

Development of *STEAM-Based e-Chemistry Magazine* as a Teaching Material on Electrolyte and Non-Electrolyte Solution Materials

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ABSTRACT

This research aims to develop a STEAM-based *e-Chemistry Magazine* as a teaching material on electrolyte and non-electrolyte solution materials and determine its conceptual feasibility. *e-Chemistry Magazine* is an electronic teaching material that contains text, images, videos, animations, virtual labs, games, and quizzes, so that it can be accessed through smartphones, laptops, and other devices. The product is developed using the Lee & Owens model which consists of five stages, namely analysis, design, development, implementation, and evaluation. The research instruments used were interview guidelines and questionnaires. The products were validated by media experts and material experts, assessed by practitioners (teachers), then tested on a small group of students of grade XII Science at SMA Negeri 2 Jambi City. The data was analyzed qualitatively and quantitatively. The results of the study showed that the average final validation score of media experts and subject matter experts was 4.8 and 4.6 respectively with the very feasible category, the teacher's assessment obtained an average of 4.7 with the very feasible category, and the response of students obtained a percentage of 87.69% with the very good category. Based on these results, the *STEAM-based e-Chemistry Magazine* was declared to be suitable for conceptual use as one of the teaching materials to increase students' motivation to learn in electrolyte and non-electrolyte solution materials.

Keywords: *e-Chemistry Magazine*, STEAM, Teaching Materials, Electrolyte and Non-Electrolyte Solutions

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1. INTRODUCTION

Education has a strategic role in improving the quality of human resources who are able to face the challenges of scientific and technological development. In line with the change in the educational paradigm, the implementation of the Independent Curriculum emphasizes student-centered learning and 21st century competency development. This curriculum is not only oriented towards mastering knowledge, but also encourages students to develop critical thinking, creativity, communication, and collaboration skills known as the 4C skills. Therefore, the learning process needs to be supported by teaching materials that are able to facilitate the active involvement of students through contextual, innovative, and meaningful learning experiences.

One of the subjects that plays an important role in shaping students' scientific thinking skills is chemistry. However, the characteristics of chemical materials that contain a lot of abstract concepts are often an obstacle in the learning process. One of the materials that requires a good conceptual understanding is electrolyte and non-electrolyte solutions, because students are not only required to understand the concept of electrical conductivity of solutions, but also to be able to relate them to phenomena found in daily life, biological processes, and various applications in the fields of industry and technology. Therefore, learning the material requires media that is able to visualize concepts so that they are easier for students to understand.

The results of a preliminary study conducted at SMA Negeri 2 Jambi City show that the learning process of electrolyte and non-electrolyte solution materials is still dominated by the use of textbooks, printed modules, and student worksheets (LKPD), while interactive digital teaching materials are not yet available. This condition has an impact on students' low motivation to learn and understanding of concepts. The observation data showed that only 50% of students were able to achieve the Minimum Completeness Criteria (KKM) of 70, while the results of the questionnaire analysis revealed that as many as 77.8% of students had difficulty understanding the material. On the other hand, all students already have smartphones that have the potential to be used as a means of digital learning. These findings show that there is a need for electronic teaching materials that are able to present materials in a more interesting, interactive, and accessible way.

One alternative teaching material that can meet these needs is *e-Chemistry Magazine*, which is an electronic chemistry magazine that presents materials with text, images, videos, animations, and simple games so that it can increase students' motivation to learn. Previous research has shown that the development of e-

magazines as teaching materials is stated to be feasible and practical and able to increase students' motivation and interest in learning (Puri et al., 2019; Arief et al., 2021; Yulianto & Rohaeti, 2013; Jariati & Yenti, 2020). To strengthen student engagement, *e-Chemistry Magazine* in this study was developed with a student-centered STEAM (Science, Technology, Engineering, Art, and Mathematics) approach and in accordance with the characteristics of 21st century learning (Sirait et al., 2024; Eka Sari et al., 2023). Research by Herlina et al. (2022) also showed that STEAM-based electronic learning devices received a positive response and were able to increase students' interest and learning outcomes.

To optimize the learning process, the *e-Chemistry Magazine* in this study was developed by integrating the STEAM (Science, Technology, Engineering, Art, and Mathematics) approach. The STEAM approach provides students with the opportunity to connect science concepts with technology, engineering, art, and mathematics through contextual, creative, and problem-solving-oriented learning activities. The integration of this approach is expected not only to improve conceptual understanding, but also to develop critical thinking, creativity, communication, and collaboration skills that are the demands of 21st century learning. Several previous studies have reported that the application of STEAM-based learning on digital media is able to increase student engagement, motivation, and learning outcomes (Herlina et al., 2022; Eka Sari et al., 2023; Sirait et al., 2024).

Based on this description, this study aims to develop a STEAM-based *e-Chemistry Magazine* as a teaching material on electrolyte and non-electrolyte solution materials, analyze the feasibility of products based on validation of media experts and subject matter experts, and find out the teacher's assessment and students' response to the developed product. The results of this research are expected to provide alternative digital teaching materials that are innovative, interactive, and in accordance with the characteristics of chemistry learning in the digital era and support the implementation of the Independent Curriculum in schools.

2. RESEARCH METHODS

This research is a research and development (R&D) that aims to produce products in the form of digital teaching materials *e-Chemistry Magazine* based on Science, Technology, Engineering, Art, and Mathematics (STEAM) on electrolyte and non-electrolyte solution materials. The development model used is Lee & Owens, which consists of five stages, namely assessment/analysis, design, development, implementation, and evaluation. This model was chosen because it is specifically designed for the development of multimedia-based learning products so that it is in accordance with the characteristics of *e-Chemistry Magazine* which integrates various multimedia elements, such as text, images, videos, quizzes, educational games, and virtual laboratories, in one interactive learning medium.

This study uses the Lee & Owens development model which consists of five stages, namely analysis, design, development, implementation, and evaluation. The analysis stage aims to identify the need for the development of STEAM-based *e-Chemistry Magazine* based on real conditions in the field. The analysis was carried out through observation, interviews with chemistry teachers, and the distribution of questionnaires to students of grade XII Science at SMA Negeri 2 Jambi City. Analysis activities include analysis of learning needs, characteristics of students, material analysis, analysis of learning objectives, and analysis of educational technology. Needs analysis is carried out to obtain information about the learning process, the use of teaching materials, learning motivation, and problems faced by teachers and students in electrolyte and non-electrolyte solution materials. Furthermore, the analysis of student characteristics is carried out to identify the initial abilities, cognitive development, skills, and learning needs of students so that the products developed are in accordance with the characteristics of the user. The material analysis is focused on the suitability of facts, concepts, principles, and procedures with the Independent Curriculum, while the analysis of learning objectives is carried out as the basis for the preparation of indicators and learning outcomes. In addition, an analysis was carried out on the availability of digital learning facilities and infrastructure, such as laptops, computers, and smartphones that will be used to access *e-Chemistry Magazine*.

The design stage is carried out as a product design process based on the results of needs analysis. At this stage, a development team is prepared consisting of researchers as product developers, media experts, material experts, chemistry teachers as practitioners, and students as users. Furthermore, a development schedule is prepared so that each stage of research takes place systematically and in a directed manner. Product design includes the preparation of media specifications in the form of a STEAM-based *e-Chemistry Magazine* that contains opening, content, and closing sections with various multimedia features, such as materials, images, learning videos, educational games, interactive quizzes, and virtual laboratories equipped with instructions for use and practicum procedures. The product is designed to be accessible via a link using smartphones, laptops, or computers, providing flexibility in the learning process. As a development guideline,

at this stage, a flowchart is also prepared that describes the flow of media navigation and a storyboard that explains in detail the content of each page. The design that has been prepared is then evaluated through discussions with supervisors and peers to obtain input before entering the development stage.

The development stage is the process of realizing a design into a real product using the Canva application. *The resulting e-Chemistry Magazine* consists of an opening section containing the cover, editorial greetings, and main menu, a content section containing materials, practicum guides, learning videos, virtual laboratories, quizzes, and educational games, and a closing section containing a flashback of the material, bibliography, and author profiles. After the initial product is completed, validation is carried out by media experts and material experts to assess the feasibility of the design, appearance, content of the material, presentation, language, and suitability with the STEAM approach. The validation results are used as a basis for revising and improving the product to meet the eligibility criteria. The revised product is then assessed by the chemistry teacher as a practitioner to obtain input on the suitability of the media with the learning process before being implemented to students.

The implementation stage was carried out through a small group trial of ten students of class XII SCIENCE SMA Negeri 2 Jambi City who were selected using the purposive sampling technique. At this stage, students access *e-Chemistry Magazine* through their respective digital devices after obtaining an explanation of how to use it and the available features. Furthermore, students learn the material independently by utilizing the various interactive features provided, then provide assessments through response questionnaires. The data obtained is used to determine the level of practicality, ease of use, attractiveness, and quality of media in supporting students' understanding of electrolyte and non-electrolyte solution materials.

The evaluation stage is carried out formatively at each stage of development to ensure the quality of the products produced. The evaluation was carried out based on the results of validation of media experts, material experts, teacher assessments, and students' responses to *e-Chemistry Magazine*. The comments, criticisms, and suggestions obtained are analyzed as the basis for the implementation of the revision in stages until the product meets the aspects of validity, practicality, and usability. Through this formative evaluation, every weakness found during the development process can be systematically corrected so that it produces a *STEAM-based e-Chemistry Magazine* that is in accordance with learning needs, easy to use, and feasible to implement as digital teaching materials on electrolyte and non-electrolyte solution materials.

The subjects of the research trial consisted of 10 students of class XII SCIENCE SMA Negeri 2 Jambi City who were selected using purposive sampling techniques by considering the variations in students' academic abilities, namely the high, medium, and low categories. The research data includes qualitative data and quantitative data. Qualitative data is obtained from comments, criticisms, and suggestions provided by media experts, subject matter experts, and teachers during the product validation and evaluation process. Meanwhile, quantitative data was obtained from the results of the media expert validation questionnaire, material expert validation, teacher assessment, and student responses to *the e-Chemistry Magazine* developed. Data collection was carried out using interview guidelines and several questionnaire instruments, namely student needs analysis questionnaires, media expert validation questionnaires, material expert validation questionnaires, teacher assessment questionnaires, and student response questionnaires. Quantitative data is analyzed using descriptive statistics to determine the level of product feasibility based on the average score and percentage which is then interpreted into the eligibility category according to the criteria that have been set.

To calculate the questionnaire instrument for students' needs, the following formula is used:

$$\% \text{Score} = \frac{\text{Jumlah skor yang diperoleh}}{\text{Jumlah total maksimum seluruh skor}} \times 100\%$$

Data from the validation results of media experts, material experts, and teacher assessments were analyzed using a five-category Likert scale. With reference to the criteria as in Table 1 below

Table 1. Instrument rating criteria using the likert scale

Yes	Average Answer Score	Validation Level
1	> 4.2 - 5.0	Excellent
2	> 3.4 - 4.2	Good
3	> 2.6 - 3.4	Not Good
4	> 1.8 - 2.6	Not Good
5	1,0 - 1,8	Very Bad

To calculate the percentage of student responses, the formula is used:

$$K = \frac{F}{N \times I \times R} \times 100\%$$

And the results of student responses can be categorized into criteria as contained in Table 2.

Table 2. Assessment criteria for the percentage of student responses

Yes	Value Scale (%)	Criteria
1	81-100	Excellent (SB)
2	61-80	Good (B)
3	41-60	Poor (KB)
4	21-40	Not Good (TB)
5	0-20	Very Bad (STB)

3. RESULTS AND DISCUSSION

The product produced in this study is in the form of *a STEAM-based e-Chemistry Magazine* as a digital teaching material on electrolyte and non-electrolyte solution materials. This media is developed in the form of an interactive electronic magazine consisting of an opening section (cover, editorial greetings, editorial team, and main menu), a content section (learning materials, videos, practicum guides, virtual laboratories, educational games, and quizzes), and a closing section containing a summary of the material, bibliography, and author profile. The product is designed to be accessible flexibly through links or barcodes using smartphones, laptops, or computers, so that it can be used both in the classroom learning process and as an independent learning resource outside of school. Media development refers to the Lee & Owens model which includes five stages, namely analysis, design, development, implementation, and evaluation, because the model is suitable for the development of multimedia-based learning media.

The analysis stage was carried out to identify media development needs through observation, interviews with chemistry teachers, and the distribution of questionnaires to students at SMA Negeri 2 Jambi City. The results of the analysis show that the learning process is still dominated by the use of textbooks and lecture methods so that it has not been able to facilitate interactive learning. This condition has an impact on the low learning outcomes of students, which is shown by only 50% of students achieving the Minimum Completeness Criteria (KKM), while 77.8% stated that they had difficulties in understanding electrolyte and non-electrolyte solution materials. On the other hand, all students already have smartphones that have the potential to be used as a digital learning medium. Based on these findings, *e-Chemistry Magazine* is designed by integrating materials, learning videos, quizzes, educational games, and virtual laboratories to present a more interactive, contextual, and appropriate learning experience for students.

The design stage is focused on preparing product designs based on the results of needs analysis. The activities carried out include the preparation of media specifications, the formation of a development team, the preparation of a development schedule, the design of material structures according to the learning outcomes of the Independent Curriculum, as well as the preparation of flowcharts and storyboards as guidelines in the

development process. All media components are designed by integrating elements of Science, Technology, Engineering, Art, and Mathematics (STEAM) so that each material not only emphasizes mastery of concepts, but also encourages students to develop critical thinking skills, creativity, problem solving, and relate chemistry concepts to phenomena encountered in daily life.

In the development stage, the storyboard that has been compiled is realized into an *e-Chemistry Magazine* using the Canva application. The product then goes through a validation process by media experts and subject matter experts in two stages to assess the feasibility of the aspects, presentation, content of the material, language, and suitability with the STEAM approach. The validation results showed that there was an improvement in product quality after revisions were made based on validator input. The average value of media expert validation increased from 3.8 with the feasible category to 4.8 with the very feasible category, while the average value of the validation of material experts increased from 3.6 to 4.6 with the very feasible category. The revisions carried out include improving the visual appearance, arranging the material according to the learning objectives, adding image references, improving illustrations, and adjusting the layout of the components to make them more systematic and interesting. After being declared to meet the eligibility criteria by the validators, the product was assessed by the chemistry teacher as a practitioner and obtained an average score of 4.7 in the very feasible category. The teacher assessed that the media has an attractive appearance, is easy to operate, presents material systematically, and is supported by video features, quizzes, educational games, and virtual laboratories that are able to help students understand the concept of electrolyte and non-electrolyte solutions.

The implementation stage was carried out through a small group trial involving 10 students of class XII SCIENCE SMA Negeri 2 Jambi City. Before using the media, students get an explanation on how to access and utilize all available features. Furthermore, students explore *e-Chemistry Magazine* independently using their respective smartphones, then provide an assessment through a response questionnaire that includes aspects of display, material content, ease of use, and the benefits of media for the learning process. The results of the trial showed a percentage of student responses of 87.69% with the very good category, which shows that the media is easy to use, attractive, and able to support students' understanding of electrolyte and non-electrolyte solution materials.

The results of the study show that the *STEAM-based e-Chemistry Magazine* is able to integrate various multimedia elements, such as text, images, audio, videos, quizzes, educational games, and virtual laboratories, into one interactive learning medium. The integration of these various components allows students to have a more meaningful learning experience because they not only read the material, but also observe phenomena, conduct practicum simulations, work on exercises, and get direct feedback. This characteristic makes *e-Chemistry Magazine* more adaptive to the needs of digital learning compared to conventional teaching materials that rely only on text. These findings are in line with the research of Herlika and Sahono (2023), which reported that interactive multimedia equipped with virtual laboratories and evaluations was able to improve the quality of chemistry learning and obtain positive responses from students.

The integration of the STEAM approach is one of the main advantages of the developed media. This approach allows students to learn the concepts of electrolyte and non-electrolyte solutions through the interplay between aspects of science, technology, engineering, art, and mathematics, so that learning is not only oriented towards mastering concepts, but also on developing critical thinking skills, creativity, collaboration, communication, and problem-solving. The presence of virtual laboratories and practicum videos provides opportunities for students to explore concepts more realistically, especially when the implementation of practicum in the laboratory is limited. The results of this study support the findings of Hanif et al. (2026) who stated that STEAM-based learning through virtual laboratories is able to help students understand abstract chemistry concepts and increase their involvement during the learning process. Similar results were also reported by Herliyanto (2023), who stated that the application of the STEAM approach contributes to increasing students' activeness and understanding through a more authentic learning experience.

Overall, all stages of development that refer to the Lee & Owens model succeeded in producing a STEAM-based *e-Chemistry Magazine* that meets the eligibility criteria based on the assessment of media experts, subject matter experts, teachers, and students. The validation results that continue to increase at each stage show that the formative evaluation carried out during the development process is able to improve product quality optimally. Thus, STEAM-based *e-Chemistry Magazine* can be recommended as an alternative to digital teaching materials that are innovative, interactive, and in accordance with the characteristics of chemistry learning in the Independent Curriculum, especially in electrolyte and non-electrolyte solution materials.

4. CONCLUSION

Based on the results of the research and discussion, it can be concluded that: (1) the STEAM-based *e-Chemistry Magazine development process* was carried out through five stages of the Lee & Owens model, with the main obstacle in adjusting the interactive design to be in harmony with the STEAM approach and easy to understand by students; (2) *e-Chemistry Magazine* was declared very feasible based on the assessment of media experts (average 4.8) and material experts (average 4.6); and (3) *e-Chemistry Magazine* received a very decent assessment from teachers (average 4.7) and very good responses from students (87.69%), so that this media is suitable for use in learning electrolyte and non-electrolyte solution materials. Follow-up research is suggested to test the effectiveness of the product in a larger group as well as measure its effect on students' learning motivation.

BIBLIOGRAPHY

- [1] Arief, M. D., Auliah, A., & Hardin, H. (2021). Development of E-Magazine for Reduction and Oxidation Reactions as a Chemistry Learning Media for Class X High School/MA. *Journal of Chemical Learning Innovation*, 3(2), 148. <https://doi.org/10.24114/jipk.v3i2.28111>
- [2] Bernardi, F., & Pazinato, M. (2022). The Case Study Method in Chemistry Teaching: A Systematic Review. *Journal of Chemical Education*, 99, 1211-1219. <https://doi.org/10.1021/acs.jchemed.1c00733>
- [3] Eka Sari, L., Syahrial, & Risdalina. (2023). The Application of STEAM Learning to Increase the Learning Interest and Critical Thinking Ability of Elementary School Students. *Scientific Journal of Citra Bakti Education*, 10(3), 530-543. <https://doi.org/10.38048/jipcb.v10i3.1652>
- [4] Hanif, R. F., Mulyani, S., & Utomo, S. B. (2026). Exploring Learning Needs for Developing a STEAM-Oriented Differentiated Virtual Laboratory in Electroplating and Electropolishing. *Paedagogia*, 29(1), 135-144. <https://doi.org/10.20961/paedagogia.v29i1.112931>
- [5] Herlika, H., & Sahono, B. (2023). The Development of Interactive Multimedia Virtual Laboratory to Enhance Students' Academic Achievement. *IJOEM: Indonesian Journal of E-Learning and Multimedia*, 2, 96-103. <https://doi.org/10.58723/ijoem.v2i3.143>
- [6] Herlina, H., Ramlawati, R., & Hasri, H. (2022). Development of STEAM-Based Electronic Learning Tools to Increase Interest and Learning Outcomes. *Chemistry Education Review (CER)*, 5(2), 198. <https://doi.org/10.26858/cer.v5i2.32731>
- [7] Herliyanto, M. (2023). Application of STEAM (Science, Technology, Engineering, Arts, Mathematics) Learning. *Journal of Education*, 6, 57-62.
- [8] Jariati, E., & Yenti, E. (2020). Development of Multiple Representation-Based E-Magazine for Chemistry Learning in High School on Electrolyte and Non-Electrolyte Solution Materials. *Journal of Natural Science and Integration*, 3(2), 138. <https://doi.org/10.24014/jnsi.v3i2.10131>
- [9] Leba, M. A. U., Commissioner, F., & Tukan, M. B. (2021). Chemistry Tutoring for High School Students Domiciled in Penfui-Binilaka Kupang. *To Maega: Journal of Community Service*, 4(2), 124. <https://doi.org/10.35914/tomaega.v4i2.572>
- [10] Puri, D. N. A., Epinur, & Muhaimin. (2019). Development of e-Magazine for Chemical Equilibrium Materials at SMAN 1 Jambi City. *Journal of the Indonesian Society of Integrated Chemistry*, 11(1), 10-19. <https://doi.org/10.22437/jisic.v10i1.6733>
- [11] Sari, Y. G., Putra, B. E., Miranti, Y., & Setiawati, M. (2022). The Relationship between Increasing Student Learning Motivation and the Implementation of the Class X Independent Learning Curriculum at SMA 1 IX Koto Sungai Lasi. *JUPEIS: Journal of Education and Social Sciences*, 1(4), 131-138. <https://doi.org/10.57218/jupeis.vol1.iss4.375>
- [12] Sirait, E., Usman, H., & Angger Wardhani, P. (2024). Development of STEAM-Based Smart Apps Creator 3 Learning Media on Elementary School Mathematics Content. *Cognitive: HOTS Research Journal of Mathematics Education*, 4(1), 368-376. <https://doi.org/10.51574/kognitif.v4i1.1453>
- [13] Teguh Handoyo, Ashriyah, I., & Kamal, R. (2024). Development of Multimedia-Based Teaching Materials. *Harmony of Education: Journal of Educational Sciences*, 2(1), 230-250. <https://doi.org/10.62383/hardik.v2i1.1064>
- [14] Wu, M. Y. M., & Yeziarski, E. J. (2022). Secondary Chemistry Teacher Learning: Precursors for and Mechanisms of Pedagogical Conceptual Change. *Chemistry Education Research and Practice*, 24(1), 245-262. <https://doi.org/10.1039/d2rp00160h>
- [15] Yulianto, E., & Rohaeti, E. (2013). Development of Chemistry Magazine to Increase Students' Learning Motivation and Creativity. *Journal of Science Education*, 1(1), 26-36.