped Periodic Table”: Website-Based Chemistry Learning Media for Electron Configuration Material

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## Abstract

This study is intended to develop and examine the validity of a chemistry learning medium based on the Flipped Periodic Table website for grade 10 senior high school students on electron configuration material. The developed medium takes the form of an interactive digital periodic table with card-based features, electron configuration input, voice feedback, and a leaderboard to enhance student engagement and learning motivation. This study adopted a Research and Development (R&D) approach based on the ADDIE model, encompassing five phases: analysis, design, development, implementation, and evaluation. Media validity was evaluated by material experts and media expert using validation instruments covering aspects of conceptual accuracy, learning relevance, language clarity, visual quality, accessibility, and interactivity. The validation findings showed that the learning media fell into the highly valid category, with scores of 93.00% from material experts and 96.00% from the media expert, yielding an overall validity of 94.50%. Student response analysis conducted in classes X-5 and X-9 showed positive responses, with a total percentage of 89.40%, classified as highly valid. Qualitative findings revealed that students perceived the learning process as more interesting and challenging and were supported in understanding electron configuration through independent practice. These results indicate that the Flipped Periodic Table is suitable for use as an alternative instructional medium to enhance students' understanding and motivation in learning electron configuration.

**Keywords:** Learning Media, Electron Configuration, Interactive Website, Media Validity, Media Development

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## 1. Introduction

The advancement of Science and Technology (IPTEK) in the 21st century has led to substantial changes in education, particularly in relation to the competencies expected of students. Education is expected to develop human resources equipped with 21st-century skills such as creativity, innovation, collaboration, communication, and critical thinking and problem-

solving (4Cs) as indicators of readiness to face the Society 5.0 era, which is marked by the integration of digital technology across various aspects of life (Trixie et al., 2024). In line with that, Christy et al. (2023) emphasized that future generations need to be equipped with technical and soft skills to play an effective role in the era of globalization. The integration of technology in learning has become a strategic necessity rather than an option, as it supports the creation of learning experiences that are relevant, adaptive, and meaningful (Sunarya et al., 2024), this condition requires teachers to continuously innovate in developing technology-based learning media and resources that align with the characteristics of Generation Z who tend to prefer visual and interactive learning while also fostering active learning experiences that promote higher-order thinking skills (Kusasi et al., 2024; Benesova & Tupa, 2017).

In chemistry learning, the existence of technology-based learning media is very important considering the characteristics of chemistry that are abstract, conceptual, and interrelated (Silaban et al., 2023). This is because, to date, chemistry learning still faces fundamental problems, especially in the learning approach, media utilization, and student understanding (Kholid et al., 2024; Suhardi et al., 2024). Chemistry instruction is still largely dominated by lecture-based approaches and the reliance on textbooks as the primary learning resource, making it predominantly teacher-centered and limiting students' opportunities to independently explore concepts (Magdalena et al., 2021). This condition has an impact on the low motivation and activeness of students, especially in abstract and conceptual chemistry materials. In line with that, a number of studies have also revealed that the difficulty of learning chemistry is caused by the high level of abstraction of concepts, students' inability to connect macroscopic, sub-microscopic, and symbolic representations, and the lack of visualization support in learning (Taber, 2013; Johnstone et al., 2018)

One of the basic and crucial materials in chemistry is the configuration of electrons. Mastery of this material is an important foundation for the understanding of later chemical materials, such as the periodic system of elements, chemical bonds, and elemental reactivity (Hijriansyah et al, 2024). However, electron configuration is a concept that is difficult for students to understand because it is very abstract and cannot be observed directly in daily life, so it often causes misconceptions and difficulties in building a complete understanding of concepts. Based on research by Prayitno & Nugroho (2023), it shows that as many as 38% of students experience misconceptions, 23% have understood concepts correctly, 17% have made mistakes in answering, and 22% have not adequately understood the concept of electron configuration. This is because students fail to reconstruct abstract concepts correctly, so that wrong understanding continues to be carried over and hinders the understanding of advanced chemistry concepts. In addition, in the research of Herdien, R. A. (2024), from 35 students, it is known that in the subconcept of electron configuration, there is still a misconception of 34.29%, which shows that students have difficulty in determining the electron configuration of an element. In addition, misconceptions also occurred in the determination of valence electrons with a percentage of 31.43%. Therefore, the right learning media is needed so that learning goals are achieved optimally. Learning media not only function to convey information, but also play a role in increasing students' interest and learning outcomes (Basri et al., 2024; Shirley & Shirley, 2024; Mufidah & Nasution, 2024). Digital learning media in chemistry education includes interactive simulations, virtual labs, video demonstrations, online quizzes, and digital platforms in the form of interactive websites (Kumar, 2025). One type of learning media that offers effective visualization is web-based learning media, as it enhances interactivity in the learning process and helps increase students' motivation to learn (Ahyan et al., 2022)

Web-based learning media has great potential to answer these problems because it is able to integrate text, visuals, audio, and interactive elements in one learning platform. Studies

show that the use of interactive web media in chemistry learning can improve students' concept understanding, learning motivation, and high-level thinking skills as students are actively involved in the learning process (Iyamuremye et al., 2023). Web-based learning facilitates access to learning materials that are flexible, interactive, and responsive to students' needs, including self-paced learning, which is an important skill in 21st century learning (Huang & Pei, 2024). Other research shows that web-based learning can significantly improve students' self-study and self-regulation skills, which contributes to better chemistry learning outcomes compared to traditional learning (Indriani et al., 2023).

Several previous studies have indicated that the development of web-based media in chemistry learning makes a significant contribution to enhancing students' conceptual understanding, learning motivation, and critical thinking skills (Pertwi et al., 2024; Cotiangco et al., 2024; Syafruddin et al., 2024). This is also in line with the research of Rahmatsyah et al. (2021) which shows that the integration of interactive visuals in website media in elemental periodic system materials is able to improve learning outcomes and student engagement compared to conventional learning. Meanwhile, Riska et al. (2025) also shows that interactive website media on atomic structure materials can facilitate the understanding of submicroscopic and symbolic representations in abstract concepts more effectively so as to support independent and meaningful learning. Research by Suryapranata et al. (2023) shows that the use of gamification with visual novels can increase students' learning motivation, but the focus of development is still on the introduction of elements in the periodic table in general and has not specifically trained students in compiling electron configurations. Lalu Nsabayezu et al. (2023) developed an online periodic table that connects to external sources of information such as Wikipedia to help students access atomic numbers, chemical properties, and periodic trends of elements. The media functions as a means of exploring elemental information, but it has not been designed as a learning environment that actively and independently trains students in writing electron configurations. Similarly, research by Mandasari et al. (2021) developed electron configuration learning media that emphasizes conceptual aspects, such as the introduction of atomic structure, constituent particles of atoms, atomic numbers, mass numbers, and the process of forming electron configurations, so that it functions more as an informative medium than a constructive training medium. Meanwhile, Wijayanti et al. (2021) has integrated electron configuration exercises in learning media, but it is packaged in the form of 25 multiple-choice questions so that it has not facilitated students to practice writing electron configurations openly on all elements in the periodic table and has not been visualized in the context of an interactive periodic table. In addition, the learning media developed by Faisal et al. (2021) is a media that also facilitates students to fill in electron configurations but is still based on ICT where not all devices can access. The research also emphasizes the conversion of media on a website-based basis so that it can be accessed by all mobile devices.

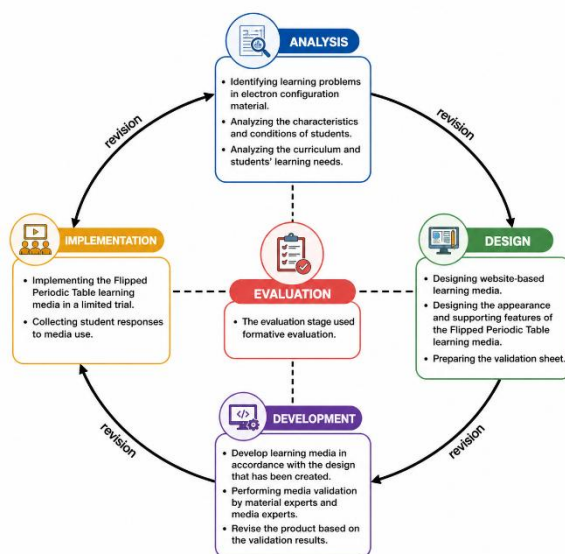
Therefore, there is a research gap, namely the absence of a website-based learning media that explicitly integrates the practice of writing electron configurations into the interactive periodic table visual as the main learning environment and is equipped with feedback mechanisms through audio and visuals and a leaderboard system) both at the class and global levels. Most of the existing media are still informative, procedural, or closed evaluative (multiple choice) so they have not fully trained students to construct electron configurations independently, openly, and contextually within the framework of elemental periodic systems. Accordingly, the development of a website-based learning medium called the "Flipped Periodic Table" for electron configuration topics is proposed, integrating practice in writing electron configurations directly within interactive periodic table visuals, featuring a leaderboard, and incorporating audio as feedback.

## 2. Methods

This study applies the Research and Development (R&D) approach using the ADDIE model, which includes five stages: analysis, design, development, implementation, and evaluation (Branch, 2009). In the field of education, this method is used to develop learning media, teaching materials, or learning tools that can improve the quality of the teaching and learning process. (Read et al., 2024; Juniar et al., 2023; Putri et al., 2025). Visually, the stages of the ADDIE model in development research to produce a website-based Flipped Periodic Table learning media are presented in Figure 1.

**Figure 1**

*Research steps for the development of flipped periodic table learning media*



The analysis phase involves identifying learning needs and issues. The design phase focuses on designing the media and developing the content. The development phase involves creating the media and having it validated by experts. The implementation phase involves piloting the media with students to gather feedback. The evaluation phase is conducted formatively at each stage to assess and refine the media based on expert validation results and student feedback.

The research sample used cluster random sampling technique with class X-5 (19 students) and class X-9 (27 students) at SMA Negeri 6 Malang City. Data analysis was conducted through validation tests involving a panel of expert validators in both material and media, aimed at evaluating the feasibility and quality of the instructional material and its presentation. Validation includes assessing material suitability, clarity of presentation, and media interactivity. In addition, students' responses and responses to the media were also collected through questionnaires with a likert scale of 1-5 to see the acceptance rate, ease of use, and appeal of the media (Juniar et al., 2023). Validity analysis was carried out through construct validation by two material experts and one media expert. The assessment is given using a Likert scale of 1-5, then the score obtained is analyzed using the formula in Equation (1) and converted into percentage form to determine the feasibility level of the product based on the criteria set in Table 1. (Nurussalma et al., 2024).

$$\text{Validity} = (\text{Score obtained} / \text{Total score}) \times 100\% \dots\dots\dots (1)$$

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**Table 1.***Product Validity Criteria*

Percentage	Criteria
$81.25\% < P \leq 100\%$	Highly Valid
$62.5\% < P \leq 81.25\%$	Valid
$43.75\% < P \leq 62.5\%$	Quite Valid
$25\% < P \leq 43.75\%$	Invalid

(Nurussalma et al., 2024)

**3. Result and Discussion**

This study aims to develop and validate a website-based Flipped Periodic Table learning media using the ADDIE model. The feasibility of the media was evaluated through validation by material experts, a media expert, and student responses, all of which indicated that the developed media is appropriate for use in chemistry instruction, particularly on electron configuration topics.

**3.1 Analysis Stage**

During the analysis phase, the research focused on identifying learning needs and issues arising in the chemistry learning process, particularly regarding the topic of electron configuration in 10th-grade high school classes. The analysis was conducted through direct observation of classroom learning activities and the distribution of a questionnaire on instructional media needs to teachers in order to obtain more structured data regarding learning conditions and media needs. This phase aimed to provide a realistic picture of learning conditions and student characteristics.

Based on the results of the analysis of the curriculum used, chemistry learning at the high school level, especially in grade X of SMA Negeri 6 Malang City, is directed at the application of a deep learning approach that emphasizes the development of conceptual understanding (meaningful), active involvement of students in the joyful learning process, and the ability to reflect and relate knowledge to learning experiences (mindful). The deep learning approach demands a learning process that is not only oriented to the delivery of information, but also to the creation of learning experiences that encourage students to actively explore, understand, and build their knowledge independently (Yang, 2023; Feriyanto & Anjariyah, 2024; Kovač et al., 2025).

The results of a needs analysis conducted via a questionnaire administered to teachers indicate that the instructional media currently in use are still dominated by PowerPoint and other simple media, and that the utilization of interactive digital media has not yet been optimized. Teachers also stated that the use of instructional media significantly influences student engagement and that more interactive and easily accessible media are needed to help students understand the material. In line with this, the results of classroom observation indicate that instruction remains teacher-centered, with textbooks serving as the primary resource, leading students to adopt a passive role in the learning process. This is evidenced by low student participation in discussions, a reluctance to ask questions, and a tendency for students to merely absorb information without further exploring the subject matter.

Findings in previous studies suggest that teacher-centered learning is often associated with one-way knowledge transfer in which students are positioned as passive recipients, without encouraging active engagement in chemistry learning (Fichtner & Groß, 2025). In addition, other research has also revealed that classes dominated by traditional lectures provide a passive

learning experience for students and negatively impact their motivation and ability to participate, ask questions, or dig into further material (Deslauriers et al., 2019). From the analysis that has been carried out, it is necessary to facilitate optimal chemistry learning that can make students more active so that they can increase their participation and motivation, especially in materials with difficult concepts such as electron configuration.

During the student analysis process, it can be seen that class X students have characteristics as a digital generation who are used to using technological devices in their daily lives. However, the use of this technology has not been optimally integrated in chemistry learning in schools. Students are also more interested in learning that involves interactive activities, challenges, and direct feedback on the answers given. This indicates the need for learning media that is able to realize students' needs for digital media by involving interactive and challenging activities.

Based on the results of the analysis, it can be concluded that learning chemistry on electron configuration materials requires innovative learning media that is able to increase students' activeness, motivation, and understanding of concepts. One of the solutions offered in this study is the development of a website-based learning media in the form of a Flipped Periodic Table.

### 3.2 Design Stage

The findings from the analysis in the previous stage, it was found that chemistry instruction on the topic of electron configuration is still dominated by teacher-centered methods, with limited and lack interactivity, which contributes to reduced levels of student participation and motivation. Additionally, the analysis revealed that students, as members of the digital generation, require learning media that is interactive, challenging, and provides immediate feedback. Based on these findings, the design phase developed a website-based learning medium in the form of a Flipped Periodic Table tailored to the identified needs: the need for interactive media that provides immediate feedback and enhances student engagement. Therefore, the design of the media focused on providing an interactive periodic table feature in the form of digital element cards that students can fill out independently, equipped with an immediate visual and audio feedback system to help students understand their mistakes and correct their answers. Furthermore, to boost student motivation and engagement, the media was also designed with gamification features, such as a leaderboard displaying points earned based on students' success in completing tasks.

The design stage begins with the determination of the media concept, as well as the form of interaction that will be provided in the media. Media Flipped Periodic Table is designed as an interactive digital periodic table that contains chemical elements from the main group and transition group in the form of element cards according to the order of the group and period. Each element card is equipped with an electron configuration fill field that the student must fill in independently. This design aims to encourage students to independently build their understanding of concepts through the process of trying, evaluating, and reflecting on their own answers. Once the media concept is defined, the next stage is the preparation of the media framework and the determination of the main components that should be present in the Flipped Periodic Table. Media components include: opening pages, interactive periodic table displays, digital element cards, electron configuration fields, feedback systems, leaderboards, and supporting audio elements. The design of the media interface pays attention to the principles of simplicity, consistency of layout, the selection of contrasting and attractive colors, and the ease of navigation so that the media is easy for students to use.

Interactivity is the main focus in this design phase. When students fill in the electron configuration correctly, the element card will flip and display the correct electron configuration along with a more attractive card color and audio feedback in the form of a correct answer sound. Conversely, if the answer is incorrect, the card will not be flipped over and the student will receive corrective audio feedback. This hands-on feedback is designed to help students quickly spot mistakes and improve their understanding. This design is in line with the multimedia learning theory which states that the combination of visual, text, and audio can be able to help deliver more meaningful information, thereby increasing students' understanding of the concept of learning (Abdulrahman et al., 2020). In addition, the Flipped Periodic Table is also designed with a gamification feature in the form of a leaderboard that displays student points based on the number of element cards that have been successfully reversed. Each card answered correctly awards one point, thus encouraging students to keep trying and completing challenges. The addition of this competitive element is supported by international research findings that indicate that gamification in digital learning can increase learning motivation, student engagement, and positive attitudes towards learning (Chans & Portuguese Castro, 2021). To strengthen students' emotional engagement, this media is equipped with competitive background music during the exploration process. The music and sound effects are designed not to interfere with concentration, but serve as a reinforcement of a more interesting and enjoyable learning atmosphere. Research shows that audio use has been shown to correlate positively with student motivation and engagement in learning (Erlitaviana & Tyas, 2025). In addition, the color change on the element card that is successfully reversed also serves to help increase the appeal of the media.

Thus, the design stage of the Flipped Periodic Table emphasizes the integration of interactivity, visualization, audio, and gamification in one website-based medium. This medium is designed to facilitate active learning, help students relate electron configurations to the location of elements in the periodic system, and make abstract concepts more concrete and easier to understand. This media design is expected to be able to answer the learning needs that have been identified at the analysis stage and become a strong basis for the next stage of development and validation.

In addition, during the design phase, research instruments were developed, including subject matter expert validation sheets for material experts, validation sheets for media expert, and questionnaires intended to obtain students' responses. These instruments were designed to assess the suitability of the developed instructional media in terms of content appropriateness, media quality, and user acceptance. The expert validation sheets were used to obtain evaluations and feedback from experts regarding the content and design of the media, while the student response questionnaires were used to determine students' perceptions of the use of the Flipped Periodic Table media during the implementation phase.

### 3.3 Development Stage

The development stage aims to realize the design of the website-based Flipped Periodic Table media into a learning product that is ready to be tested for feasibility. At this stage, the media is developed according to the design that has been set in the previous stage by utilizing several web developer platforms and adjusting the learning needs of the high school class X electron configuration material.

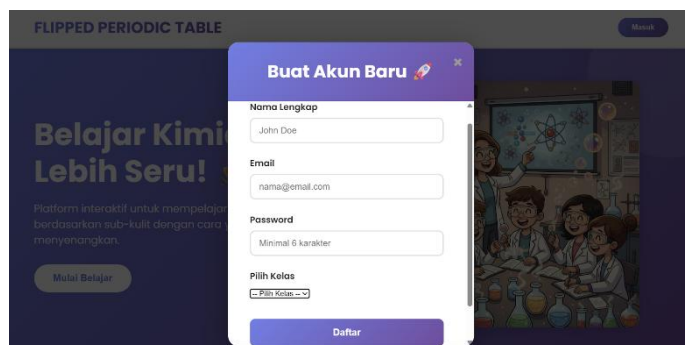
The product developed consists of several main components, namely the home page, user authentication feature (register and login), the main page of the Flipped Periodic Table, and the leaderboard. The home page displays the media title, a brief description, and a "Start Learning" button that directs users to register or log in shown in Figure 2.

**Figure 2**  
*Home page flipped periodic table*

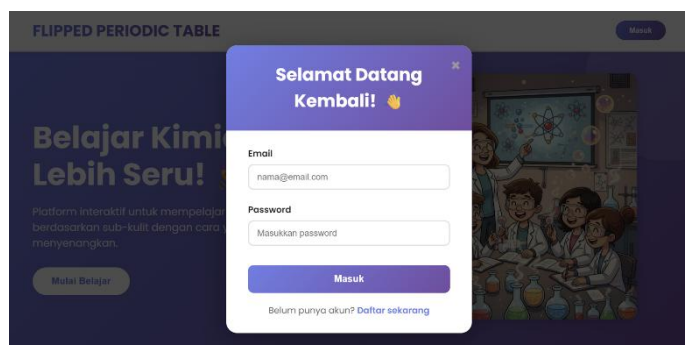


The registration and login system on the Flipped Periodic Table website is implemented as a user authentication mechanism that supports learning continuity. As shown in Figure 3, new users can register by filling in the basic identity and selecting a class (e.g. X-5 or X-9), so that the system is able to group learning data based on their respective classes. Furthermore, registered users can log in again to continue learning and game activities according to the progress that has been saved previously, as shown in Figure 4.

**Figure 3**  
*Registration page for new users*



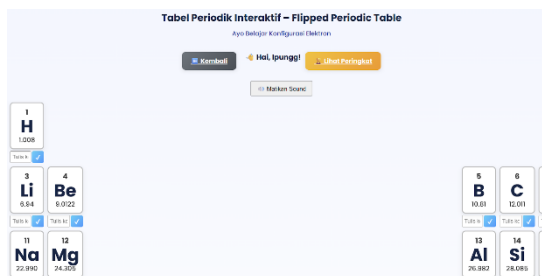
**Figure 4**  
*Login pages for existing users*



Once the user has successfully logged in, the design of the Flipped Periodic Table main page that has been set in the design stage is realized into the form of a fully functional interactive website. The initial view of the main page when accessed is shown in Figure 5., where the periodic table is not yet fully visible on a single screen. Therefore, users need to scroll down to display the entire periodic table in full, as shown in Figure 6.

**Figure 5**

*Home page flipped periodic table (scroll up)*



**Figure 6**

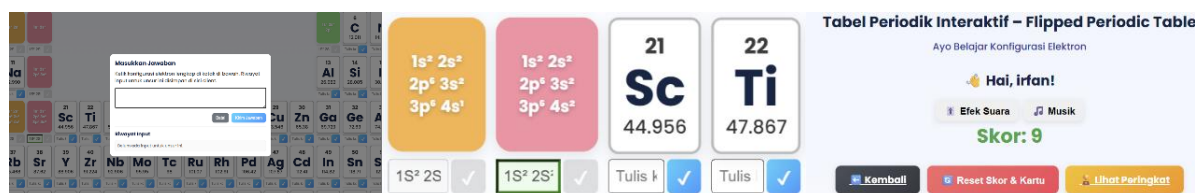
*Home page flipped periodic table (scroll down)*



The periodic table of the elements of the main group and the transition group is implemented in the form of an interactive digital card that can be operated directly by the user. All navigation, leaderboard, and voice management components are developed and integrated into the system so that they can run as they should. As shown in Figure 7., users can enter electron configurations based on subshells on the columns available on each element card. If the answer given is correct, the element card will be inverted and display the correct electron configuration with positive sound feedback. Conversely, if the answer is incorrect, the card does not reverse and the system provides corrective feedback in the form of different sound effects. In addition, users are also provided with features for.

**Figure 7**

Display of electron configuration input columns, inverted element cards, and system navigation.



In addition, the leaderboard system displays the user's score based on the number of element cards successfully reversed, with each card worth one point. These leaderboards are differentiated into global rankings that display the accumulated user scores of different classes, and local rankings that only display the user's score gains in one specific class, as shown in Figure 8. This leaderboard feature is expected to create healthy competition between students through a comparison of score achievements that can increase learning motivation, active engagement, and encouragement to achieve a better understanding of electron configuration materials.

**Figure 8**

Global leaderboard and class leaderboard view

Peringkat	Nama	Kelas	Skor
1	Diandra Arsyah Azalhia	X-5	95
2	Latifah	X-9	90
3	Raysa Atzzifah Andriani	X-9	90
4	Echa dwi s. (08)	X-9	90
5	Farras Isy Thatbiqis	X-5	90
6	Muhammad Rasyah Aliffian	X-5	87
7	Avila Hajah Aulia	X-9	72
8	Natzwa wanda pratiwi	X-9	70
9	Virni Alea A.	X-8	67

Peringkat	Nama	Kelas	Skor
1	Latifah	X-9	90
2	Raysa Atzzifah Andriani	X-9	90
3	Echa dwi s. (08)	X-9	90
4	Avila Hajah Aulia	X-9	72
5	Natzwa wanda pratiwi	X-9	70
6	GILANG MICHAEL	X-9	55
7	Evan Danan Musley	X-9	53
8	Devi Oktavia A	X-9	46
9	Azzam Faiz Ramadhan	X-9	44
10	Ushalling Putri	X-9	44

After the Flipped Periodic Table learning media has been developed, the next stage is a validation test to assess the product's feasibility. Validation was carried out by media expert and material experts using the same assessment criteria as a eligibility reference, as shown in Table 1. The media expert in this study is one of the teachers at SMA Negeri 6 Kota Malang, while the material expert consists of class X chemistry teachers. The validation process aims to assess the suitability of the media with the learning objectives, the accuracy and correctness of the electron configuration concept, as well as the quality of the display, interactivity, and functionality of the learning media.

The web-based Flipped Periodic Table learning media is subjected to validation by material experts to evaluate the feasibility of its content and suitability of the electron configuration material with the objectives of class X chemistry learning. The material experts in this study consisted of two 10th-grade chemistry teachers with direct experience teaching the topic of electron configuration in school. The material expert validation focused on several key aspects, including conceptual accuracy, learning fit, language clarity, and concept

understanding support. The assessment data from both validators were then processed using the following formula:

$$\bar{X} = \frac{V_1 + V_2}{2}$$

The results of the assessment from the material experts are presented in Table 2.

**Table 2.**

*Material experts' validation score*

Assessment Aspects	V <sub>1</sub>	V <sub>2</sub>	Scores Obtained	Total Score	Percentage	Remarks
Conceptual Accuracy	20	19	19.5	20	97.5%	Highly Valid
Learning Fit	9	9	9	10	90%	Highly Valid
Language Clarity	9	9	9	10	90%	Highly Valid
Concept Understanding	9	9	9	10	90%	Highly Valid
Support						
Total Score			46.5	50	93%	Highly Valid

Based on the results of the validation, the learning media obtained a validity percentage of 93%, so it is included in the category of being very valid in terms of material content. The electron configuration material presented is in accordance with the correct scientific concept and is able to represent the relationship between electron configuration and the location of elements in the periodic system in a clear and systematic manner.

Besides undergoing validation by material experts, the website-based Flipped Periodic Table learning media was also tested for feasibility by media expert. The media expert validator in this study is a teacher at SMA Negeri 6 Malang who has competence and experience in the use and evaluation of technology-based learning media. Media expert validation is conducted to evaluate the quality of media from the aspect of interface display, usability, text readability, color and design quality, navigation consistency, as well as interactivity and voice feedback functions contained in the media. The results of media experts' assessments of the Flipped Periodic Table media are presented in Table 3.

**Table 3.**

*Media expert validation score*

Assessment Aspects	Scores Obtained	Total Score	Percentage	Remarks
Accessibility and Interactivity	15	15	100%	Highly Valid
Visual and Design Quality	19	20	95%	Highly Valid
Typography and Language	14	15	93%	Highly Valid
Total Score	48	50	96%	Highly Valid

Based on the results of the assessment by the media expert, the learning media obtained a validity percentage of 96%, so it is included in the category of being very valid and feasible to be used in chemistry learning. The media display is considered attractive, the layout of the components is easy to understand, and the navigation between pages runs well. Interactive

features in the form of reversible element cards, voice feedback for correct and false answers, and a leaderboard system are considered capable of enhancing the media's attractiveness and promoting active student participation in the learning process.

**Table 4.**

*Flipped Periodic Table validation score*

Validator	Scores Obtained	Total Score	Percentage	Remarks
Material Experts	46.5	50	93.00%	Highly Valid
Media Expert	48	50	96.00%	Highly Valid
Total Score	94.5	100	94.50%	Highly Valid

Based on Table 4, the overall validation results of the Flipped Periodic Table media show a very high level of validity. The total score obtained was 94.5 out of a maximum score of 100 with a percentage of 94.50%. This percentage is in the very valid category, which indicates that the learning media developed has met the feasibility criteria both in terms of content and overall appearance.

The revision stage is an important part of the development process of Flipped Periodic Table learning media based on the website, which is carried out after obtaining advice from material experts and media expert. The revision aims to improve the quality of the media to be in accordance with pedagogical standards, conceptual correctness, and characteristics of high school class X students. Suggestions from validators are displayed on table 5.

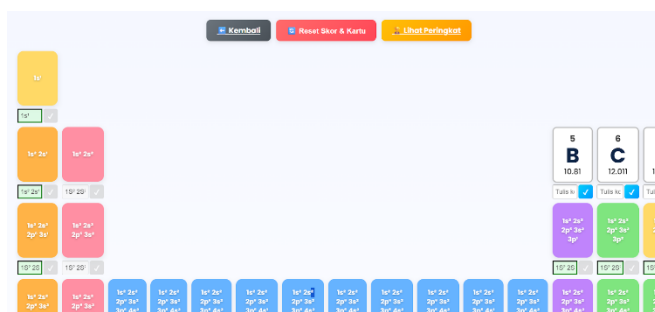
**Table 5.**

*Validator advice*

Validator	Suggestions
Media Expert	Add more colorful elements to the atomic card to make it more appealing to students
Material Expert 1	The writing of the electron configuration of the Wolfram element must pay attention to the rules of writing the aufbau principle
Material Expert 2	Writing electron configurations for subshells d and f using the aufbau principle

Based on suggestions given by material experts and media expert, several improvements to the Flipped Periodic Table media have been made to improve the readability, visual appeal, and scientific suitability of the content. One of the main inputs from media validators is the need to add color variations to atomic cards. Other studies show that the color of the learning environment affects students' attention and perception, so the appropriate use of color in learning media can increase students' cognitive and emotional engagement with the material (Akram et al., 2025). The revision to the media was made by adding several different color elements to the atomic card that was successfully inverted in the periodic table of Figure 9.

**Figure 9**  
*Display of color elements on media*



In addition, material experts suggest improvements to the rules of writing electron configurations, especially for elements with complex configurations such as Wolfram (W). This suggestion led to an adjustment of the writing to be fully in line with the Aufbau principle, which is a fundamental rule in determining the order of electron charge based on the energy of the orbital subshell.

The revision results indicate that the developed media fulfills the feasibility criteria as a learning tool for teaching electron configuration in chemistry. Not only does this media present scientifically correct content, but it is also designed to encourage active student engagement through interactivity, direct feedback, and gamification elements. Thus, the Flipped Periodic Table is ready to proceed to the implementation stage in supporting chemistry learning in grade X of high school.

### 3.4 Implementation Stage

The implementation stage is a trial stage of a website-based Flipped Periodic Table learning media in chemistry learning activities on electron configuration materials in class X of high school. This stage aims to determine the implementation of the use of media in the context of real learning and to obtain an initial overview of students' responses to the media used in learning.

The implementation of the media was carried out through a limited trial involving students in grades X-5 and X-9. The media trial began with an explanation by the teacher about the electron configuration material as the theoretical basis that students need before interacting with the media. Furthermore, students use the Flipped Periodic Table media independently with the assistance of teachers. Learning at this stage is carried out by applying a Deep Learning approach that is oriented towards aware, encouraging, and meaningful learning. In the context of this approach, the Flipped Periodic Table media plays an encouraging aspect, namely creating an interactive, challenging, and fun learning experience, thus encouraging students' active involvement in understanding the concept of electron configuration.

To support the creation of an encouraging and challenging learning atmosphere, this media is equipped with gamification elements in the form of a leaderboard feature. During the process of using media, the existence of the leaderboard feature has an influence on student involvement and activeness in learning. Students show enthusiasm to complete more elements to earn higher points, as well as trying to correct mistakes and try again in order to improve their position on the leaderboard. This shows that the leaderboard feature serves as a trigger for motivation and healthy competition that encourages students to be more active and focused, and enthusiastic in following learning. This is in line with the results of Zhang & Watson's

(2025) research, which states that interactively designed digital learning media can increase students' motivation and interest in learning.

Beyond enhancing motivation, the use of leaderboards also promotes greater interaction among students as well as between students and teachers, especially in discussing mistakes and electron configuration strategies, thereby helping students reflect on the understanding of the concepts learned. Ippoliti et al. (2022) states that digital-based interactive learning resources increase student engagement with the material compared to traditional approaches.

At the implementation stage, student responses to the use of Flipped Periodic Table learning media were collected. Student responses were collected using a Likert scale questionnaire of 1-5 which aimed to find out students' perceptions of the quality and feasibility of the learning media developed. The questionnaire covers several aspects, including the appearance and design of the media, the ease of use of media, media interactivity, the level of students' interest and motivation to learn, the suitability of the material, and its impact on student understanding. Student responses were obtained from classes X-5 and classes X-9 as media implementation test subjects. The response data of students in grades X-5 is presented in Table 6., while the response data of students in grades X-9 is presented in Table 7. The Likert scale questionnaire data obtained was analyzed in a quantitative descriptive manner by calculating the total score, average score, and percentage in each aspect of the assessment. The results of the analysis are then interpreted based on the feasibility criteria of learning media to determine the level of feasibility of Flipped Periodic Table media from the perspective of users (students).

**Table 6.**

*X-5 students' perspective score against the Flipped Periodic Table (19 students)*

Aspects	Scores Obtained	Total Score	Average	Percentage	Category
Media display and design	156	190	4.10	82.10%	Highly Valid
Ease of use (usability & accessibility)	78	95	4.10	82.10%	Highly Valid
Media interactivity and features	249	285	4.37	87.37%	Highly Valid
Learning motivation and engagement	505	570	4.43	88.60%	Highly Valid
Suitability of the material with learning objectives	82	95	4.32	86.31%	Highly Valid
Impact on understanding and learning outcomes	163	190	4.29	85.79%	Highly Valid
Total Score	1233	1425		86.53%	Highly Valid

**Table 7.***X-9 students' perspective score against the Flipped Periodic Table (27 students)*

Aspects	Scores Obtained	Total Score	Average	Percentage	Category
Media display and design	245	270	4.54	90.74%	Highly Valid
Ease of use ( <i>usability</i> & accessibility)	122	135	4.52	90.37%	Highly Valid
Media interactivity and features	374	405	4.62	92.34%	Highly Valid
Learning motivation and engagement	739	810	4.56	91.23%	Highly Valid
Suitability of the material with learning objectives	125	135	4.63	92.59%	Highly Valid
Impact on understanding and learning outcomes	246	270	4.55	91.11%	Highly Valid
Total Score	1851	2025		91.41%	Highly Valid

**Table 8.***X-5 and X-9 students' perspective scores against the Flipped Periodic Table (46 students)*

Classes	Scores Obtained	Total Score	Percentage	Remarks
X-5	1233	1425	86.53%	Highly Valid
X-9	1851	2025	91.41%	Highly Valid
Total Score	3084	3450	89.40%	Highly Valid

Based on the results of the questionnaire analysis of the response of students in grades X-5 and X-9 to the use of Flipped Periodic Table learning media, a score percentage of 86.53% was obtained for class X-5 and 91.41% for class X-9. Overall, the total percentage of student responses reached 89.40% with very valid criteria. The findings indicate that the developed media was highly well received by students and is deemed appropriate for use in chemistry instruction. Judging from the aspect of media display and design, the high scores obtained show that students assess that the media has an attractive appearance, a clear layout, and a visual design that supports learning comfort. The interactive and modern display of the periodic table is able to create a learning atmosphere that is not boring, thus helping to increase students' attention during the learning process. In terms of ease of use of media, students' responses showed that media is easy to operate through various devices such as mobile phones, tablets, and laptops. This indicates that the media has a good level of usability, so that students do not experience technical obstacles in accessing or using the features available during learning. Furthermore, in the aspect of media interactivity, the results of the questionnaire showed a very positive response. The features contained in the Flipped Periodic Table allow students to interact directly with the electron configuration material, so that the learning process is not passive. This interactivity helps students understand concepts gradually and contextually, while increasing student engagement in learning. In terms of interest level and learning motivation, a high score percentage indicates that the use of Flipped Periodic Table media is able to increase students' interest in chemistry learning. This media makes students more enthusiastic, focused, and motivated to learn, especially with support systems such as interactive displays that are challenging and fun. In the aspect of material suitability, students assessed that the electron

configuration material presented in the media was in accordance with the learning objectives and needs of students. The systematic and integrated presentation of the material with the periodic table helps students understand the relationship between concepts more completely. Finally, in the aspect of impact on student understanding, positive responses showed that the Flipped Periodic Table media contributed to improving students' understanding of the concept of electron configuration. Students feel more confident in learning and writing down electron configurations after using this medium, which ultimately supports improved learning quality. Overall, the results of the responses of students in grades X-5 and X-9 showed that the Flipped Periodic Table learning media met the criteria for being very valid in all aspects assessed. Therefore, this medium is declared suitable for use as a chemistry learning medium in electron configuration materials.

### **3.4.1 Students Responses**

To reinforce these quantitative findings, the researchers also collected qualitative student feedback through written statements regarding the use of the “Flip Periodic Table” media. The analysis results showed that the majority of students responded positively to the use of the Flip Periodic Table media. Some students stated that “chemistry lessons are fun,” “learning is really fun,” and “the game is good and fun.” These statements indicate that the use of this media was able to shift students’ perceptions of chemistry learning which was previously often viewed as difficult and boring into something more engaging and enjoyable. These findings align with several studies indicating that learning media integrating gamification elements can significantly enhance enjoyable learning experiences and student engagement (Nadeem et al., 2023; Li et al., 2024; Nurhikmah et al., 2024).

Additionally, students reported that they “study more frequently using their phones” and found the “ranking system to be engaging and challenging.” This aligns with quantitative data on learning motivation, which indicates that gamification elements in the media can boost student engagement and the desire for self-directed learning. These statements indicate that the “Flipped Periodic Table” media developed is capable of leveraging students’ digital habits to support more flexible and self-directed learning. This is consistent with the findings of Ardiansyah & Nana (2020), which show that mobile learning-based instruction can improve student learning outcomes and serve as a media solution that can be used anywhere and anytime. Furthermore, the ranking system as part of gamification has been proven to create an active learning environment through healthy competition, and this point system can function as a means of providing immediate feedback (Jun & Lucas., 2024; Saleem et al., 2022; Li et al., 2024).

Some students also provided constructive suggestions, such as “to make it more challenging by setting a time limit per question” and “in the future, create more games like this so that learning doesn’t get boring.” These suggestions indicate that students not only enjoy using the media but also have expectations for its further development. Beyond the motivational aspect, students also stated that “learning becomes easier to understand, especially with practice in the ‘Flipped Periodic Table’ media” and “we can practice on our own.” These statements reinforce the findings regarding the media’s impact on student understanding, indicating that the “Flipped Periodic Table” learning media is not only visually engaging but also effective in supporting conceptual understanding of electron configuration material. Similar studies also indicate that website-based learning media are not only visually appealing but also help students understand abstract chemical concepts in a more concrete way (Dianti et al., 2023; Riska et al., 2025).

Based on both quantitative and qualitative analyses, the Flipped Periodic Table media was found to elicit a very positive response from students. Quantitative data indicate a high level of media feasibility across all evaluation aspects, while qualitative data reinforce these findings through students' direct experiences and positive impressions during media use. Thus, the Reverse Periodic Table is considered suitable for use as a chemistry learning medium and has the potential to enhance students' motivation and understanding of electron configuration material.

### 3.5 Evaluation Stage

The evaluation phase represents the final step in the ADDIE model, focusing on determining the quality and appropriateness of the developed instructional media. In this study, evaluation was conducted in the form of formative evaluation (Branch, 2009).

Formative evaluation is conducted continuously during the design, development, and implementation stages to ensure the quality of the developed media. During the design stage, evaluation is conducted by reviewing the alignment of the media design with the results of the needs analysis, ensuring that the designed media is relevant to the characteristics and needs of the students. At the development stage, evaluation is carried out through validation by both material and media experts to examine the appropriateness of the content, presentation, language, and visual design of the media. The results of this validation are used as the basis for revising and refining the media. Furthermore, during the implementation stage, evaluation is conducted by collecting student feedback on the use of the media, which includes quantitative data in the form of Likert scale questionnaire scores (1-5) and qualitative data in the form of student comments and suggestions, to determine the level of practicality, appeal, and student engagement in learning.

Thus, this series of formative assessments ensures that the resulting Flipped Periodic Table resource not only meets the academic standards of chemistry but also effectively addresses the need for student engagement at State High School 6 in Malang.

## 4. Conclusion

The results of the study indicate that the development of the Flipped Periodic Table website-based chemistry learning media on electron configuration material is feasible and highly valid as a learning medium. Validation by material experts and media expert obtained percentages of 93% and 96%, respectively, with an overall validity of 94.50%, indicating the suitability of scientific content, clarity of display, and effectiveness of interactive design in supporting students' understanding of the concept of electron configuration and its relationship to the periodic table of elements. The revision process based on validator input further strengthened the quality of the media in terms of conceptual accuracy and visual appeal. In addition, the results of the response questionnaire for students in grades X-5 and X-9 showed an overall percentage of 89.40% with a highly valid criterion, indicating that the media received very positive responses from students in terms of appearance, ease of use, interactivity, learning motivation, material suitability, and its impact on concept understanding. These findings are reinforced by qualitative responses from students who stated that learning has become more interesting, enjoyable, and easy to understand, and that there has been an increase in motivation and independence in learning through challenging gamification elements. Thus, the Flipped Periodic Table learning media is not only theoretically valid, but also practical and effective as an alternative learning resource in high school chemistry education.

## 6. References

- Abdulrahman, M. D., Faruk, N., Oloyede, A. A., Surajudeen-Bakinde, N. T., Olawoyin, L. A., Mejabi, O. v., Imam-Fulani, Y. O., Fahm, A. O., & Azeez, A. L. (2020). Multimedia Tools in The Teaching and Learning Processes: A Systematic Review. In *Heliyon* (Vol. 6, Issue 11). Elsevier Ltd. <https://doi.org/10.1016/j.heliyon.2020.e05312>
- Ahyan, R. R., Saputra, H. N., & Darman, D. (2022). Development of Web-Based Learning Media as A Chemistry Learning Supplement. *JINOTEP (Jurnal Inovasi Dan Teknologi Pembelajaran) Kajian Dan Riset Dalam Teknologi Pembelajaran*, 9(3), 219. <https://doi.org/10.17977/um031v9i32022p219>
- Akram, A., Sardar, R., & Siyab, M. (2025). Impact of Colors in Classroom: A Visual Study on Educational Attention and Psychological Comfort. *Research Consortium Archive*, 3(3), 538-554. <https://rcresearcharchive.com/index.php/Journal/article/view/186>
- Ardiansyah, A. A., & Nana, N. (2020). Peran Mobile Learning sebagai Inovasi dalam Meningkatkan Hasil Belajar Siswa pada Pembelajaran di Sekolah. *Indonesian Journal of Educational Research and Review*, 3(1), 47–56. <https://doi.org/10.23887/ijerr.v3i1.24245>
- Basri, M. F. M., & Ikhsan, J. (2024). The Development of Enrichment Book of Chemistry in Our Body Based on Augmented Reality and its Influence on Chemistry Literacy and Scientific Attitude of High School Student. *Jurnal Pendidikan Kimia*, 16(3), 311 – 317. <https://doi.org/10.24114/jpkim.v16i3.65200>
- Benešová, A., & Tupa, J. (2017). Requirements for Education and Qualification of People in Industry 4.0. *Procedia Manufacturing*, 11, 2195-2202 <https://doi.org/10.1016/j.promfg.2017.07.366>
- Branch, R. M. (2009). *Instructional design: The ADDIE approach*. Springer.
- Chans, G. M., & Portuguez Castro, M. (2021). Gamification as a Strategy to Increase Motivation and Engagement in Higher Education Chemistry Students. *Computers*, 10(10). <https://doi.org/10.3390/computers10100132>
- Cotiango, E. N., Huraño, N. J., Sodoso, E. R. G., Sumagang, M. G. P., Jumao-as, J. J., Canoy, J. H., Picardal, M. T., & Sanchez, J. M. (2024). Android-based audio-visual comics in enhancing conceptual understanding and motivation of chemistry concepts. *Orbital: The Electronic Journal of Chemistry*, 16(2), 125–135. <https://doi.org/10.17807/orbital.v16i2.19953>
- Cristy, L. V. R., & Pamenang, F. D. N. (2023). Development of Ethnoscience-based Student Worksheets of Redox Reactions, Volta Cells, and Corrosion Using Liveworksheets. *Jurnal Pendidikan Kimia*, 15(3), 182–190. <https://doi.org/10.24114/jpkim.v15i3.51211>
- Deslauriers, L., McCarty, L. S., Miller, K., Callaghan, K., & Kestin, G. (2019). Measuring Actual Learning Versus Feeling of Learning in Response to Being Actively Engaged in the Classroom. *Proceedings of the National Academy of Sciences of the United States of America*, 116(39), 19251–19257. <https://doi.org/10.1073/pnas.1821936116>
- Dianti, E., Adibatuzzakiyah, G. W., Khalida., & Analita, R. N. (2023). Efektivitas Penggunaan Media E-Learning Berbasis Website untuk Meningkatkan Minat Belajar pada Pembelajaran Kimia: Sebuah Kajian Pustaka. *Journal of Chemistry and Education (JCAE)*, 7(2), 70-78. <https://doi.org/10.20527/jcae.v7i2.2718>
- Erlitaviana, D., & Tyas, D. N. (2025). The Relationship Between the Use of Audio-Visual Learning Media and Learning Motivation with Learning Outcomes in Elementary School. *Jurnal Penelitian Pendidikan IPA*, 11(3), 163–170. <https://doi.org/10.29303/jppipa.v11i3.10375>
- Faisal, S., Supardi, U. S., & Sriyono, H. (2021). Aplikasi Media Pembelajaran Berbasis ICT pada Sub Materi Mekanika Kuantum. *Alfarisi: Jurnal Pendidikan MIPA*, 4(3), 216-225

- Feriyanto, F., & Anjariyah, D. (2024). Deep Learning Approach Through Meaningful, Mindful, and Joyful Learning: A Library Research. *Electronic Journal of Education, Social Economics and Technology*, 5(2), 208–212. <https://doi.org/10.33122/ejeset.v5i2.321>
- Fichtner, B., & Groß, K. (2025). What Beliefs do Chemistry Teachers Have About Instructional Explanations? An Exploratory Investigation. *Chemistry Education Research and Practice*, 26(3), 660–681. <https://doi.org/10.1039/d4rp00341a>
- Habib, A., Astra, M. I., & Utomo, E. (2021). Use of Multimedia Interactive based on PjBL (Project Based-Learning): Study Effectiveness of Student Creativity in Subject Natural Sciences. *International Journal of Multicultural and Multireligious Understanding*, 8(5), 628-636.
- Hemayanti, K. L., Muderawan, I. W., & Selamat, I. N. (2020). Analisis Minat Belajar Siswa Kelas XI MIA pada Mata Pelajaran Kimia. *Jurnal Pendidikan Kimia Indonesia*, 4(1), 20–25. <https://doi.org/10.23887/jpk.v4i1.24060>
- Herdien, R. A. (2024). Identification of Misconceptions in 10th Grade Students on Atomic Structure Material. *Journal of Chemistry Sciences and Education*, 1(02), 50–57. <https://doi.org/10.69606/jcse.v1i02.129>
- Huang, L., & Pei, X. (2024). Exploring the Impact of Web-based Inquiry on Elementary School Students' Science Identity Development in a STEM Learning Unit. *Humanities and Social Sciences Communications*, 11(1). <https://doi.org/10.1057/s41599-024-03299-5>
- Indriani, N. C. L., Mustaji, M., & Mariono, A. (2023). The Influence of Web-Based Learning on Students' Self-Regulated Learning in High School Chemistry Learning. *International Journal of Educational Research Review*, 8(2), 257-267. <https://doi.org/10.24331/ijere.1249689>
- Ippoliti, F. M., Chari, J. V., & Garg, N. K. (2022). Advancing Global Chemical Education Through Interactive Teaching Tools. In *Chemical Science. Royal Society of Chemistry*. 13(20), 5790–5796. <https://doi.org/10.1039/d2sc01881k>
- Iyamuremye, A., Twagilimana, I., & Niyonzima, F. N. (2025). Investigating The Impact of Using Web-based Discussion Tools on Students' Conceptual Understanding and 21st Century Skills Development in Organic Chemistry Education. *Discover Education*, 4(1). <https://doi.org/10.1007/s44217-025-00548-w>
- Johnson, E. U., & Ramnarain, U. (2018). Representation of Chemical Phenomenon in Secondary School Chemistry Textbooks. *Chemistry Education Research and Practice*. 20, 146-159. DOI: 10.1039/C8RP00191J
- Jun, M., & Lucas, T. (2024). Gamification Elements and Their Impacts on Education: A Review. *Multidisciplinary Reviews*, 8(5), 1-7. <https://doi.org/10.31893/multirev.2025155>
- Juniar, A., Rahmah, S., Tambunan, T. P., & Tambunan, P. M. (2023). Development of Interactive Teaching Materials Based on Inquiry-Based Learning Models Based on the Outcome-Based Education Curriculum in Analytical Chemistry Learning. *Jurnal Pendidikan Kimia (JPKIM)*, 15(3), 243–252. <https://doi.org/10.24114/jpkim.v15i3.50780>
- Kholid, I., Harizon, H., & Hasibuan, M. H. E. (2024). The Development of a Project-based Multimedia and its Effectiveness in Improving Students' Higher Order Thinking Skills About Chemistry Bonding Concept. *Jurnal Pendidikan Kimia*, 16(3), 230 – 237. <https://doi.org/10.24114/jpkim.v16i3.65171>
- Kovač, V. B., Nome, D. Ø., Jensen, A. R., & Skreland, L. Lj. (2025). The Why, What and How of Deep Learning: Critical Analysis and Additional Concerns. *Education Inquiry*. 16(2), 237–253. <https://doi.org/10.1080/20004508.2023.2194502>

- Kumar, J. (2025). Student Perceptions of E-Learning Tools in Chemistry Education. *International Journal of Innovations in Science Engineering and Management*. 336– 343. <https://doi.org/10.69968/ijisem.2025v4i3336-343>
- Kusasi, M., Bakti, I., & Astuti, R. T. (2024). Development of e-Modules of Reaction Rate Problem-Based Learning Model to Improve Students' Critical Thinking Skills and Wasaka Character. *EduChemia: Jurnal Kimia dan Pendidikan*, 9(2), 219–238. <https://doi.org/10.30870/educhemia.v9i2.27504>
- Lee, K. Y. R., Ng, Y. N. B., & Chen, M. D. (2024). Adoption of the Addie Approach in An Agile Way for the Development of Biochemistry Courseware for Learning Metabolism. *Journal of Chemical Education*, 101(3), 1292–1301. <https://doi.org/10.1021/acs.jchemed.3c00851>
- Li, C., Liang, L., Fryer, L. K., & Shum, A. (2024). The Use of Leaderboards in Education: A Systematic Review of Empirical Evidence in Higher Education. *Journal of Computer Assisted Learning*, 40, 3406-3442. DOI: 10.1111/jcal.13077
- Li, Y., Chen, D., & Deng, X. (2024) The Impact of Digital Educational Games on Student's Motivation for Learning: The Mediating Effect of Learning Engagement and the Moderating Effect of the Digital Environment. *PLoS ONE*, 19(1), 1-21. <https://doi.org/10.1371/journal.pone.0294350>
- Mandasari, Y. D., Subandowo, M., & Gunawan, W. (2021) Pengembangan Media Pembelajaran Interaktif Konfigurasi Elektron Elektronik Otomatis Mata Pelajaran IPA di Masa Pandemi Covid-19. *JKTP: Jurnal Kajian Teknologi Pendidikan*, 4(3), 233-328. DOI:10.17977/um038v4i32021p309
- Mufidah, R., & Kusumawati,. (2024) Development of a Problem-Based Learning-Oriented Interactive E-worksheet on Chemical Equilibrium to Enhance Students' Scientific Literacy Skills. *Jurnal Kimia dan Pendidikan Kimia (JKPK)*, 9(2), 370–385. <http://dx.doi.org/10.20961/jkpk.v9i2.89480>
- Nadeem, M., Oroszlanyova, M., & Farag, W. (2023). Effect of Digital Game-Based Learning on Student Engagement and Motivation. *Computers*, 12(9), 177. <https://doi.org/10.3390/computers12090177>
- Nsabayeze, E., Iyamuremye, A., Nungu, L., Mukiza, J., Mukama E., & Niyonzima F. N. (2023). Online periodic table of elements to support students' learning of trends in properties of chemical elements. *Education and Information Technologies*, 11793–11817 <https://doi.org/10.1007/s10639-023-11650-7>
- Nurhikmah, N., S, R., & Nurdin, N. (2024). Literature Review: Media Game Edukasi Interaktif dalam Pembelajaran Matematika. *Journal of Education Research*, 5(4), 4382–4390. <https://doi.org/10.37985/jer.v5i4.1573>
- Nurussalma, S., Yuniastuti, A., Mustikaningtyas, D., & Parmin, P. (2024). Analysis of the Validity and Readability of Google Sites Learning Media with a Stem Approach on Mutation Material to Improve Student Critical Thinking Skills. *Unnes Science Education Journal*, 13(2), Artikel 8364. <https://doi.org/10.15294/usej.v13i2.8364>
- Pertiwi, P. N., Saputro, S., Yamtinah, S., & Kamari, A. (2024). Enhancing Critical Thinking Skills Through STEM Problem-Based Contextual Learning: An Integrated e-Module Education Website with Virtual Experiments. *Journal of Baltic Science Education*, 23(4), 739-753. <https://doi.org/10.33225/jbse/24.23.739>
- Putri, Z. A., Zulyusri, Z., Syamsurizal, S., Vauzia, V., & Arsih, F. (2025). Development of an ESQ-integrated E-book on Biodiversity to Increase Student's Motivation and Character. *JPBI (Jurnal Pendidikan Biologi Indonesia)*, 11(2), 774–786. <https://doi.org/10.22219/jpbi.v11i2.40893>

- Prayitno, M. A., & Nugroho, D. E. (2023). Misconception Diagnostic in Quantum Number Materials and Electron Configuration. *JP (Jurnal Pendidikan): Teori dan Praktik*, 8(1), 9–15. <https://doi.org/10.26740/jp.v8n1.p9-15>
- Rahmatsyah, S. W., & Dwiningsih, K. (2021). Development of interactive e-module on the periodic system materials as an online learning media. *Jurnal Penelitian Pendidikan IPA*, 7(2), 255–261. <https://doi.org/10.29303/jppipa.v7i2.582>
- Riska, R., Erna, M., & Linda, R. (2025). Development of Web-Based Interactive Learning Media for the Topic of Atomic Structure and the Periodic System of Elements for Grade X Senior High School Students. *Chemistry Education Practice*, 8(2), 329–342. <https://doi.org/10.29303/cep.v8i2.9455>
- Saleem, A. N., Noori, N. M., & Ozdamli, F. (2022). Gamification Applications in E-learning: A Literature Review. *Technology, Knowledge, and Learning*, 27, 139-159. <https://doi.org/10.1007/s10758-020-09487-x>
- Sari, S. A., & Nasution, N. S. (2024) Development of PBL-Based Chemistry E-Modules for Colloidal Systems. *Jurnal Kimia dan Pendidikan Kimia (JKPK)*, 9(2), 355-369, <http://dx.doi.org/10.20961/jkpk.v9i2.85301>
- Silaban, R., Girsang, O. A. B., Manalu, R. T., Sitorus, M., Tarigan, S., & Alexander, I. J. (2023). Preparing of Chemical Bonding Learning Media Based Android Using Smart Apps Creator Program. *Jurnal Pendidikan Kimia*, 15(3), 273–280. <https://doi.org/10.24114/jpkim.v15i3.51492>
- Suhardi, S., Side, S., & Allo, E. L. (2024). Development of Chemino Card Learning Media (Chemical Domino Cards) on Elemental Stability Material. *Jurnal Pendidikan Kimia*, 16(2), 127–135. <https://doi.org/10.24114/jpkim.v16i2.56574>
- Sunarya, R. R., Hijriansyah, R., & Aisyah, R. (2024). Implementation of Problem Solving-Based Electron Configuration E-Modules to Improve Student Learning Outcomes. *Jurnal Pendidikan Kimia Indonesia*, 8(1), 11–20. <https://doi.org/10.23887/jpki.v8i1.70029>
- Suryapranata, K. P. L., Bahagia, I. F., & Lazarusli, I. A. (2023). Gamification Using Visual Novel to Improve Chemistry Learning Motivation. *Journal of Games, Game Art, and Gamification*, 8(1), 13-17. <https://doi.org/10.21512/jggag.v8i1.9411>
- Syafruddin, A. B., Widarti, H. R., & Rokhim, D. A. (2024). Development of Instagram-Based Learning Media Increase Students Learning Interest in Acid-Base Materials. *The Online Journal of Distance Education and E-Learning (TOJDE)*, 25(2), 228- 247. <https://doi.org/10.17718/tojde.1312770>
- Taber, K. S. (2013). Revisiting the Chemistry Triplet: Drawing Upon the Nature of Chemical Knowledge and the Psychology of Learning to Inform Chemistry Education. *Chemistry Education Research and Practice*, 14(2), 156–168. DOI:10.1039/C3RP00012E
- Trixie, S., & Cahyaning Ratri, M. (2024). The Development of Interactive Multimedia on The High School's Nanotechnology. *Jurnal Pendidikan Kimia Indonesia*, 8(1), 21–28. <https://doi.org/10.23887/jpki.v8i1.73130>
- Wijayanti, M. T., & Lutfi, A. (2021). Pengembangan Permainan Element Go sebagai Media Pembelajaran pada Materi Konfigurasi Elektron yang Mempengaruhi Retensi Peserta Didik. *PENDIPA: Journal of Science Education*, 5(3), 269-276. <https://doi.org/10.33369/pendipa.5.3.269-276>
- Yang, X. (2023). Teaching Strategy of Chemistry Concepts Based on Deep Learning. *Advances in Social Sciences Research Journal*, 10(6), 427–432. <https://doi.org/10.14738/assrj.106.14913>
- Zhang, Y., Watson, S.L. (2025). Impacts of Gamified Project-Based Learning on Students' Achievement Motivation in Rural China. *TechTrends* 69, 471–484. <https://doi.org/10.1007/s11528-025-01051-7>