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Alkaan Speil Game: Encouraging Higher-Order Thinking in Alkane Learning Material

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Abstract

This research aims to describe and analyze the validation and feasibility of the Alkaan Speil game interface. The method used in this research was design-based research (DBR), which encompasses three stages: analysis, design, and development. The validation test results yielded a calculated r-value of 0.93, indicating a high level of validity. Furthermore, the feasibility test, which includes content and material aspects, software engineering, and audio-visuals, resulted in a percentage of 84.08%, suggesting that the Alkaan Speil game was effective as a learning tool for alkane material with a higher-order thinking approach. The findings of this research present significant implications for educational technology and pedagogy. The high validity score of 0.93 for the Alkaan Speil game underscores its robust design and affirms its potential as an innovative educational tool. The feasibility test results, with an impressive 84.08% score, further reinforce the game's effectiveness in facilitating higher-order thinking skills in the context of learning alkanes. This finding underlines the game's capacity to enhance understanding and engagement in chemistry education. Although this current study was confined to the application's development phase, the implications extend to the need for comprehensive testing of the game's efficacy in a real-world educational setting. Future research should focus on deploying the game in classroom environments to empirically assess its impact on learning outcomes and student engagement, thereby contributing to the broader knowledge base of educational strategies in science teaching.

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INTRODUCTION

Learning media plays a significant role in facilitating and enhancing the educational experience for students (Şencan & Atacak, 2023; Bamaga et al., 2023; Sinaga et al., 2019). The development of various educational media has been significantly enriched by leveraging technological advancements (Abd Halim et al., 2022;). Using multimedia in the learning process significantly improves student learning outcomes (Sari et al., 2017). Multimedia in the learning process contributes significantly to improving student learning outcomes (Hartini et al., 2017; Méndez & Navarro, 2023;Ljubojevic et al., 2014). Contrary to common belief, learning media are not always effective in enhancing students' interest in learning, affecting their critical thinking ability. This issue often occurs due to ineffective educational media engaging students' attention. Nonetheless, this challenge also opens opportunities for innovation in educational media. Using technology in learning media can be an innovative way to attract students' interest and increase their involvement in learning. Among these are technology-

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based educational media (Rusman et al., 2023; Parvathy & Mishra, 2023;Núñez et al., 2023; Ahmadi et al., 2023).

Digital technology as learning media has become a widespread trend, particularly in the context of teaching chemistry (Ummah et al., 2021), physics (Aulia & Yuliani, 2022; Darma et al., 2019; Fitri et al., 2021; Liliarti & Kuswanto, 2018), biology (Garcia-Bonete et al., 2019; Khastini et al., 2021), and mathematics (Netriwati et al., 2023). Specifically in chemistry education, learning media is greatly needed. Students require increased motivation and understanding in chemistry (Perets et al., 2020). Alkane material is a chemistry topic that often poses challenges for students, given the need to integrate various concepts through higher-order thinking processes. Moreover, high motivation is necessary to prevent boredom during the learning process of alkanes, which is often regarded as complex and requires in-depth understanding (Flynn, 2014). Therefore, educational media on alkane topics are needed to make the level of motivation in learning, understanding, and students' thinking accessible (Ying & Tiemann, 2024). Alkane concepts are often difficult to grasp abstractly (Gillette et al., 2017; Mayerhöfer & Spange, 2023). By using media such as molecular models, chemical reaction simulations, or molecular structure animations, students can better visualize the molecular structures of alkanes and how chemical reactions occur among them (Zhao et al., 2022). Educational media enable students to actively explore the properties of alkanes and apply these concepts in real situations (Winfield et al., 2019). Furthermore, educational media can introduce variations in alkane structures, which often require in-depth understanding, and assist students in mastering the names of different alkane compounds. All this makes educational media essential in facilitating the understanding and learning of alkane material in chemistry.

The current development of technology has given birth to various game-based learning media, including Ludo Word Game (LWG) (Sakinah, 2018), Diamond Chemistry Adventure (Andiastutik & Lutfi, 2017), Organic Fanatic (Shoesmith et al., 2020), Time Bomb (da Silva Júnior et al., 2020), and ChemFlo (Astuti & Sugijarto, 2018). Based on research and data analysis, quiz-based games have received positive responses. Organic Fanatic, for example, is an exciting game that supports learning while playing and effectively increases student engagement in organic chemistry (Shoesmith et al., 2020). Meanwhile, the Ludo Word Game (LWG) has been proven to be an effective learning medium for hydrocarbon materials at the high school level, engaging students' attention and interest to complete exercises happily (Sakinah, 2018). Additionally, Diamond Chemistry Adventure has been rated as a viable learning medium for hydrocarbons, evidenced by post-learning test results that showed scores above 80 after students interacted with the game (Andiastutik & Lutfi, 2017).

Based on the research conducted, there are weaknesses in the developed game applications. Most questions within these applications are still focused on lower-order thinking skills (LOTS), which implies limitations for educators in measuring higher-order thinking skills. Considering the importance of using interactive learning media such as games to facilitate engaging learning experiences, it is essential to integrate elements that can support the development of higher-order thinking abilities in students. This is particularly relevant in chemistry education, especially regarding alkane materials (Bell et al., 2020; Hooshyar et al., 2021). Therefore, this development research aims to create the Alkaan Speil game, designed with a high-level thinking orientation related to alkane material. The visualization in this game is presented more appealingly, combined with complex thought processes and pedagogical values. This development research aims to enhance student interest and ability and provide a more effective learning evaluation method, especially for the topic of alkanes.

METHOD

The research method employed in this research was design-based research (DBR), which developed teaching materials and technology designed to support the learning process, resulting in a product that can assist students in their educational journey (Tweeten & Hung, 2023). The approach used in this research was the ADDIE model, which included several stages: analysis, design, development, implementation, and evaluation (Ole, 2023). However, this research was conducted up to the development stage, as detailed further in Figure 1.

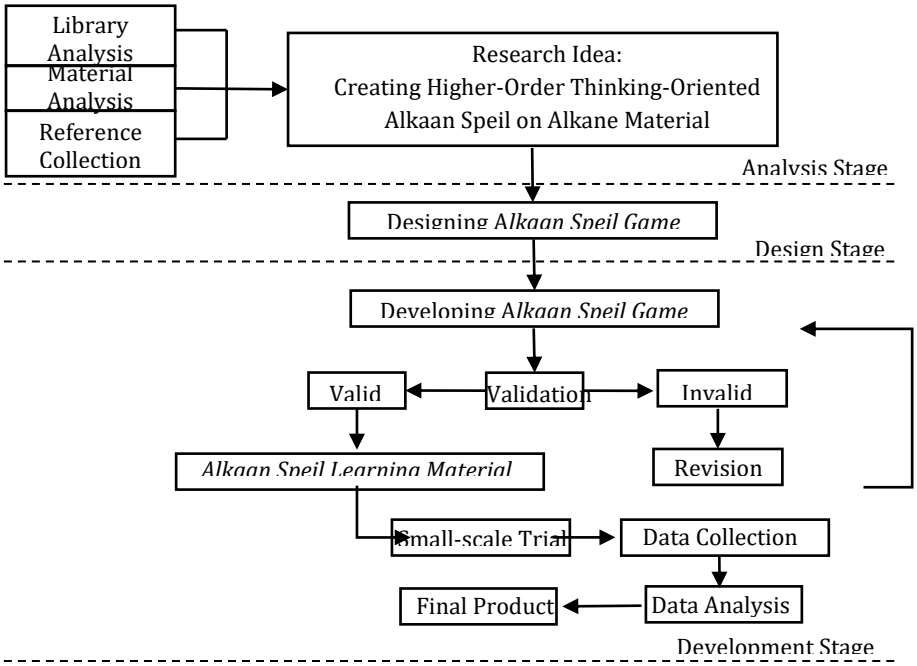


Figure 1. Developmental Research Procedure

Data collection was carried out after completing the three stages of development (Shen et al., 2023). The data collection techniques used in this research consisted of two forms: needs analysis and validation questionnaires. The needs analysis was conducted as a literature study from various sources such as textbooks, e-books, and journals (Jarial, 2023). This analysis aimed to collect and analyze the data needed for product creation. Meanwhile, the questionnaire form included a statement within the questionnaire consisting of a) a validation questionnaire for the Alkaan Speil learning media by media expert validators and subject matter experts before feasibility testing and b) a feasibility test questionnaire for the Alkaan Speil learning media targeted at 25 Chemistry Education students who had taken Organic Chemistry I as respondents and also as data sources for the research.

After obtaining the validation test data, data analysis techniques compared the feasibility score with the critical value. The media is considered valid if the calculated r-value exceeds the critical r-value with an r > 0.3. If the r-value of the criterion element is < 0.3, it is declared invalid. The calculation is performed using the formula $r = \frac{x}{N.n}$ (Arikunto, 2010). Data analysis of the feasibility test instrument was conducted to determine and ascertain the percentage of feasibility through the score of statements categorized into four categories: Strongly Agree (SA), Agree (A), Disagree (D), and Strongly Disagree (SD). The calculation is done with the following formula to obtain the value of the feasibility percentage:

$$\%\ Result = \frac{total\ score\ obtained}{maximum\ score}\ x\ 100\%\ \text{(Arikunto, 2010)}$$

This includes descriptive statements about learning, dual representation, visual communication, and software engineering. Three expert sources in media and subject matter filled it out as validators. The validation aims to evaluate the content and structure of the digital book with suggestions and comments as measures for improvement and refinement.

RESULTS AND DISCUSSION

The results obtained from this research are utilized as data for discussion and conclusion. This research aimed to describe the display, analyze the validation test results, and analyze the feasibility test outcomes of the Alkaan Speil game, which is oriented towards higher-order thinking in alkane material. The first topic to be discussed is displaying the Alkaan Speil game product.

The Description of the Application Display

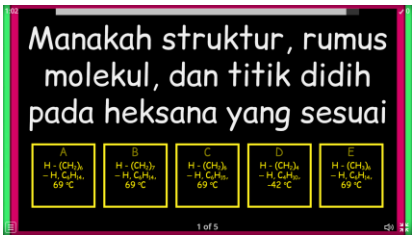
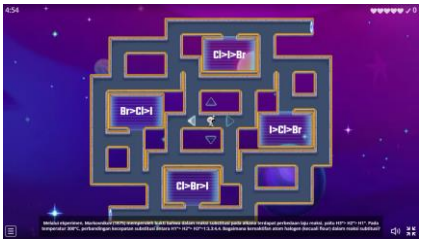
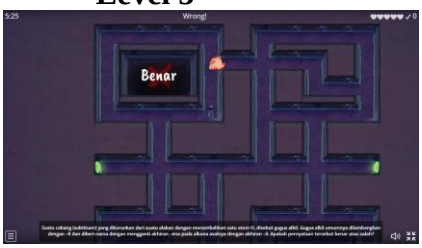
One of the most important aspects of designing and creating game-based media is considering the display's aesthetics (Andersen et al., 2011; Hebert, 2021;Thaleia Deniozou, Mariza Dima, 2020). For example, the images displayed must be relevant to the material, considering the composition and/or placement of images and text and ensuring that the instructions presented are easily understood so that the game can be played effortlessly. Alkaan Speil is a game developed with an innovative visual approach and requires advanced analytical thinking, accompanied by integrating pedagogical values. Its primary goal is to enhance students' interests and abilities and provide a more engaging learning evaluation tool, particularly in alkane material.

Learning about alkanes often challenges students, requiring a deep understanding of the associated concepts and analytic thinking. This demands high motivation to prevent boredom during learning (Watts, 2023). Thus, to measure how well students understand alkane material with the previously mentioned concepts, HOTS (Higher-Order Thinking Skills) questions are needed to measure thinking (Walid et al., 2019). According to Bloom's theory, human thinking ability is classified into six levels. These levels include basic knowledge or remembering (C1), understanding (C2), application (C3), analysis (C4), evaluation (C5), and creation (C6). In the context of Bloom's Taxonomy, higher-level thinking is identified through an individual's ability to analyze (C4), evaluate (C5), and create (C6) (Nofiana et al., 2017; Semsar & Casagrand, 2017). Each of these concepts is then broken down into several indicators. Each indicator measures whether the desired learning outcomes of a particular material are achieved. The display of the Alkaan Speil game can be seen in Table 1.

Table 1. Display and Description of the Alkaan Speil Game

No	Display	Description
1		This page will appear when opening the link to the Alkaan Speil Game
2		The main menu display features several buttons, such as "start," "usage instructions," "learning objectives," "media creator profile," music, and an "x." The "start" button directs students to the level tier page available in the Alkaan Speil game. The "usage instructions" button leads to the Alkaan Speil usage instruction page, which includes general instructions and game usage guidelines. The "learning objectives" button navigates to the learning objectives page. The "media creator profile" button takes students to the media creator profile page, which contains the profiles of the media creator and the first and second supervising lecturers, including names, ID numbers, functional positions, email, and scholar profiles.

No	Display	Description
3		On the level tier page, buttons from levels 1 to 5 are available, along with a field to input scores to proceed to the next level. There is also a "home" button to return to the main menu page, a music symbol button to turn music on or off, an "X" button to exit the game, and a question mark symbol button leading to the usage instructions page.
4		On the level tier page, buttons from levels 1 to 5 are available, along with a field to input scores to proceed to the next level. There is also a "home" button to return to the main menu page, a music symbol button to turn music on or off, an "X" button to exit the game, and a question mark symbol button leading to the usage instructions page. The Alkaan Speil usage instructions display consists of general instructions and game usage guidelines. The general instructions include: (1) Start by reading Basmallah, (2) Be honest because everything is compiled in one file, (3) It is advisable to read the alkane material provided by the organic chemistry lecturer beforehand, (4) Ensure your internet signal is stable, (5) Pay attention to your device's battery to avoid low battery during the game. The game usage instructions include: (1) Ensure your internet signal is stable; (2) Each level has different levels of difficulty and bonuses; (3) The minimum score at each level is 350 to proceed to the next level; (4) In levels 3-5, each correct answer is multiplied by 150/answer.
5		The learning objectives page contains the expected objectives after playing the Alkaan Speil game.
6		The media creator profile page contains information about the application's developers. The information on this page is presented in text and photo format.

No	Display	Description
7	**Levels 1 and 2** 	Levels one and two are the introductory levels in the Alkaan Speil game. At this level, the game presented is a quiz gameshow. Students are given 60 seconds to answer each question. The quiz gameshow contains questions about alkane molecular formulas, IUPAC nomenclature, physical properties of alkanes, alkane molecular structures, and classification of carbon atoms with question indicators: sorting, focusing, organizing, elaborating, and evaluating.
8	**Level 3**  **Level 4**  **Level 5** 	Levels three to five are advanced levels available in the Alkaan Speil game if students pass levels one and two. At this level, the game presented is a chase in a maze. Students are given approximately five to seven minutes at each level to answer all the questions. In the maze chase game section, questions about alkanes include several concepts, such as reactions occurring in alkanes consisting of sulfonation, nitration, pyrolysis, and cracking reactions. Besides reactions in alkanes, this section contains questions about the uses of alkanes, IUPAC nomenclature, and classification of carbon atoms. Unlike the quiz gameshow section, this part features characters that can be played to answer the given questions. The function of these characters is to determine the correct answer to the given questions. The questions have indicators at the cognitive levels C4 and C5.

Alkaan Speil is an educational game to boost students' learning motivation while evaluating their higher-order thinking abilities. The game consists of five levels, where the first two are easier and take the form of multiple-choice quizzes. Meanwhile, levels three to five are designed as a sequence of chases in a maze. The gameplay begins with a login screen where students enter their names. Next, they proceed to the main page containing buttons for 'start', usage instructions, learning objectives, and information about the game's development. Educators guide students to understand the usage instructions first for easier gameplay. Then, students are encouraged to explore the learning objectives and the developer's profile. Students must obtain at least 350 points to advance to the next level. Alkaan Speil has the advantage of being an evaluation tool for learning and practice. Additionally, its integration with the education system allows for direct monitoring of student results.

Results of the Validation Test

The validation test is used to determine the accuracy of the content in the research instrument (Treceñe et al., 2023). The validation test was conducted by providing questionnaires to validators. The validators testing it were lecturers competent in their fields. The validation test was conducted by validator lecturers, namely subject matter experts, media experts, and learning experts. The validation test was offline from March 31, 2023, to April 6, 2023. The overall results of the validation test can be seen in Table 2.

Table 2. Validation Test Results

No	Statement	V1	V2	V3	$R_{calculate}$	R_{Crit}	Result
Aspects of Material Substance and Content							
1.	Theoretical and conceptual accuracy of material	5	4	5	0,97	0,30	Valid
2.	Appropriateness of term usage according to field of study	4	4	4	0,97	0,30	Valid
3.	Compatibility of questions with learning objectives	4	4	4	0,97	0,30	Valid
4.	Diversity of question difficulty levels	4	4	5	0,97	0,30	Valid
5.	Suitability of material in the Alkaan Speil game	5	4	5	0,97	0,30	Valid
6.	Completeness and quality of learning media materials	4	4	4	0,97	0,30	Valid
Aspects of Software Engineering							
7.	The Alkaan Speil game link is easily accessible	4	5	4	0,97	0,30	Valid
8.	Speed of application performance	4	4	3	0,73	0,30	Valid
9.	Ease of operation of the Alkaan Speil game	4	4	4	0,97	0,30	Valid
10.	Clarity of usage instructions presentation	5	4	5	0,97	0,30	Valid
11.	Operation by usage instructions	4	4	5	0,97	0,30	Valid
Visual and Audio Aspects							
12.	The music used is interesting and appropriate	4	5	4	0,97	0,30	Valid
13.	Attractive design used in the application	5	4	4	0,97	0,30	Valid
14.	The text is readable and clear	4	3	4	0,73	0,30	Valid
15.	Appropriateness of colours used	4	4	5	0,97	0,30	Valid
16.	Clarity of language used	5	4	4	0,97	0,30	Valid
17.	The language used is easy to understand	5	5	4	0,97	0,30	Valid

Based on the validation test results for the substance and content aspect, the average calculated r-value was 0.97. This indicates that the product is valid regarding material aspects, has a calculated r-value greater than the critical r-value of 0.30, and is considered to have a high interpretation (Zhiwei, 2023). This shows that the theoretical and conceptual accuracy of the material, the appropriateness of term usage according to the field of study, the compatibility of questions with learning objectives, and the diversity of question difficulty levels have been accurately developed.

The software engineering aspect includes the ease of accessing the link, the speed of application performance, the ease of operation, and the clarity of game usage instructions. The average result of the validation test for the software engineering aspect yielded a calculated r-value of 0.92. This indicates that the software engineering aspect is valid and falls into a high interpretation category (Arikunto, 2010) as the calculated r-value > critical r-value.

The third validation test was conducted on audio and visual aspects to determine the assessment of the presentation of the Alkaan Speil game. This aspect includes audio, text, font size, and type, as well as the appropriateness of colour selection and media design. Based on the validation test results for audio and visual aspects, the lowest calculated r-value was 0.73 for the statement "the

text is readable and clear," and the highest was 0.97. The average calculated r-value obtained was 0.93, meaning the Alkaan Speil game is valid in audio and visual aspects according to the theory in Sugiyono's book on qualitative, quantitative, and R&D research methods (Sugiyono, 2015) stating that if the calculated r-value is greater than the critical r-value, then the criteria are considered valid.

The Alkaan Speil game has been assessed as valid, accompanied by feedback and recommendations from validators for enhancements in specific areas. The game, having its validity level known and having undergone some improvements based on validator suggestions and inputs, was then subjected to a feasibility test with 25 Chemistry Education students who had taken Organic Chemistry I. This feasibility test was conducted using a checklist questionnaire as a measuring tool for the completed Alkaan Speil game. This limited test produced data obtained from the students' questionnaire responses. The feasibility test results can be seen in Table 3.

Table 3. Feasibility Test Results

No.	Presentation Aspect	Percentage	Remark	Interpretation
1.	Programming Aspect	86,67	Feasible	High
2.	Content Aspect	85,06	Feasible	High
3.	Display Aspect	80,53	Feasible	High
Average		84,08	Feasible	High

There are three aspects in the feasibility test sheet: programming, content, and linguistic aspects. Based on the feasibility test results for the programming aspect, which includes the ease of media usage, ease of selecting program menus, and ease of entering and exiting the program, the average percentage was 86.67%, thus falling into the suitable category with a high interpretation (Arikunto, 2010). The percentage results indicate that the Alkaan Speil game can be used easily.

The content aspect includes the clarity of the language used, the ease of understanding the language, the appropriateness of questions to the alkane material, the alignment of questions with learning objectives, the diversity of question difficulty levels, and the appropriateness of questions for higher-order thinking processes. The average percentage result obtained was 85.06%, thus falling into the suitable category with a high interpretation (Ernawati, 2017). The results for the content aspect indicate that the evaluation questions presented are easy to understand, and the questions with the presented material are appropriate.

The linguistic aspect includes the ease of understanding the language used, not causing dual meanings in language usage and the clarity and comprehensibility of sentences. The display aspect includes the layout of text and images, colour harmony, and font size and type appropriateness. The average obtained was 80.53%, thus falling into the suitable category with a high interpretation. Looking at all aspects, the average score for the application was 84.04%. This indicates that the Alkaan Speil game is suitable for a learning medium with a high interpretation (Ernawati, 2017).

In addition to completing the checklist questionnaire, respondents provided suggestions and contributions to support the educational game's development. Among these suggestions were comments on linguistic aspects, as some questions had too little text. This issue arose because the size and type of text followed the size and type used on each respondent's device, and it was not possible to change or adjust this due to the limitations of the application and web developer.

Compared to previous research, such as the ChemFlo application by (Astuti & Sugijarto, 2018), Diamond Chemistry Adventure by (Andiastutik & Lutfi, 2017), and Time Bomb by (da Silva Júnior et al., 2020), the Alkaan Speil game offers an advantage in the form of more engaging visualizations combined with higher-order thinking processes. Additionally, this application contains pedagogical values and a point system that integrates directly with educators. This is evidenced by 20 out of 25 respondents stating that the Alkaan Speil game makes learning more enjoyable and adrenaline-boosting.

This research focuses on the development stage of learning media for alkane material in chemistry education. However, it is crucial to remember that the next essential step is the effectiveness test. This test will provide a deeper understanding of how far this medium can enhance students' higher-order thinking skills (HOTS) in the context of chemistry learning. By involving students in trials, researchers can measure the actual impact of this learning medium on

understanding alkane concepts and students' ability to apply this knowledge in solving complex problems.

LIMITATION

While this research successfully highlights the development and feasibility of the Alkaan Speil game, it does not extend to evaluating its long-term effectiveness or adaptability in varied educational settings. Future investigations are encouraged to bridge this gap by assessing its broader impact on student learning outcomes.

CONCLUSION

The Alkaan Speil game, accessible on laptops and smartphones, offers students an engaging and interactive educational experience. Emphasizing user-friendly navigation, the game welcomes users with a straightforward login interface, leading to a comprehensive main page. This page houses essential features like start options, detailed usage instructions, educational goals, and developer information, ensuring a seamless user experience. With a structure comprising five progressively challenging levels, the game effectively balances simplicity in the initial two levels with a more complex maze chase format in the subsequent levels. This design approach aligns well with pedagogical objectives and caters to diverse student needs. The game's rigorous validation process has yielded commendable results, demonstrating high validity in critical aspects such as material substance, software engineering, and audio-visual quality. Specifically, the game scored exceptionally well in material substance (0.97), followed closely by software engineering (0.92) and audio-visual aspects (0.93). These scores, averaging 0.93, underscore the game's reliability and reflect its high educational standard.

Furthermore, the feasibility assessment, conducted by 25 respondents, validated the game's practicality across three key domains: programming, content, and display. The game achieved high scores in all categories, notably 86.67% in programming, 85.06% in content, and 80.53% in display, culminating in an impressive overall average of 84.08%. This evidence-based evaluation strongly suggests that the Alkaan Speil game is an effective and suitable educational tool. The study's limitations, primarily its focus on the developmental phase, pave the way for future research to evaluate the game's effectiveness more comprehensively. Future studies should delve into understanding the impact of Alkaan Speil on enhancing students' higher-order thinking skills within the context of chemistry education, thereby contributing significantly to educational technology.

AUTHOR CONTRIBUTIONS

EYP conducted a study on designing and drafting an article. NW and FSI developed the Alkaan game. All researchers read and approved the final draft of the article.

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