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Articulate Storyline chemistry learning with socio-scientific issues to enhance students' critical thinking

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ABSTRACT

Critical thinking is essential for students' academic and life success, yet many students perform poorly because instructional approaches often fail to promote higher-order thinking. This study developed an interactive learning medium that integrates Socio-Scientific Issues (SSI) using Articulate Storyline and evaluated its validity, practicality, and effectiveness in improving students' critical thinking about chemical bonding. The research employed a Research and Development (R&D) design based on the ADDIE model (Analysis, Design, Development, Implementation, Evaluation). Participants were 67 eleventh-grade students (34 from XI-1 and 33 from XI-4), aged 15–16 years. Data were collected using validation sheets, questionnaires, observation sheets, and pretest–posttest critical thinking tests. Results showed the media was valid (content validity index = 0.97), highly practical (mean practicality score = 4.33), and effective (mean N-gain = 0.77), indicating substantial improvement in students' critical thinking. The study concludes that SSI-based interactive materials developed with Articulate Storyline are feasible and effective for teaching chemical bonding; theoretically, the findings support the role of SSI and digital interactive media in fostering higher-order thinking, and practically, teachers are recommended to adopt these materials to enhance critical-thinking instruction.

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INTRODUCTION

Critical thinking can be defined as the ability to draw logical conclusions from existing evidence, engage in rational thinking, and maintain intellectual honesty (Santyasa et al., 2021). Critical thinking skills are essential for everyone to have, because through critical thinking skills, everyone can think logically, be able to interpret information, make decisions and the right choices based on the data obtained and conduct analysis in various areas (Safarati & Zuhra, 2023; Sudiarti et al., 2023; Zuhra & Arifiyanti, 2021). Students' critical thinking skills are suboptimal because school learning still lacks activities to hone them (Agnafia, 2019).

Cooperation and interaction between teachers and students are needed to support the improvement of students' critical thinking skills (Ramadhanti & Agustini, 2021). In addition, teachers must integrate learning media, learning processes, and assessment methods to train essential thinking skills (Yulianti et al., 2022). PowerPoint (PPT) is a learning medium often used (Susilawati et al., 2021). Although often used, learning media such as PPTs have several limitations. A lecture-based approach can reduce students' active involvement in the learning process, as they tend to receive information passively without meaningful interaction, leading to boredom (Trisantri et al., 2024). This limited interaction also contributes to the underdevelopment of students' critical thinking skills (Baker et al., 2018).

Learning media suitable for the current era is interactive, engaging learners through images, colours, text menus, animations, videos, audio, and quizzes. Learners can directly use and interact with the material being studied (Safira et al., 2021). This approach aims to create a more memorable learning experience, make it easier for students to understand the material, encourage them to be more active, and enhance the effectiveness of the classroom learning process (Inayah et al., 2023). One learning medium that can improve critical thinking skills is interactive learning media (Blyznyuk & Kachak, 2024; Dermawan et al., 2025; Febliza et al., 2023). The use of interactive learning media is considered necessary in the learning process because it can create broader and deeper interactions (Mustika et al., 2018). Interactive media is an innovation on previous learning media; it combines text, sound, images, and video in a single digital format (Jazuli et al., 2017).

The software used to create interactive learning media is Articulate Storyline. It is a software that functions as a presentation and communication tool. This application allows users to start with available templates and customise the characters according to their preferences (Wahyuni et al., 2022). Articulate Storyline also has features for adding audio, video, animation, quizzes, and assessments (Sukmarini et al., 2021).

Various studies have developed Articulate Storyline-based learning media used across fields such as biology, chemistry, and others (Daryanes et al., 2023). In chemistry, this media is used to support learning, both in class and in independent learning at home. For example, on chemical bonding materials, Articulate Storyline media is designed using videos, images, interactive characters, and evaluation questions to improve student understanding (Lestarani et al., 2023). In addition, similar media have been developed for atomic structure and the periodic table of elements, which can help students interact actively and assist them in understanding concepts through visualisation and demonstrations of materials (Lestarani et al., 2023).

Although previous studies have demonstrated that the use of Articulate Storyline (AS) is effective in enhancing student engagement, visualisation, and conceptual understanding, most have primarily emphasised its technological aspects, such as animations, videos, and interactive features. On the other hand, research on Socio-Scientific Issues (SSI) highlights the importance of incorporating real, controversial, and socially relevant issues to foster critical thinking and evidence-based decision-making. Nevertheless, studies that explicitly integrate the interactive technological affordances of AS with the contextual depth provided by SSI remain scarce, particularly in chemistry learning. This gap establishes the research gap while simultaneously opening the space for novelty, namely the development of interactive learning media that are not only visually engaging but also designed to cultivate higher-order critical thinking through the integration of socio-scientific issues. However, to date, no articulate storyline has been developed that integrates with the socio-scientific issues (SSI) approach in chemistry learning. The use of social problems in education is believed to train students' critical thinking skills (Şaşmazören et al., 2022). SSI is a pedagogical approach that combines social and scientific perspectives to address real-world problems and foster critical thinking among learners (Cebesoy & Rundgren, 2023).

Chemical bonding material is an abstract concept Rahman et al., (2024), complex and challenging to understand by students because it is not enough to rely solely on theory, but also requires learning strategies that can manage conceptual plurality, such as microscopic side visualisation to clarify understanding of atomic structure and ionic interactions (Nehring & Schanze, 2025). This difficulty increases if the material is only delivered theoretically without direct experience, which can hinder students' understanding of fundamental concepts, such as the mechanism of electron acceptance and release in ions (Sutrisno et al., 2020) To overcome these obstacles, exploratory activities are needed that encourage students in the process of investigation, analysis, and inference, so that they can understand abstract chemical concepts more deeply and contextually (Harefa, 2020; Natasya et al., 2025).

Applying the SSI approach can be an effective strategy to help learners better understand the concept of chemical bonding while improving their critical thinking skills. A study by Gulacar et al., (2022) provides empirical evidence that discussions around socio-scientific issues (SSI) are effective in changing students' perceptions of science and their career aspirations, and recommends practical methods to encourage students to become science-literate and global citizens. In line with these findings, (2024) showed that integrating SSI into science learning significantly increased students' interest in science.

Based on previous studies, most developments of Articulate Storyline (AS)-based media in science education have focused either on enhancing visualisation and interactivity or on incorporating contextual issues through the Socio-Scientific Issues (SSI) approach. However, these two aspects are rarely combined within a single instructional design, particularly in chemistry learning. Accordingly, the identified research gap concerns the limited application of AS-based media in combination with the SSI approach within chemistry education. Addressing this gap is expected to yield theoretical contributions by advancing the development of instructional media models that unify digital interactivity and socio-scientific contexts. In addition, it offers practical contributions by providing chemistry teachers with interactive learning media that enhance contextualization, reflection, and meaningful learning experiences for secondary students.

This research aims to develop an interactive learning media in Articulate Storyline using the Socio-Scientific Issues (AS-SSI) approach to improve critical thinking skills in understanding chemical bonds. This media is designed to be interesting and easy to use by integrating text, sound, images and videos. The use of media and social issues in learning is expected to train students' critical thinking skills in solving daily life problems. The results of this study make a significant contribution to improving the quality of chemistry learning by encouraging the development of students' critical thinking skills through the application of Facione critical thinking framework-based tests. The use of articulate storyline interactive learning media designed with a socio-scientific issues approach, thus creating a more contextual, reflective, and meaningful learning experience.

Theoretically, this research contributes to the literature by offering an integrated framework of digital interactive media and SSI to enhance critical thinking. In practice, it provides teachers with an alternative instructional medium that can enrich classroom practice and motivate students to learn chemistry more meaningfully.

METHOD

This study uses a Research and Development (R&D) approach to design and develop interactive learning media on chemistry bonding materials, grounded in Socio-Scientific Issues (SSI), using the Articulate Storyline 3 application. The development model chosen is ADDIE (Analysis, Design, Development, Implementation, Evaluation). Theoretically, ADDIE was selected because it provides a systematic, iterative framework for needs analysis, learning objectives and interface design, product development, implementation in a real context, and formative and summative evaluation, allowing for repeated revisions until the product meets the expected criteria of validity, practicality, and effectiveness. ADDIE is also suitable for digital media development because each phase connects pedagogical aspects (learning objectives & indicators), content (scientific/content), and technical aspects (interaction design, multimedia, and evaluation), thereby supporting the instructional quality of the developed media (Dewi et al., 2022).

Time and Place of Research

The research was conducted at Senior High School 1 Alalak, Barito Kuala Regency, South Kalimantan Province, in the odd semester of 2024/2025 (September–October 2024).

Research Subjects and Samples (Sample Characteristics)

a. Population & Sample: The main sample consisted of two 11th-grade classes (class XI-1, n = 34; class XI-4, n = 33; total n = 67) that were selected purposively (entire courses) due to considerations of accessibility and suitability of the learning schedule.
b. Reported demographics: For each class, the following will be reported: number of participants per class, age range (15–16 years old), gender (M/F), final semester report card scores in chemistry (average and standard deviation), and basic digital literacy level (e.g., self-reported familiarity with learning platforms: high/medium/low).
c. Validators/experts: There are 4 Chemistry Education lecturers and 1 high school chemistry teacher (total = 5 experts) who act as validators of materials and media. The criteria for selecting experts are explained in the following section.

Operational Definition & Criteria for "Expert"

Operationally, an expert is defined as an individual who meets at least two of the following criteria:
a. Minimum Master's degree (M.Pd/M.Si) or Doctorate in Chemistry Education, Science Education, or Educational Technology;
b. Have ≥ 3 years of experience teaching chemistry at the upper secondary level (for teachers) or ≥ 3 years of research/publication experience related to science/educational technology learning (for lecturers);
c. Have experience or technical understanding of using Articulate Storyline or developing digital learning media;
d. Have been involved as a validator/assessor of educational instruments in previous research or development.

The selection of experts was conducted using purposive sampling, based on recommendations from the principal and the academic network of the study program. The identities of the experts were reported in summary form (qualifications, affiliations, experience) without presenting sensitive personal data.

Development Procedure (Details of Each ADDIE Phase)

The development stages used in this study are shown in Figure 1.
1. Analyse
   a. Literature study to determine competencies, learning indicators, and curriculum standards (Merdeka Curriculum).
   b. Semi-structured interviews with chemistry teachers and small group discussions with several students to identify barriers to learning chemical bonding and media needs.
   c. Results: learning objective design and media content blueprint (material, contextual SSI, and critical thinking measurement indicators).
2. Design
   a. Develop measurable learning objectives and media story maps (navigation flow, SSI scenarios, interaction types, formative evaluation).
   b. Develop a table of critical thinking test item specifications (question blueprint) based on Facione (1990) indicators: interpretation, analysis, evaluation, inference, explanation, and self-regulation.
   c. Design an essay (analytical) assessment rubric and practicality questionnaire (teacher/student), along with a learning observation sheet.
3. Development
   a. Content development (text, video, images, quizzes) and interaction coding using Articulate Storyline 3.
   b. Initial prototype creation and interface design (background created with Canva; converted into deployable files using Web2Apk Builder for mobile testing purposes if needed).
   c. Preparation of expert validation sheets (consisting of the following components: content validity, construction, language, and media/usability aspects).

4. Validation (Expert Assessment)
   a. Experts receive a validation package that includes: prototype products, validation sheets (Likert scale 1–5 for each item), assessment instructions, and open comment areas.
   b. Experts are asked to assess the following dimensions: (a) content validity (suitability of material to learning indicators), (b) scientific accuracy, (c) suitability of SSI context, (d) clarity of language, (e) interface and navigation design, (f) interactive functions (quizzes/feedback).
   c. Quantitative validity analysis was performed using Aiken's V for each item; items were considered valid if $V \geq 0.80$. In addition, qualitative comments from experts were used to revise the product. If there were items with $V < 0.80$, revisions were made and (if necessary) a second round of validation was conducted.
   d. The operationalisation of expert assessment and the Aiken formula will be explained in the instrument appendix (validation form and calculation examples).
5. Trial
   a. Individual trial: 5 students (to test readability, navigation, and technical errors). Data: completion time, navigation difficulties, open comments.
   b. Small group trial: 10 students (to observe the learning flow and initial responses to SSI-based tasks). Revisions were made after each trial phase based on feedback.
   c. Field implementation: application in two full classes (n = 67) to test practicality and effectiveness.

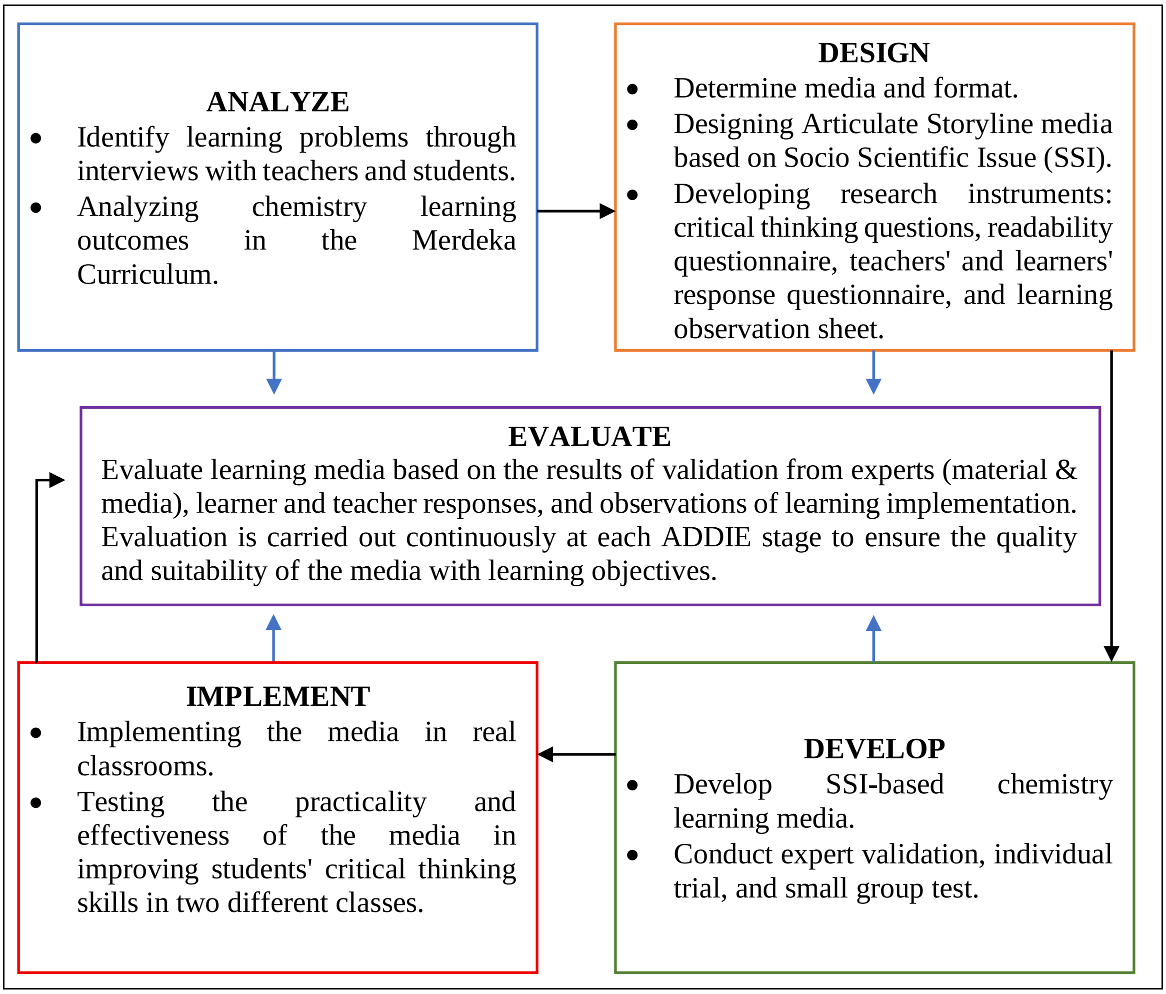

Figure 1. Steps of the ADDIE Development Model

Research Instruments

a. Expert Validation Form
   1) Likert scale 1–5 with dimensions: content relevance, conceptual completeness, scientific accuracy, language, interface & navigation, multimedia quality, and evaluation quality (quiz).
   2) Open a comment column for improvement suggestions.
   3) Analysis: Aiken's V per item & per domain; quantitative summary report plus a summary compilation of qualitative suggestions.

b. Practicality Questionnaire
   1) Administered to teachers and students after implementation; 5-point scale (1 = strongly disagree to 5 = strongly agree).
   2) Domains: ease of use, visual appeal, learning engagement, SSI relevance, and timing appropriateness.
   3) Construct validity tested through expert review; instrument reliability tested using Cronbach's alpha ($\alpha \geq 0.70$ considered acceptable).

c. Learning Observation Sheet
   1) Structured checklist to observe implementation (e.g., student engagement, use of AS features, SSI discussion activities, and time management).
   2) Two observers (researcher + trained observer) will conduct observations at several meetings; inter-observer reliability will be calculated using Cohen's kappa or percentage of agreement (threshold values will be reported).

d. Critical Thinking Test
   1) Consists of 6 items based on the blueprint (Facione, 1990); each item is designed to measure specific indicators.
   2) Analytical assessment rubric: each indicator is assessed on a scale of 0–4 (0 = no response; 4 = complete and in-depth answer). A detailed rubric is included in the appendix.
   3) reliability & Inter-rater Agreement: two independent raters will assess all responses; the Intraclass Correlation Coefficient (ICC) or Cohen's kappa will be calculated depending on the nature of the score (ICC for interval/total scores; kappa for categories). An ICC value ≥ 0.75 is considered good.

Expert Assessment and Instrument Validation Procedure (Step by Step)

1. Initial instrument development by the research team based on the curriculum blueprint and Facione (1990).
2. Submission of the validation package (media + validation sheet) to 5 experts who meet the criteria.
3. Experts fill out the validation sheet (quantitative) and write comments per item (qualitative) within 10 working days.
4. The research team calculates Aiken's V per item and domain; compiles qualitative comments.
5. Items/sections with $V < 0.80$ or receiving must-fix comments are revised. If substantial revisions are needed, a second round of validation is conducted to ensure improvements.
6. After adequate expert validation ($V \geq 0.80$ and expert agreement on key aspects), the instrument proceeds to the student trial phase.

Data Analysis Techniques: Practicality (questionnaires & observation)

1) Calculate the mean score and standard deviation for each domain/questionnaire.
2) Practicality categories use predetermined criteria (e.g., 4.20–5.00 = efficient, etc.) presented in Table 1.

Table 1. Practicality Analysis Criteria

No.	Score	Category
1	$4.20 < V \leq 5.00$	Very Practical
2	$3.40 < V \leq 4.20$	Practical
3	$2.60 < V \leq 3.40$	Practical Enough

No.	Score	Category
4	1.80 < V ≤ 2.60	Not Practical
5	1.00 ≤ V ≤ 1.80	Not Very Practical

(Syahmani et al., 2022)

3) Questionnaire reliability test: Cronbach's alpha; report α values and item-totals if there are items with reduced reliability.
4) Observation: calculate the percentage of compliance with learning indicators; inter-observer reliability is calculated (Cohen's kappa or ICC).

a. Content Validity (Aiken's V)
1) Calculate Aiken's V for each item on the validation sheet; the formula and interpretation of the results are reported. Items with V ≥ 0.80 are retained; V between 0.40–0.79 are revised; V < 0.40 are considered necessary for deletion or reconstruction. Content validity is analysed using Aiken's V formula (Azwar, 2012).

$$V = \frac{\Sigma s}{[n(c-1)]} \quad (1)$$

Description:
s = r – 1Fa
r = the number given by an assessor
1 = the lowest validity assessment number
c = the highest validity assessment number
n = number of raters

The validity assessment criteria based on Aiken's V scale are shown in Table 2.

Table 2. Validity based on Aiken's V scale

No.	Aiken's V Scale Statistics	Category
1	V ≤ 0.4	Less
2	0.4 < V ≤ 0.8	Moderate
3	0.8 < V	Valid

(Yolanda, 2020)

b. Effectiveness (Critical Thinking Test)
1) Initial step: test the normality of the pretest and posttest score distributions (e.g., Shapiro-Wilk).
2) If the data are normally distributed: perform a paired-sample t-test to test the difference between the pretest and posttest means; report the t-value, df, and p-value.
3) If not normally distributed: use the non-parametric Wilcoxon signed-rank test.
4) Calculate the N-Gain for each student and the class average N-gain; use Hake's criteria (n > 0.7 = high, 0.3 ≤ n ≤ 0.7 = moderate, n < 0.3 = low). The N-Gain Score is calculated as follows:

$$\text{N-gain} = \frac{S_{post} - S_{pre}}{S_{mask} - S_{pre}} \quad (2)$$

Description:
N_{gain} = gain normality test value
S_{post} = post-test score
S_{pre} = pre-test score
S_{max} = max score

The criteria for assessing the n-gain score are shown in Table 3.

Table 3. N-Gain Criteria

No	Score N-gain	Category
1	n > 0.7	High
2	0.3 ≤ n ≤ 0.7	Moderate
3	n < 0.3	Low

(Hake, 1999)

5) Practical effect report: calculate Cohen's d (paired) to measure effect size (d = mean difference / pooled SD). Interpretation of the three categories (small/medium/large) is included.
6) If possible, additional analyses can be performed to test the influence of demographics (e.g., gender, prior ability) on critical thinking improvement using independent t-tests or ANOVA/Mann-Whitney tests as needed.

c. Reporting
   1) All results are reported with descriptive values (mean ± SD), effect sizes (Cohen's d), and statistical significance (p-values). Qualitative results (expert comments and student feedback) are presented as thematic summaries to explain quantitative findings and justify product revisions.

d. Analysis Software
   1) Descriptive and inferential statistical analyses were performed using statistical software (e.g., the latest version of SPSS or R). Aiken's V calculations can be performed manually or using the script/sheet described in the appendix.

RESULTS AND DISCUSSION

Results

This development produces interactive learning media for chemical bonds using AS-SSI. The following are the research results based on the stages completed.

Analysis Phase

Based on the results of the initial needs analysis, learner analysis, and material analysis, it was found that students show low interest in chemical bonding due to its abstract nature. Consequently, conventional media such as PowerPoint presentations and whiteboards are considered less effective in facilitating students' understanding of the topic (Mulyasari & Doly, 2023). Therefore, it is necessary to develop interactive learning media that integrate a social science issue-based approach, helping students better understand the material and improve their critical thinking skills.

Design Stage

This stage is a continuation of the analysis stage, where the primary focus is to design interactive learning media (Fitriyah et al., 2021), including designing media backgrounds to suit learning objectives and characteristics, then collecting videos and images supporting learning, compiling materials along with research tools and instruments to assist quantitative data collection and recapitulation during research. The results from this stage are in the form of interactive learning media using AS-SSI, ready for development, along with research tools ready for use.

Development Stage

This stage is for developing interactive learning media on chemical bonds using AS-SSI. The learning media developed is an application that can be accessed directly on a cellphone. This interactive learning media is structured with a framework that includes a login page, a user manual page, a main menu, core competencies, basic competencies, learning materials, sample questions, practice questions, and the author's bio. The parts of this interactive learning media are classified as follows:

a. Login Page
   The attractive appearance of the login page aims to create a positive first impression, motivating students to be more enthusiastic about exploring the material presented. The illustration for the login page is shown in Figure 2.

Figure 2. Login Page of Interactive Learning Media

b. Instructions for Use

Instructions for use serve as an initial guide for students to understand how to interact with the media. The illustration for the instructions-for-use page is shown in Figure 3.

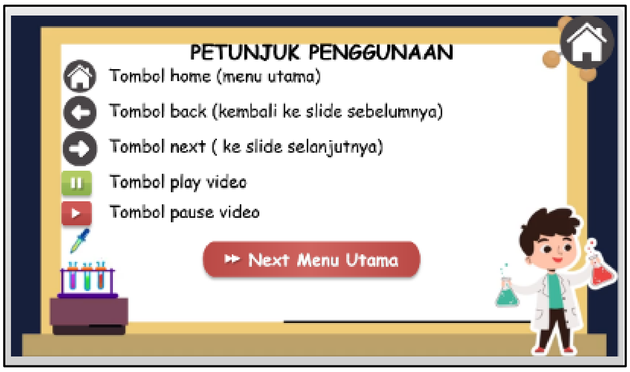

Figure 3. Instructions for Using Interactive Learning Media

The main menu page serves as a navigation hub, making it easy for learners to access media content. The illustration for the main menu page is shown in Figure 4.

Figure 4. Main Menu of Interactive Learning Media

c. Introduction Page

The introduction page features two buttons that direct users to pages containing the learning outcomes and learning objectives. An illustration of the introduction page is shown in Figure 5.

Figure 5. Interactive Learning Media Introduction Page

d. Material

This section presents learning materials and example problems using the SSI (Socio-Scientific Issues) approach. The topics covered include the duplet and octet rules, covalent bonds, ionic bonds, and metallic bonds. Students will also learn how to identify the type of covalent bond—polar or nonpolar based on the electronegativity difference between the atoms and the molecular shape. An illustration of the Materials page is shown in Figure 6.

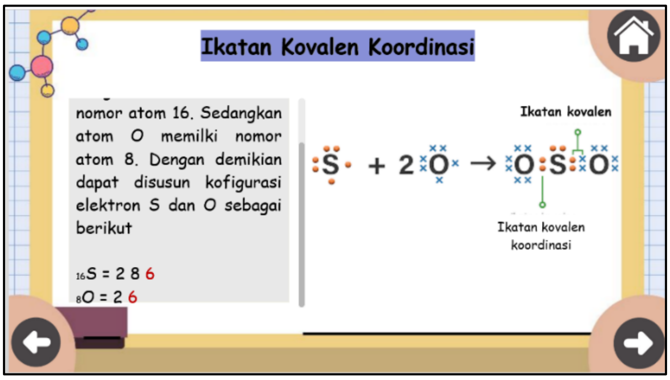

Figure 6. Interactive Learning Media Material Page

e. Evaluation

The evaluation section in this media is designed to measure students' understanding through quizzes. The illustration for the evaluation page is shown in Figure 7.

Figure 7. Interactive Learning Media Evaluation Page

A team of validators then validated the interactive learning media, testing their validity and feasibility before proceeding to the implementation stage. The validators chosen were 4 Chemistry Education lecturers and 1 chemistry teacher. This validation process involves material expert validators and media expert validators. The results of the validity test of interactive learning media using AS-SSI for material experts are presented in Table 4.

Table 4. Interactive Learning Media Validation Test Results According to Material Experts

No.	Assessment Aspects	Validator					Score Validation	Information
		I	II	III	IV	V		
1	Material Suitability	24	25	23	25	25	0.97	Valid
2	Affective Impact	10	9	10	10	10	0.98	Valid
3	Expediency	15	15	14	15	15	0.98	Valid

Table 5 presents the results of the validity assessment of the AS-SSI–based interactive learning media as evaluated by media experts.

Table 5. Results of Interactive Learning Media Validation Tests According to Media Experts

No	Assessment Aspects	Validator					Score Validation	Information
		I	II	III	IV	V		
1	Design	28	30	27	30	30	0.96	Valid
2	Language	25	24	25	25	25	0.99	Valid
3	Illustration	9	10	9	10	10	0.95	Valid
4	Typography	18	20	18	20	20	0.95	Valid

Implementation Stage

At this stage, the interactive learning media and research instruments have been improved based on feedback from experts or validators, and the results of individual and small-group readability tests were implemented in the classroom. The media, distributed in application form, are used in the chemistry learning process and can be accessed directly by both teachers and students. During this implementation phase, the practicality and effectiveness of the developed interactive learning media are evaluated. The practicality test results are based on limited-trial readability, student responses to the media, teacher responses, observations of teacher proficiency in using the media, and observations of lesson implementation. A summary of the practicality results of the interactive learning media is presented in Table 6.

Table 6. Recapitulation of Practicality Test

No.	Component	Class XI 1		Class XI 4	
		Average	Category	Average	Category
1	Legibility	4.51	Very Practical	4.40	Very Practical
2	Student Response	4.49	Very Practical	4.33	Very Practical
3	Teacher Response	4.80	Very Practical	4.80	Very Practical
4	The teacher's ability to use media	4.15	Practical	4.10	Practical
5	Learning Implementation	4.09	Practical	4.03	Practical
Score		**4.41**	**Very Practical**	**4.33**	**Very Practical**

The effectiveness of the developed interactive learning media was evaluated using students' pre-test and post-test scores. The pre-test was designed to assess students' prior knowledge and level of critical thinking skills before learning the chemical bonding material through interactive media, while the post-test aimed to measure their final understanding, specifically their critical thinking skills. The test items for both the pre-test and post-test were developed based on Facione's critical thinking skill indicators: interpretation, analysis, evaluation, inference, explanation, and self-regulation. The assessment was conducted in two classes, XI 1 and XI 4. The results of the critical thinking skills test for class XI 1 are shown in Table 7.

Table 7. Results of Critical Thinking Ability Test for Class XI 1

No.	Indicator	Pre-test	Post-test	Difference	100-Pre-test	N-gain	Category
1	Interpretation	46.32	91.17	44.85	53.67	0.83	High
2	Analysis	52.20	88.97	36.76	47.79	0.76	High
3	Evaluation	57.35	89.70	32.35	42.64	0.75	High
4	Inference	51.47	91.17	39.70	48.52	0.81	High
5	Explanation	52.94	84.55	31.61	47.05	0.67	Medium
6	Self-Regulation	47.05	91.17	44.11	52.94	0.83	High

As shown in Table 7, the indicators of interpretation, self-regulation, inference, analysis, and evaluation are in the high category, while the explanation indicator is in the medium category. The results of the critical thinking skills test for class XI 4 are presented in Table 8.

Table 8. Results of Critical Thinking Ability Test for Class XI 4

No	Indicator	Pre-test	Post-test	Difference	100-Pre-test	N-gain	Category
1	Interpretation	58.33	92.42	34.09	41.66	0.81	High
2	Analysis	45.45	85.60	40.15	54.54	0.73	High
3	Evaluation	37.87	84.09	46.21	62.12	0.74	High
4	Inference	49.24	92.42	43.18	50.75	0.85	High
5	Explanation	57.57	90.15	32.57	42.42	0.76	High
6	Self-Regulation	45.45	84.09	38.63	54.54	0.70	High

While Table 8 shows that the most significant increase is the inference indicator, followed by indicators of interpretation, explanation, evaluation, analysis, and self-regulation, all in the high category. From these two datasets, it can be concluded that the developed interactive learning media is efficacious in improving all indicators of critical thinking skills.

Evaluation Stage

Evaluation is carried out at every stage of development to ensure the quality of the outcomes. Furthermore, a comprehensive assessment is conducted at the end of the study to review all completed stages. This process aims to refine the interactive learning media tested in two classes, enabling further development and making them ready for dissemination and sustainable use in chemistry learning.

Discussion

Innovation in school learning has been proven to have a significant positive impact on the quality of the learning process. For example, a meta-analysis concluded that the use of innovative learning methods or approaches in mathematics and science can improve students' overall learning achievement (Niza & Suyanto, 2023). These findings indicate that teachers need to provide media and strategies that can stimulate student engagement, so that learning is not only informative but also transformative.

One crucial aspect that can be improved through learning innovation is critical thinking skills. These skills develop when students are exposed to media that require them to analyse, evaluate, and compare information independently. Previous studies have reported that the application of e-learning and digital media in learning has a significant impact on improving students' critical and creative thinking (Indriani et al., 2023). Thus, integrating appropriate learning media is an essential foundation for honing students' thinking skills.

Articulate Storyline is one of the interactive media that can support the development of critical thinking skills. Through interactive features, diverse media visualisations, and the ability to provide immediate feedback, this media allows students to be actively and reflectively involved in the learning process. The use of simulations, graded questions, animations, and visual icons can trigger students to ask questions, discuss, and build arguments critically. Several features, such as interactive buttons, structured quizzes, multimedia/HTML output, and branching that allows for different learning paths based on student responses, make Articulate Storyline a medium that is not only interesting but also capable of stimulating deep thinking (Miftahurrahman et al., 2024).

In this study, Articulate Storyline was further developed by integrating SSI as a learning context. This integration expands the use of Articulate Storyline from merely supporting conceptual understanding to learning that demands ethical, scientific, and social reflection in real life. This approach aligns with previous findings, which confirm that science learning using Articulate Storyline can increase student engagement and learning outcomes (Juhaeni et al., 2021). The difference is that this study emphasises that combining Articulate Storyline with SSI can lead students to engage in a more comprehensive critical thinking process, requiring them not only to understand concepts but also to consider social implications and make decisions based on scientific arguments.

The results of this study indicate that the validity of the SSI-based Articulate Storyline media developed falls within the valid category, with scores of 0.98 for material validity and 0.96 for media validity. This is in line with the research by Nuzulah et al. (2023) and Pratiwi & Alim (2022), which show that learning media developed with an Aiken's V value ≥ 0.80 falls into the highly valid category and is ready for implementation in the learning process. Meanwhile, if the validation score is ≤ 0.4, which falls in the less valid category, the interactive learning media based on an articulate storyline must be revised extensively in accordance with the suggestions and input from subject matter experts, media experts, and teachers (Adhiana et al., 2022).

The practicality of this media was also assessed based on teacher and student responses, and a practicality test score of 4.33 was obtained, indicating it is convenient. This means the media are easy to use and flexible, so they can be used anytime, anywhere, as part of the learning process about chemical bonding. This is in line with research on the practicality test results of the articulate storyline interactive learning media conducted by Ananda et al., (2024) which reported a practicality test score of 4.32 in the convenient category, indicating that the articulate storyline media is easy to use in the learning process. The practicality of this media is also reinforced by the integration of SSI, which has been proven to make students more enthusiastic about discussing and actively participating during learning.

The effectiveness of the media was also demonstrated by improvements in students' critical thinking skills after using SSI-based Articulate Storyline media. This was also confirmed by several previous findings by Rea et al., (2024); Sudiasih et al., (2022); Wijayanti et al., (2022) and Wahyuni et al., (2022), who stated that the use of Articulate Storyline can help improve students' critical thinking skills because interactive learning media are effective in arousing interest, increasing motivation, stimulating learning activities, and facilitating understanding because the material is presented interestingly. However, this study provides new evidence that effectiveness is higher when learning content is linked to socio-scientific issues relevant to everyday life, such as environmental and health issues.

Interactive learning media using AS-SSI are categorised as effective. This means that the media can improve students' critical thinking skills. This is in line with the research by Heliawati et al., (2022) which states that gamification-based multimedia articulate storyline 3 will be considered adequate if it obtains an N Gain value of ≥ 0.3, which is classified as moderate or high.

The improvement in students' critical thinking skills, as evident in the learning outcomes, is insufficient to conclude that the developed interactive learning media is effective overall. The effectiveness of the media needs to be further analysed based on each indicator of critical thinking skills, namely interpretation, analysis, evaluation, inference, explanation, and self-regulation, through questions that represent each of these competencies.

Based on the data obtained, the lowest n-gain score was observed in questions with explanation indicators in class XI-1, in the moderate category. This low score was due to the explanation indicator requirement that students provide structured, logical reasons for their answers. Difficulty in relating answers to the concepts learned was one of the contributing factors. This aligns with Laliyo et al., (2023), who stated that students often have difficulty constructing logical, structured scientific explanations, especially in chemistry. However, the moderate category is still considered adequate because it is not classified as low. In addition, in class XI-4, the n-gain score for the explanation indicator was in the high category. Thus, the six questions developed are effective in improving students' overall critical thinking skills.

This study shows that the development of SSI-based media has a strong implication for improving students' critical thinking skills. By engaging with real-world problems, students are trained to analyse data, evaluate arguments, and make evidence-based decisions. The use of Articulate Storyline makes learning more interactive, as students not only receive information but also practice identifying problems, finding solutions, and building arguments through videos and quizzes, which are then reinforced with a complex and relevant SSI approach. These findings are supported by research by Indriani et al., (2023) which shows that interactive digital media can improve students' critical thinking skills.

In addition to contributing to chemistry learning and the development of critical thinking, this study also has implications for educational management by emphasising the importance of using technology as a learning innovation. However, the media is still limited to Android devices, does not yet support iOS, and is large, requiring more storage space. These limitations form the basis for further development so that the media is more device-friendly, efficient, and can be researched in a broader context.

CONCLUSION

This study produced interactive learning media on chemical bonding using AS-SSI, which has been proven valid (0.97), practical (4.33), and effective (n-gain = 0.77), placing it in the high category. The implications of this study confirm that integrating SSI into Articulate Storyline media can enrich learning, shift the focus from mere mastery of concepts to critical thinking, help students find solutions, and increase their sensitivity to social and environmental issues.

The use of SSI-based Articulate Storyline opens up new opportunities for teachers to create more contextual, interactive, and meaningful learning experiences. Teachers are encouraged to begin integrating the SSI approach into the design of digital learning media to further hone students' critical thinking skills.

For further research, similar media can be tested with other materials or in different classes. They can also be developed with features for home and group learning to strengthen students' independence and collaborative learning. Thus, this study makes a real contribution to the development of education and opens up new opportunities for innovation in the use of SSI-based digital technology. Recommendations for further research include using the professional Articulate Storyline to support the HTML5 format so that it can be accessed on various smartphones, using premium Web 2 Apk Builder software for conversion, replacing videos with online links so that the files received by students are not too large, and involving more schools in future research.

REFERENCES

Adhiana, V. I., Yuniawatika, Y., Ahdhianto, E., & Wantoro, J. (2022). Interactive media development using Articulate Storyline-based instructional games for teaching fractions. *Profesi Pendidikan Dasar*, *9*(1), 15–27. https://doi.org/10.23917/ppd.v9i1.16927

Agnafia, D. N. (2019). Analisis kemampuan berpikir kritis siswa dalam pembelajaran biologi. *Florea: Jurnal Biologi dan Pembelajarannya*, *6*(1), 45–53. https://doi.org/https://doi.org/10.25273/florea.v6i1.4369

Ananda, R. W., Iriani, R., & Hamid, A. (2024). Development of interactive multimedia based on Articulate Storyline to improve students' creative thinking skills on support solution materials. *Edu Sains: Jurnal Pendidikan Sains dan Matematika*, *12*(1), 55–65. https://doi.org/https://doi.org/10.23971/eds.v12i1.5961

Azwar, S. (2012). *Reliabilitas dan validitas*. Pustaka Pelajar.

Baker, J. P., Goodboy, A. K., Bowman, N. D., & Wright, A. A. (2018). Does teaching with powerpoint increase students' learning? A meta-analysis. *Computers and Education*, *126*, 376–387. https://doi.org/10.1016/j.compedu.2018.08.003

Blyznyuk, T., & Kachak, T. (2024). Benefits of interactive learning for students' critical thinking skills improvement. *Journal of Vasyl Stefanyk Precarpathian National University*, *11*(1), 94–102. https://doi.org/10.15330/jpnu.11.1.94-102

Cebesoy, U. B., & Rundgren, S. N. C. (2023). Embracing socioscientific issues-based teaching and decision-making in teacher professional development. *Educational Review*, *75*(3), 507–534. https://doi.org/10.1080/00131911.2021.1931037

Daryanes, F., Darmadi, D., Fikri, K., Sayuti, I., Rusandi, M. A., & Situmorang, D. D. B. (2023). The development of Articulate Storyline interactive learning media based on case methods to train student's problem-solving ability. *Heliyon*, *9*(4), 1–14. https://doi.org/10.1016/j.heliyon.2023.e15082

Dermawan, D. D., Wuryandani, W., Herwin, H., Eliza, F., Nurzaman, I., Giwangsa, S. F., Nurdiansah, N., Fadli, R., Sari, S., Jannah, M., & Munawarah, M. (2025). Improving critical thinking ability in elementary schools with interactive e-modules. *Online Journal of Communication and Media Technologies*, *15*(2), e202513. https://doi.org/10.30935/ojcmt/16051

Dewi, N. R., Astuti, I., & Rahmani, F. A. (2022). Penerapan desain pembelajaran ADDIE e-learning materi bahasa inggris pada siswa SMA. *Jurnal Ilmiah Mandala Education (JIME)*, *8*(4), 2774–2784. https://doi.org/10.36312/jime.v8i4.3978

Facione, P. (1990). *Critical thinking: A statement of expert consensus for purposes of educational assessment and instruction (The Delphi Report).* Calfornia Academic Press.

Febliza, A., Afdal, Z., & Copriady, J. (2023). Improving students' critical thinking skills: Is interactive video and interactive web module beneficial?. *International Journal of Interactive Mobile Technologies*, *17*(3), 70–86. https://doi.org/10.3991/ijim.v17i03.34699

Fitriyah, I., Wiyokusumo, I., & Leksono, I. P. (2021). Pengembangan media pembelajaran Prezi dengan model ADDIE simulasi dan komunikasi digital. *Jurnal Inovasi Teknologi Pendidikan*, *8*(1), 84-97. https://doi.org/10.21831/jitp.v8i1.42221

Gulacar, O., Radhika, M., & Goradia, K. R. (2022). Examining changes in students' perception of science relevancy and their career aspirations: Integrating sustainability-oriented socio-scientific issues into general chemistry curriculum. *Sustainable Chemistry and Pharmacy*, *25*(10057). https://doi.org/10.1016/j.scp.2021.100577

Hake, R. (1999). *Analyzing change gain score* (R. Hake, Ed.). Indiana University.

Harefa, D. (2020). Peningkatan hasil belajar siswa dengan pembelajaran kooperatif make a match pada aplikasi jarak dan perpindahan. *GEOGRAPHY: Jurnal Kajian, Penelitian dan Pengembangan Pendidikan*, *8*(1), 1–18. https://doi.org/10.31764/geography.v8i1.2253

Heliawati, L., Lidiawati, L., & Pursitasari, I. D. (2022). Articulate Storyline 3 multimedia based on gamification to improve critical thinking skills and self-regulated learning. *International Journal of Evaluation and Research in Education*, *11*(3), 1435–1444. https://doi.org/10.11591/ijere.v11i3.22168

Inayah, A. N., Maftuh, B., & Sumantri, Y. K. (2023). Pengaruh penggunaan media interaktif berbasis Articulate Storyline terhadap minat belajar IPS. *JIPSINDO (Jurnal Pendidikan Ilmu Pengetahuan Indonesia)*, *10*(02), 173–187. https://doi.org/10.21831/jipsindo.v10i2.59735

Indriani, R. P., Sigit, D. V., & Miarsyah, M. (2023). Meta-analisis: Pengaruh media e-learning terhadap keterampilan berpikir kritis dan kreatif. *Jurnal Ilmu Pendidikan*, *6*(1), 58–71. https://doi.org/10.37329/cetta.v6i1.1862

Jazuli, M., Azizah, L. F., & Meita, N. M. (2017). Pengembangan bahan ajar elektronik berbasis Android sebagai media interaktif. *Jurnal Lensa (Lentera Sains): Jurnal Pendidikan IPA Jurnal Lensa*, *7*(2), 47–65. https://doi.org/https://doi.org/10.24929/lensa.v7i2.22

Juhaeni, J., Safaruddin, S., & Salsabila, Z. P. (2021). Articulate Storyline sebagai media pembelajaran interaktif untuk peserta didik madrasah ibtidayah. *AULADUNA: Jurnal Pendidikan Dasar Islam*, *8*(2), 150. https://doi.org/10.24252/auladuna.v8i2a3.2021

Kumar, V., Choudhary, S. K., & Singh, R. (2024). Environmental socio-scientific issues as contexts in developing scientific literacy in science education: A systematic literature review. *Social Sciences and Humanities Open*, *9*, 1–10. https://doi.org/10.1016/j.ssaho.2023.100765

Laliyo, L. A. R., Utina, R., Husain, R., Umar, M. K., Katili, M. R., & Panigoro, C. (2023). Evaluating students' ability in constructing scientific explanations on chemical phenomena. *Eurasia Journal of Mathematics, Science and Technology Education*, *19*(9), 1-21. https://doi.org/10.29333/ejmste/13524

Lestarani, D., Lalang, A. C., & Manggi, I. (2023). Development of Articulate Storyline 3-based digital teaching materials on the subject of atomic structure and periodic elements system for SMA/MA students in class X. *Orbital*, *15*(2), 127–132. https://doi.org/10.17807/orbital.v15i2.17959

Lestarani, D., Tanone, K. L. K., Parera, L. A. M., Lalang, A. C., & Naat, J. N. (2023). Development of Articulate Storyline 3-based for chemical bonding teaching materials. *Hydrogen: Jurnal Kependidikan Kimia*, *11*(2), 106-115. https://doi.org/10.33394/hjkk.v11i2.7403

Miftahurrahman, U., Zulfitria, & Amirullah, F. (2024). Articulate Storyline: Inovasi pembelajaran sains yang menarik dan interaktif. *Jurnal Kajian Pendidikan IPA*, *4*(2), 323-327. https://doi.org/10.52434/jkpi24181

Mulyasari, R., & Doly, M. (2023). Pengembangan bahan ajar bangun ruang sisi datar dengan model ADDIE (sekolah dasar). *Jurnal Genta Mulia*, *14*(1), 334–342. https://doi.org/10.61290/gm.v14i1.698

Natasya, Q., Hairida, Masriani, Enawaty, E., & Rasmawan, R. (2025). Development of video tutorials for making learning media based on augmented reality on ion material. *Jurnal Penelitian Pendidikan IPA*, *11*(1), 1157–1165. https://doi.org/10.29303/jppipa.v11i1.7356

Nehring, A., & Schanze, S. (2025). Turning the plurality of chemistry into a resource for learning: A core competency of chemistry teachers. *Science and Education*, *34*, 2051–2078. https://doi.org/10.1007/s11191-025-00624-5

Niza, & Suyanto, S. (2023). Impact of innovative learning in mathematics and natural sciences on student learning achievements: A meta-analysis. *Jurnal Iqra': Kajian Ilmu Pendidikan*, *8*(1), 87–99. https://doi.org/10.25217/ji.v5i1.2801.

Nuzulah, D. F., Kirana, T., & Ibrahim, M. (2023). Validity of inquiry-based learning tools on students' scientific argumentation ability. *IJORER : International Journal of Recent Educational Research*, *4*(2), 137–148. https://doi.org/10.46245/ijorer.v4i2.309

Pratiwi, H., & Alim, J. A. (2022). Development of interactive multimedia based on Adobe Flash geometry introduction material in grade I elementary school. *EduTech: Education Technology Journal*, *1*(1), 33–47. https://doi.org/https://doi.org/10.56787/edutech.v1i1.5

Rahman, H., Wahid, S. A., Ahmad, F., & Ali, N. (2024). Game-based learning in metaverse: Virtual chemistry classroom for chemical bonding for remote education. *Education and Information Technologies*, *29*(15), 19595-19619. https://doi.org/10.1007/s10639-024-12575-5

Ramadhanti, A., & Agustini, R. (2021). Analisis keterampilan berpikir kritis peserta didik melalui model inkuiri terbimbing pada materi laju reaksi. *Jurnal Kependidikan: Jurnal Hasil Penelitian dan Kajian Kepustakaan di Bidang Pendidikan, Pengajaran dan Pembelajaran*, *7*(2), 385-394. https://doi.org/10.33394/jk.v7i2.3458

Rea, S. C. E., Maasawet, E. T., Hudiyono, Y., Raharjo, B., Palenewen, E., & Tindangen, M. (2024). Improving critical and creative thinking skills with Articulate Storyline media in learning food and the human digestive system in grade XI. *Jurnal Penelitian Pendidikan IPA*, *10*(11), 8899–8910. https://doi.org/10.29303/jppipa.v10i11.9127

Safarati, N., & Zuhra, F. (2023). E-learning assisted AIR learning model to improve students' critical thinking skills. *Jurnal Inovasi Teknologi Pendidikan*, *10*(2), 181–188. https://doi.org/10.21831/jitp.v10i2.53648

Safira, A. D., Sarifah, I., & Sekaringtyas, T. (2021). Pengembangan media pembelajaran interaktif berbasis web Articulate Storyline pada pembelajaran IPA di kelas V sekolah dasar. *Prima Magistra: Jurnal Ilmiah Kependidikan*, *2*(2), 237–253. https://doi.org/10.37478/jpm.v2i2.1109

Santyasa, I. W., Agustini, K., & Pratiwi, N. W. E. (2021). Project based e-learning and academic procrastination of students in learning chemistry. *International Journal of Instruction*, *14*(3), 909–928. https://doi.org/10.29333/iji.2021.14353a

Şaşmazören, F., Karapinar, A., Sari, K., & Demirer, T. (2022). The effect of using scientific scenarios in teaching socioscientific issues in science course on students' logical thinking skills. *Kuramsal Eğitimbilim*, *15*(2), 420–452. https://doi.org/10.30831/akukeg.1001361

Sudiarti, D., Ashilah, N. M., & Nurjanah, U. (2023). Implementation of flipped learning with flipbook media assistance on learning outcomes and critical thinking abilities. *Jurnal Inovasi Teknologi Pendidikan*, *10*(4), 385–394. https://doi.org/10.21831/jitp.v10i4.58191

Sudiasih, Y., Sinaga, R. M., & Widodo, S. (2022). The development of sociology teaching materials based on articulate storyline to improve students' critical thinking skill. *IARJSET*, *9*(2), 1-6. https://doi.org/10.17148/iarjset.2022.9201

Sukmarini, F., Mauludiyah, L., Roziqi, M. A., & Nurdianto, T. (2021). Interactive Arabic learning media based on Articulate Storyline 3 to increase students' motivation. *Al Mahāra: Jurnal Pendidikan Bahasa Arab*, *7*(1), 106–121. https://doi.org/10.14421/almahara.2021.071-06

Susilawati, C. L., Suyanto, & Gufron, A. (2021). Edutainment-based learning model with powerpoint media enhancing students' learning motivation. *International Journal of Elementary Education*, *5*(3), 409–415. https://doi.org/10.23887/ijee.v5i3.35458

Sutrisno, H., Wahyudiati, D., & Louise, I. S. Y. (2020). Ethnochemistry in the chemistry curriculum in higher education: Exploring chemistry learning resources in Sasak local wisdom. *Universal Journal of Educational Research*, *8*(12), 7833–7842. https://doi.org/10.13189/ujer.2020.082572

Syahmani, S., Iriani, R., Riana, S., & Bakti, I. (2022). E-Magazine development with social emotional learning approach on colloid material in context of local wisdom. *Tadris: Jurnal Keguruan dan Ilmu Tarbiyah*, *7*(2), 289–304. https://doi.org/10.24042/tadris.v7i2.11442

Trisantri, Z., Surmilasari, N., & Jayanti. (2024). Pengembangan media pembelajaran menggunakan Articulate Storyline pada materi pecahan sederhana untuk Kelas 3 SD Negeri 117 Palembang. *Jurnal EduTech*, *10*(2), 457–464. https://doi.org/10.30596/edutech.v10i2.20357

Wahyuni, S., Ridlo, Z. R., & Rina, D. N. (2022). Pengembangan media pembelajaran interaktif berbasis Articulate Storyline terhadap kemampuan berpikir kritis siswa SMP pada Materi tata surya. *Jurnal IPA & Pembelajaran IPA*, *6*(2), 99–110. https://doi.org/10.24815/jipi.v6i2.24624.

Wijayanti, F. A., Utami, S., & Sumaji. (2022). Development of Articulate Storyline interactive learning media based on realistic mathematical education (RME) to improve critical thinking ability of elementary school students. *ICCCM Journal of Social Sciences and Humanities*, *1*(5), 13–22. https://doi.org/10.53797/icccmjssh.v1i5.3.2022.

Yolanda, T. (2020). Validitas modul asam basa berbasis inkuiri terbimbing dilengkapi soal (HOTS) untuk melatih keterampilan berpikir tingkat tinggi siswa kelas XI SMA/MA. *Ranah Research: Journal of Multidisciplinary Research and Development*, *3*(1), 53–60. https://doi.org/10.38035/rrj.v3i1.

Yulianti, Y., Lestari, H., & Rahmawati, I. (2022). Penerapan model pembelajaran RADEC terhadap peningkatan kemampuan berpikir kritis siswa. *Jurnal Cakrawala Pendas*, *8*(1), 47–56. https://doi.org/10.31949/jcp.v6i1.3350.

Zuhra, F., & Arifiyanti, F. (2021). Indonesian review of physics (IRiP) the analysis of students' critical thinking and scientific literacy skills. *Rev. Phys*, *4*(1), 32–38. https://doi.org/10.12928/irip.v4i1.3980.