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Development of Technopreneurship-Based E-Modules for Ethnochemistry, Redox, and Science Literacy

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ABSTRACT

This research is very important to improve the quality of student learning, which is supported by good knowledge and a teaching process. It uses various sources and teaching materials presented interestingly so that students get various experiences in the field of chemistry as expected. By developing an Emodule based on ethnochemistry (culture related to chemistry), this study bridges the **gap** in existing teaching materials that lack cultural integration, which often hinders students engagement and scientific literacy development. The **novelty** of this research lies in the integration of local cultural practices, such as Batak culture, into redox chemistry learning, creating an innovative approach to enhance students scientific literacy. The **method** used in this study is a qualitative and quantitative approach, specifically employing a 4D model (define, design, development, dissemination) to develop and validate the module. The **results** show that the ethnochemistry based module teaching materials on redox material are the characteristics of effective modules, achieving validation scores of 3.45 from media experts and 3.37 from material experts, categorized as "very appropriate". Additionally, student responses to the E-Module were very positive, with an average score of 3.70, indicating its effectiveness in enhancing students understanding and engagement.

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1. INTRODUCTION

The Industrial Revolution 5.0 demands educators embrace innovative teaching strategies to improve learning outcomes [1]. Chemistry learning is crucial in equipping students to understand and investigate chemical concepts methodically while making the experience enjoyable and meaningful [2]. However, teaching materials that exclude local cultural elements tend to hinder the development of students scientific literacy skills [3]. This research addresses this gap by introducing Emodules based on ethnochemistry, a field that integrates cultural practices with chemical principles to promote scientific literacy among students [4]. The methodology for developing Emodules involves a 4D model defined, designed, developed, and disseminated to ensure the teaching material aligns with pedagogical goals and cultural relevance [5]. Existing teaching resources were

analyzed in the define stage to identify deficiencies in connecting chemical concepts to real world applications [6, 7]. In the design stage, outlines and frameworks for the E-Module were created, emphasizing local cultural practices like the redox process in Naniura preparation [8]. The development stage focused on material validation by subject matter experts and the integration of multimedia elements [9]. Finally, the dissemination stage ensured the accessibility of the modules through online platforms [10].

A significant gap exists in the current educational landscape where the teaching materials of chemistry do not incorporate cultural relevance, leaving students unable to connect theoretical knowledge with their cultural environment [11]. Existing resources often focus solely on abstract scientific concepts without providing students with the contextual tools to apply these principles in their daily lives. This research addresses this void by merging chemistry education with local ethnochemical practices, creating an innovative approach that enhances both understanding and appreciation of chemistry [4]. The novelty of this research lies in its integration of cultural ethnochemistry into the Emodule framework. Unlike conventional chemistry modules, these E modules incorporate local practices, such as the preparation of naira carp, a traditional Toba Batak dish, to teach redox reactions [12]. Additionally, the modules are designed to be digitally accessible, incorporating multimedia tools such as videos and interactive elements to bridge traditional knowledge with modern pedagogical methods [13]. This not only introduces a unique way of teaching chemistry but also fosters cultural preservation and student engagement [14].

The development and validation of the Emodule yielded highly favorable outcomes. Material experts rated the modules at an average score of 3.37, while media experts provided an overall score of 3.45, both indicating a very high level of appropriateness [15]. Furthermore, student responses averaged 3.70, demonstrating a strong preference and acceptance of the E-Module content and design. These results highlight the effectiveness of integrating ethnochemistry into teaching materials and its potential to enhance students scientific literacy and engagement. The results of this research underline the potential for ethnochemistry based Emodules to be adapted across other cultural contexts and scientific disciplines [16]. For example, similar methodologies can be employed to teach biological concepts through local medicinal plant studies or physics principles through traditional crafting techniques [17, 18]. Beyond education, this approach opens avenues for entrepreneurial and technopreneurship by enabling the commercial distribution of culturally integrated educational materials [19]. Fostering educational innovation and cultural preservation, this research sets the stage for scalable and impactful teaching solutions in the era of Industry 5.0 [20].

2. RESEARCH METHOD

The approach in this study uses a qualitative and quantitative approach. The type of research used is a development research type with a 4D model, namely define, design, development, dissemination [21]. These steps are briefly summarized as follows:

- Define Stage: An analysis of existing teaching materials is conducted to identify their strengths and weaknesses, providing a basis for the development of new, improved materials.
- Design Stage: Teaching materials are developed by selecting appropriate media, optimizing layouts, and addressing content gaps identified during the analysis phase.
- Development Stage: This includes revising and validating materials with expert feedback to ensure they meet the desired quality standards.
- Dissemination Stage: The finalized materials are shared with intended users, including students and educators.

The instrument used in this study will be validated by experts beforehand to determine whether the instrument questions are good for use in research so that it will be known whether or not they meet the criteria seen from the material and media expert aspects [22].

Next, the percentage of eligibility is obtained and then interpreted into categories based on the image below:

Table 1. Validity Classification

Validity Value	Validity
$0 < V \leq 0.4$	Less Valid
$0.4 < V \leq 0.8$	Quite Valid
$0.8 < V \leq 1$	Very Valid

The student response questionnaire contains questions which are then filled in by ticking the categories provided based on a Likert scale consisting of 4 assessments, namely: "Very appropriate" (4 points), "Appropriate" (3 points), "Inappropriate" (2 points), and "Very Inappropriate" (1 point). To ensure consistency and reliability, the validity of the student response questionnaire was assessed using the criteria outlined in Table 1. Based on the validity classification, the responses are categorized as "Less Valid", "Quite Valid", or "Very Valid" depending on the Value (V) obtained from the analysis. This classification provides a clear framework for interpreting the reliability and accuracy of the student feedback data, aligning it with the overall validation process of the E-Module development [23].

Table 2. Validity Classification

Information	Score
Very appropriate	4
Appropriate	3
Inappropriate	2
Very Inappropriate	1

The scoring criteria for the student response questionnaire were developed to ensure clarity and consistency in evaluating student feedback. As outlined in Table 2, the questionnaire uses a four point Likert scale, ranging from "Very appropriate" (score 4) to "Very Inappropriate" (score 1). This scoring system allows for a detailed assessment of how well the E-Module meets student expectations in terms of content, design, and usability. By categorizing responses into numerical scores, the evaluation process becomes quantifiable and comparable between different groups of students.

The results of the questionnaire are then thoroughly analyzed to identify the key strengths and areas requiring improvement in the E-Module [24]. Responses categorized as "Very appropriate" and "Appropriate," which correspond to scores of 4 and 3 respectively, reflect a strong positive reception among the students. These high scores signify that the E-Module successfully addresses student needs in areas such as content clarity, design accessibility, and overall usability [25].

On the other hand, responses in the "Inappropriate" or "Very Inappropriate" categories, associated with lower scores of 2 and 1, serve as indicators of specific elements that require further refinement [26]. These may include areas where the content lacks sufficient clarity, where the design elements are less intuitive, or where the module fails to fully engage the learn [27]. Such constructive feedback is invaluable in guiding iterative improvements to the E-Module [28]. By systematically addressing these weaker areas, the development process ensures that the module evolves to meet the diverse needs of students more effectively [29].

The structured feedback mechanism built into the evaluation process plays a critical role in maintaining a student-centered approach [30]. By basing decisions on empirical data collected from real users, the development team ensures that the module is not only technically sound but also pedagogically effective [31, 32]. This iterative cycle of receiving feedback, analyzing results, and implementing improvements creates a robust framework for continuous enhancement of the E-Module. The approach fosters an adaptive learning tool that evolves in response to student input, ultimately leading to better learning outcomes and a more satisfying educational experience [33].

3. RESULT AND DISCUSSION

The research and development conducted resulted in an E-Module product on the Basics of Chemistry course on Redox (Reduction and Oxidation) at HKBP Nommensen University, Pematangsiantar [34]. This media was developed using the 4D model, namely define, design, development, dissemination.

3.1. Define

At this stage, analyze the teaching materials used in making teaching materials by collecting various information about the teaching materials from books, modules and other sources, so that the advantages and disadvantages of the teaching materials available on the market can be found, so that development is needed for the teaching materials to be developed [35]. From the results of the analysis carried out on various sources of reading books for theoretical reviews on redox material, it is very good, only there is a lack of explanation on the redox material in everyday life. That is the deficiency in the redox material in reading books circulating on the market [36, 37]. So it is necessary to develop it so that the deficiencies in the analysis results become something that needs to be fixed.

3.2. Design Stage

In the design stage, the primary focus is on developing the teaching materials, specifically the E-Module. This stage involves creating a comprehensive instrument to assess the feasibility of the E-Module, ensuring it aligns with the pedagogical objectives and effectively meets the learning needs of students. The E-Module is structured around key learning activities that are intended to explain complex concepts in an engaging and culturally relevant way.

The first learning activity introduces the concept of reduction and oxidation reactions, breaking it down into several key areas [38, 39]. These include the concept of redox reactions based on the involvement of oxygen atoms, electron transfer, and oxidation numbers. Additionally, ethnochemical insights are integrated, such as the application of redox reactions in Nyirih preparation, Bajakah roots, Tempoyak, and the traditional dish Dekke Naniura. This cultural integration not only aids in the understanding of redox concepts but also connects chemistry to local cultural practices, making the learning experience more relatable for students [40, 41]. Each section in the activity includes learning objectives, material descriptions, a summary, independent assignments, practice questions, and self-assessments to reinforce the learning process.

The second learning activity delves into oxidation number rules and the determination of elemental oxidation numbers in compounds or ions. It also explores the use of oxidation numbers to determine redox reactions and discusses autoredox or disproportionation reactions. Similar to the first activity, this section includes clear learning objectives, material descriptions, a summary, independent assignments, practice questions, and self-assessments [42].

Finally, the design stage includes an evaluation process for both learning activities, as well as the creation of a well-structured E-Module framework. This framework serves as the foundation for the module layout, ensuring that the content is organized logically and is easily navigable for students.

The preparation of an E-Module framework generally consists of three main parts, namely the introduction, material, and conclusion [43]. The introduction contains the background, brief description, competency standards and basic competencies, concept maps, benefits and objectives, and instructions for using the E-Module. The material section consists of basic competencies and indicators, material explanation descriptions, ethnochemical insights, summaries, assignments and independent tests. The closing section contains a post test/evaluation, bibliography, and answer key [44].

3.3. Development Stage

The E-Module was developed using the Canva application to compile the cover, introductory content, and closing content. While the E-Module material first uses the Microsoft Office Word 2010 application to compile it, then the format is changed to PDF.

As shown in Figure 1 inserting videos from YouTube by including YouTube links is also done with the Canva application so that when the YouTube link is clicked, the YouTube video can be seen. This is done so that students can learn easily and can immediately see virtually what the author wants to convey. Specifically in the video section, ethnochemical insights are presented from how to cook naniura carp (dekke naniura) so that it is not only imagined but can be seen through the video. The lack of discussion on the challenges or limitations of the 4D model, I included a reflection on the difficulties encountered during its application. These include the extensive time and resources required for the ”Define” and ”Design” stages, which involve comprehensive analysis and iterative prototyping.Additionally, the ”Dissemination” stage presents challenges in ensuring accessibility and acceptance among diverse user groups. Highlighting these challenges provides a balanced perspective and offers insights for future adaptations of the model.

Figure 1. Creating an E-Module Cover with Canva

Expanding upon the implementation of video content in the E-Module, it is evident that the integration of multimedia resources enhances the interactivity and accessibility of the learning material. By embedding YouTube links within the Canva-designed E-Module, students are provided with an intuitive, click-and-play feature that eliminates the need for additional navigation to external platforms. This seamless integration ensures that learners can focus solely on the content and its context, reducing potential distractions. For example, the inclusion of a video demonstrating the preparation of naniura carp brings ethnochemistry concepts to life, allowing students to visualize and connect theoretical principles with cultural practices.

Moreover, the use of videos to present ethnochemical insights addresses diverse learning styles, catering particularly to visual and auditory learners. The dynamic presentation of the naniura preparation process reinforces the application of redox reactions in everyday life, deepening students understanding of chemistry in a relatable manner. This approach also fosters cultural appreciation by preserving traditional practices within the framework of scientific learning. Through this integration, the E-Module bridges the gap between abstract scientific concepts and tangible real-world applications, significantly enriching the educational experience [34, 45].

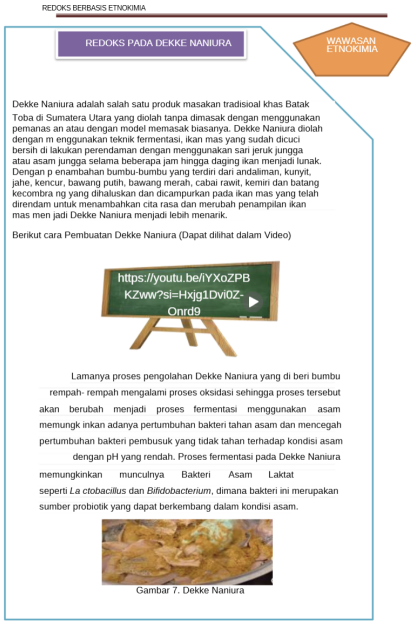

Figure 2. Inserting Video from Youtube

Figure 2 illustrates the process of embedding a video from YouTube into an E-Module design interface. The screenshot shows a section of the E-Module focusing on ethnochemistry, specifically the preparation of ”Dekke Naniura,” a traditional dish. The interface highlights tools for inserting multimedia elements such as videos, shapes, and graphics, providing interactive and visually engaging content for learners. The embedded video link supports the textual explanation and visual representation, enhancing comprehension and learner engagement. Additionally, the figure emphasizes the inclusion of culturally relevant materials, like traditional recipes, to contextualize scientific concepts in real-life applications.

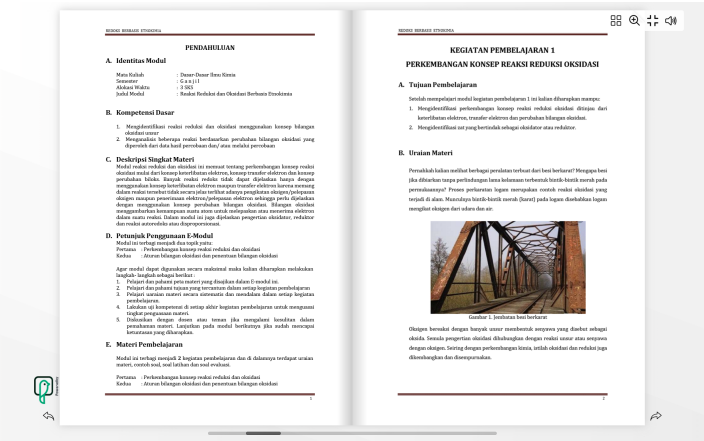

Figure 3. E-Module with Heyzine Flipbooks Application

As shown in Figure 3 the results of the E-Module validation are as follows:

- Validation by Material Experts

  Validation by material experts includes content aspects, language aspects, and presentation aspects. The results of the E-Module validation by 2 material experts can be shown in Table 3 below:

Table 3. Subject Matter Expert Validation

Assessment Aspects	Average	Category
Content suitability	3.33	Very good
Language Eligibility	3.34	Very good
Presentation Eligibility	3.44	Very good
Amount	3.37	Very good

The validation process conducted by subject matter experts evaluated the E-module across several key assessment aspects, as shown in Table 3. The content suitability scored an average of 3.33, indicating a ”Very good” alignment with the intended learning objectives and curriculum standards. Similarly, language eligibility achieved an average score of 3.34, reflecting clear, concise, and student-friendly language usage. These results demonstrate the effectiveness of the E-module in delivering high-quality educational content that aligns with the goals of fostering student scientific literacy.

The results from Table 3 emphasize the robustness of the E-Module development process, which prioritizes both content accuracy and learner engagement. The consistently high scores across all aspects validate the integration of pedagogical strategies, such as the inclusion of ethnochemistry examples and interactive components, to improve scientific literacy. This alignment between expert validation and student feedback, as seen in Table 2, underscores the module capacity to bridge theoretical knowledge with practical applications, creating a meaningful and effective learning tool for students, these validations affirm the reliability and effectiveness of the E-module in enhancing the learning process.

- Media Expert Validation

  The results of the E-Module validation by 2 media experts are shown in Table 4 as follows:

Table 4. Media Expert Validation

Assessment Aspects	Average	Category
Screen Design Display Eligibility	3.43	Very good
Eligibility Ease of Use	3.43	Very good
Consistency Eligibility	3.50	Very good
Eligibility for Benefit	3.50	Very good
Graphic Eligibility	3.43	Very good
Amount	3.45	Very good

The results from the media expert validation, presented in Table 4, indicate the exceptional quality of the E-Module design and usability. The Screen Design Display Eligibility and Eligibility Ease of Use both scored an average of 3.43, categorized as "Very good", highlighting the module visually appealing layout and user-friendly navigation. These scores reflect the deliberate effort to ensure that the module design supports an intuitive learning experience for students, enhancing their engagement and comprehension during the learning process [46].

Other critical aspects, such as Consistency Eligibility and Eligibility for Benefit, scored even higher with averages of 3.50, also classified as "Very good". These results emphasize the E-Module consistent presentation of content and its tangible educational benefits for learners. The overall average score of 3.45 confirms that the module effectively integrates media elements to optimize learning outcomes. This validation complements the findings from the subject matter expert assessment in Table 3, underscoring the module comprehensive quality in both content and media design.

- Student Response

  The results of the student responses can be seen in Table 5 as follows:

Table 5. Student Response Results

Assessment Aspects	Average	Category
Content Eligibility	3.70	Very good
Language Eligibility	3.68	Very good
Eligibility for Benefit	3.69	Very good
Graphic Eligibility	3.75	Very good
Amount	3.70	Very good

Tables 3, 4 and 5 collectively illustrate the validation results and feedback from subject matter experts, media experts, and students, respectively. Table 3 highlights the subject matter expert validation, with all assessment aspects, including content suitability, language eligibility, and presentation eligibility, receiving average scores above 3.30, categorized as "Very Good". Similarly, Table 4 presents the media expert validation, emphasizing aspects such as screen design display, ease of use, and graphic eligibility, all scoring above 3.40 and also categorized as "Very Good", showcasing the media effectiveness in delivering content. Lastly, Table 5 captures the student response results, with aspects like content eligibility, language eligibility, and graphic eligibility achieving the highest scores, averaging above 3.68, which reflects positive reception and user satisfaction. Together, these tables underscore the robustness, clarity, and usability of the material, ensuring its high quality and relevance across evaluative dimensions.

The results of the E-Module development can be seen at this link, https://heyzine.com/flip-book/566fcedb95.html. The assessment instruments for the material, media, and student response questionnaires that have been prepared are then validated so that the resulting instrument is valid and suitable for use in research. The instrument is then revised according to the results of the validator corrections so that a valid assessment instrument is obtained and can be used to assess the feasibility of the E-Module. The E-Module is then validated by material experts and media experts using the E-Module assessment sheet that was previously created. Validation by material experts and media experts aims to determine whether the E-Module that was created is suitable for use by users.

The E-Module assessment carried out by material experts on the material in the E-Module resulted in an overall average assessment score of 3.37 out of a maximum score of 4.00 with a very good product category [47, 48]. For the validation by material experts, the standard deviation was calculated as 0.05, indicating high consistency among the expert evaluations. Feedback from material experts emphasized the effectiveness of including ethnochemical insights in redox reactions [49].

Figure 4. SDG 4 and SDG 11

As shown in Figure 4 the integration of ethnochemistry into educational practices resonates strongly with SDG 4 (Quality Education) by promoting inclusive and culturally relevant education tailored to students local contexts. This approach enhances understanding and fosters cultural appreciation, addressing the goal of equitable quality education and lifelong learning opportunities for all.

Furthermore, the focus on local cultural practices, such as the ethnochemical insights into redox reactions related to traditional Batak Toba food preparation, directly supports SDG 11 (Sustainable Cities and Communities). By embedding cultural heritage into education, the study preserves and promotes traditional knowledge while equipping students with scientific literacy and critical thinking skills necessary for sustainable development in their communities [50].

Validation by media experts includes aspects of screen design appearance, ease of use, consistency, usefulness, and graphic aspects. The assessment of the E-Module carried out by media experts on the developed E-Module resulted in an overall average assessment score of 3.45 out of a maximum score of 4.00 with a very good product category, with a standard deviation of 0.04, showcasing minor variance in their assessments. Media experts highlighted the clarity of the visual presentation and user-friendly navigation [51, 52].

After being validated with the results that are suitable for use, the researcher wants to assess the students perspective on the E-Module that has been developed so that this E-Module can be used by students to increase student literacy [53]. Ten people used as samples gave responses to the E-Module. The results of the assessment of students responses to the E-Module on the completed questionnaire obtained an average overall assessment score of 3.70 from a maximum score of 4.00 with a very good product category. Students also provided qualitative feedback, mentioning that the incorporation of culturally relevant examples, like ”dekke naniura”, enhanced their understanding and engagement”.

To address the adaptability and broader application of the ethnochemistry-based E-Module methodology, this section introduces a discussion on scalability. The research findings, though focused on the Toba Batak culture, present a flexible framework for integrating local cultural elements into scientific education across diverse regions. For instance, adapting similar modules to highlight ethnochemistry concepts from other cultural contexts, such as Javanese batik dye processes or Minangkabau food preservation techniques, can ensure the wide applicability of the approach.

4. MANAGERIAL IMPLICATIONS

The findings of this research highlight several important policy recommendations. First, ethnochemistry-based E-Modules serve as a powerful tool for enhancing student engagement and improving scientific literacy by integrating local cultural practices into the science curriculum. This approach not only promotes culturally responsive learning but also helps students connect theoretical concepts to real-world applications, fostering a deeper understanding and appreciation of both science and culture. Additionally, the incorporation of multimedia elements, such as embedded videos, addresses the diverse learning styles of students and underscores the

growing importance of digital tools in modern education.

However, there are challenges in implementing the 4D model, particularly regarding the resource intensity of the define and design stages, as well as accessibility issues in remote areas. To address these challenges, strategic investments in technology, educator training, and community collaboration are essential for the scalability and long-term success of this approach. Furthermore, aligning educational strategies with Industry 5.0 demands is crucial for preparing students for the future of work and ensuring that education remains relevant in an increasingly digital and interconnected world.

5. CONCLUSION

This study highlights the development of an ethnochemistry-based E-Module focused on redox reactions, aimed at enhancing student scientific literacy. The validation results from both media and material experts, with average scores of 3.45 and 3.37 respectively, confirm the high quality of the teaching materials. Additionally, the student feedback, with an average score of 3.70, indicates strong acceptance and effectiveness in improving understanding of redox reactions, showcasing the E-Module role in bridging the gap between theoretical chemistry concepts and cultural practices.

Future studies could explore the integration of similar ethnochemistry-based E-Module in different scientific disciplines, such as biology or physics, utilizing local knowledge for broader educational contexts. Moreover, researchers should investigate the scalability of these modules in diverse cultural settings to determine their adaptability and impact on scientific literacy in varying educational environments. It would also be valuable to examine the long-term effects of using ethnochemistry in education on student academic performance and cultural appreciation.

The findings of this study have significant implications for both educational practice and policy. By integrating cultural elements into science education, the E-Module fosters a deeper connection between students and the subject matter, enhancing engagement and retention. This culturally responsive approach aligns with the goals of improving scientific literacy and preserving local heritage, and can be applied to curricula across other regions and subjects. Furthermore, this research supports the use of digital tools in education, addressing the need for innovative and accessible teaching methods in the digital age.

6. DECLARATIONS

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6.2. Author Contributions

Conceptualization: FY, AD, EK, and EP; Methodology: FY; Software: FY; Validation: FY; Formal Analysis: FY, AD, EK, and EP; Investigation: FY, AD, EK, and EP; Resources: FY; Data Curation: FY; Writing Original Draft Preparation: AD and EK; Writing Review and Editing: FY, AD, EK, EP, and NT; Visualization: FY; Supervision: FY and NT; Project Administration: FY and NT; Funding Acquisition: NT. All authors FY, AD, EK, EP, and NT have read and agreed to the published version of the manuscript.

6.3. Data Availability Statement

The data presented in this study are available on request from the corresponding author.

6.4. Funding

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6.5. Declaration of Conflicting Interest

The authors declare that they have no conflicts of interest, known competing financial interests, or personal relationships that could have influenced the work reported in this paper.

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