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GREEN CHEMISTRY LEARNING TRANSFORMATION: YOUTUBE INTEGRATED INTERACTIVE VIDEO TO IMPROVE CRITICAL THINKING SKILLS

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Abstract. The use of technology as a learning medium is a necessity that needs to be fulfilled in the learning process. Technology provides a more pleasant and interesting learning atmosphere, one of which is learning media in the form of interactive learning videos. The purpose of the study was to produce a product in the form of an interactive learning video of green chemistry integrated with YouTube to improve students' critical thinking skills. The research instrument was a validation sheet, Likert scale questionnaire, interview guidelines, and pretest and posttest questions on critical thinking skills. The learning video has been validated by material experts with an average of 90% and media experts with an average of 88% in the very valid category. Furthermore, it was tested in small groups with an average of 89% and field trials with an average of 90%. The effectiveness test was 77% with the effective category. The results of this research are that the learning video products developed are valid, practical, and effective in improving students' critical thinking skills. In addition, the results of the evaluation of students showed an increase in critical thinking skills after using the learning video. The use of YouTube-integrated videos allows wider access and flexibility in learning and is by the times. This research concludes that green chemistry learning videos integrated with YouTube can be an effective alternative to chemistry learning.

INTRODUCTION

Education is the key to success in producing quality human resources. Achieving educational goals is not easy, the purpose of education is not only the transfer of knowledge, but also the development of skills. Achieving educational goals is based on many factors, one of which is by adjusting learning patterns to technological developments, major transformations in the world of education are changing the educational landscape (Sumandya & Widana, 2022). Learning innovations are constantly evolving. In fact, the proper use of technology has the potential to improve learning outcomes, because each individual becomes active in the learning process and fosters interest and motivation (Suyuti et al., 2023; Sumandya et al., 2022). This is where the role of teachers or lecturers is to be able to choose learning strategies by utilising technology (Cayeni & Utari, 2019). The

use of appropriate technology will increase understanding, especially of abstract materials and improve the quality of learning.

Chemistry is one of the materials that require good understanding. Chemistry subjects are abstract and require simplification of concepts to be easily understood (Sewandono, 2022). Chemistry material is considered difficult because of the characteristics of chemical concepts and the way teachers teach in explaining (Sumanik et al., 2020). Green chemistry is one of the interesting materials because it emphasises the development of chemical processes and environmentally friendly products to prevent waste. Green chemistry is a relevant material in the context of current global environmental issues. Through this learning, students can analyse and apply the principles of green chemistry by preventing or reducing the impact of chemical use in the environment. On the other hand, green chemistry material has its own challenges for chemistry education students.

Based on preliminary observations and student interviews in chemistry education at Univeristas Musamus, data obtained that students' understanding of green chemistry material is still lacking this is because the evaluation results are still low. Learning green chemistry has its own challenges for students because of its complex concepts, and the lack of interesting and interactive learning media is an obstacle in the learning process. Furthermore, interviews with chemistry lecturers related to the use of teaching materials used, lecturers use printed books and power points. The use of learning videos as a teaching tool is still not optimised, especially in green chemistry. As for the learning media used, there is no media that displays audiovisuals about green chemistry in a real context. Therefore, audiovisual learning media is needed, one of which is learning video media.

Interactive learning videos are learning media by presenting information or data visually, and have great potential in the learning process, in learning videos usually also equipped with supporting sound and music. The advantages of learning videos are that the audiovisual display arouses enthusiasm and motivation in learning (Haryadi et al., 2022). Learning transformation provides innovation in encouraging students to learn. The use of social media platforms is an interesting attraction in the digital era, one of the popular social media platforms is YouTube. The use of social media platforms as publications has good potential, so that learning becomes closer and easier to access anytime and anywhere, one of which is by utilising the YouTube platform. Another advantage is that it is easy to use and has interactive features such as discussions. On the other hand, YouTube integration can increase student learning motivation and enrich the learning experience (Widana, 2020). Learning through YouTube interactive videos provides an interesting learning atmosphere because students not only see visually but also hear green chemistry material. learning videos are audio-visual learning media, namely by hearing and seeing, so that the learning process becomes more enjoyable. Through learning videos can also provide motivation for students so that the learning process becomes more effective. The use of this learning video can be integrated with a learning model that is suitable for 21st century learning. 21st century skills that are emphasised are critical thinking, creativity and cooperation (Kustianingsih & Muchlis, 2021).

The 21st century education provides challenges for chemistry teachers to be able to innovate according to the times. Quality science education will help students solve problems and make decisions related to environmental issues or daily life (Sumanik et al., 2023). One of the 21st century skills needed is the ability to think critically. Digital media

innovation can improve 21st century critical thinking skills, especially in science learning (Jannah & Atmojo, I, R, 2022). Critical thinking skills are the ability to evaluate the information received, and can make the right decision (Ariadila et al., 2023). Critical thinking needs to be trained and felt continuously, because this ability can help individuals be more thorough and train thinking through reasoning and can solve problems. Critical thinking needs to be a concern and needs to be improved, because critical thinking underlies individuals in behaviour. Through critical thinking each individual will seek the truth and analyse the information obtained. More simply, critical thinking is a person's ability to reason, understand, analyse in order to solve problems. Critical thinking is part of higher order thinking (HOTs) which is now often emphasised in education (Agustina, 2019).

There have been many studies related to learning videos that have proven effective. The use of learning videos on equilibrium material has an influence in improving critical thinking skills, but on the other hand, the duration of the content is not too long to suit students' abilities (Surtiningsih et al., 2024). The development of digital learning videos has proven effective in improving critical thinking, and allowing students to repeat the material presented in the video until they understand (Septi et al., 2022). In line with this, Latifa et al., (2023) in research on the development of interactive learning videos can improve critical thinking skills on chemical bonding material. Although there are many studies on the development of learning videos, green chemistry materials have not been developed, especially to improve critical thinking skills on the YouTube platform. This research aims to fill the void in developing interactive learning videos on green chemistry materials integrated on the YouTube platform.

METHOD

This research & development methodology uses the ADDIE model which consists of Analyze, Design, Development, Implementation, and Evaluation. The selection of the ADDIE model is based on a literature study because previous research has proven that learning video products are feasible to use (Dheadema et al., 2023; Kawete et al., 2022). The product in this study is an interactive video with green chemistry material integrated on YouTube. This research was trialled on students majoring in chemistry education, Universitas Musamus. The research trial subjects were 25 students. Research instruments in the form of validation sheets, questionnaires, interview guidelines, and pretest and posttest questions of critical thinking skills that have been validated. The purpose of this study was to determine the product in the form of Youtube integrated green chemistry learning video valid, practical and effective. The validity test uses the formula: $P = \frac{\sum F}{\sum N} \times 100$ (Riduwan, 2015). Description: P= Percentage of each respondent, ∑F= Number of answers of each respondent, ∑N= Maximum number of respondents

The validity of the product was validated by two media expert validators and material experts using a validation sheet, while the aspects assessed included the feasibility of content, language, appearance and presentation. The results of the percentage calculation are interpreted in several criteria as shown in Table 1.

Table 1. Criteria for validity

(%)	Criteria
81%-100%	Very Valid
61%-80%	Valid
41%-60%	Fairly Valid

(%)	Criteria
21%-40%	Invalid
0%-20%	Very Invalid

(Arnold, 2018)

The practicality test in this study used a Likert scale questionnaire consisting of 5 categories, namely strongly agree, agree, neutral, disagree, and strongly disagree. This practicality test is based on student response questionnaires after the YouTube-based learning media is tested. The aspects assessed in this practicality test include ease of use, usefulness, time efficiency and media attractiveness. The results of the practicality percentage calculation are interpreted
in several criteria in Table 2.

Table 2. Practicality Criteria

(%)	Criteria
81%-100%	Very Pratical
61%-80%	Practical
41%-60%	Practical enough
21%-40%	Not Practical
0%-20%	Not Very Practical

The effectiveness test can be calculated using the Normalised Gain (N-Gain) formula:

$$\text{N Gain}=\frac{\text{Mean Posttest Score - Mean Pretest Score}}{\text{Mean Ideal Score - Mean Pretest Score}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(2)}$$

Furthermore, the N-Gain values are grouped into four criteria as shown in Table 3.

Table 3. Effectiveness Categories

(%)	Criteria
< 40	Ineffective
40-55	Less Effective
56-75	Effective Enough
>76	Effective

(Sukarelawan et al., 2024)

RESULTS AND DISCUSSION

Interactive learning video development research on green chemistry materials uses the ADDIE model with the following stages:

Analyze Stage

The first stage, namely analyse, includes student needs analysis and material analysis, conducted through a process of observation and interviews with students and lecturers. Based on observations and needs analysis interviews, it is found that lecturers have not optimised the use of technology in the learning process, teaching materials used in books and learning media that are often used in the form of power points. The results of interviews with students obtained data that students often use social media including YouTube, they often use YouTube but in the context of entertainment, not for learning. For some students, they prefer videos on YouTube because it is easier to understand the context because of the use of grammar that is easy to understand, but students tend to get bored if the video duration is too long. On the other hand, chemistry material requires the

right learning media that can help students understand complex chemistry material. The results of material analysis obtained data that green chemistry material is one of the materials that is difficult to understand. The analysed green chemistry material is in accordance with the semester learning plan. The challenge for lecturers is that each student has a varied learning style, so that learning media is needed that can accommodate. At this stage, an in-depth literature review is carried out related to the development of green chemistry videos, by collecting reading sources from books, journals, or prosding.

Design Stage

The second stage of design is carried out after collecting all the material, so that it can make the desired product design prototype. At this stage, the preparation of pretest and posttest question instruments, answer keys, scoring rubrics, questionnaires and validation sheets is also carried out. The design stage of the green chemistry learning video starts from making a train of thought so that the development process is easy. The following is a learning video thought flow chart in Figure 1.

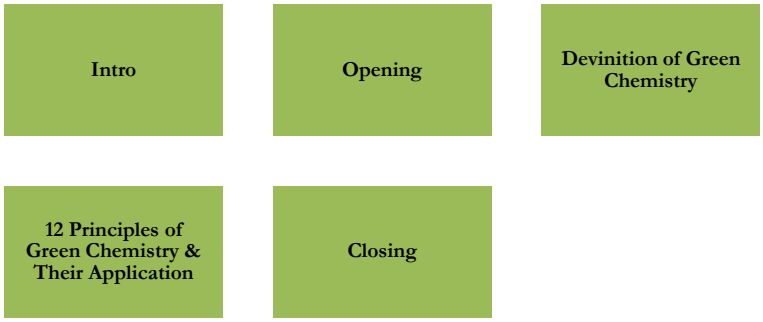

Image 1. Green Chemistry Learning Video Thought Process

Furthermore, making a storyboard is to make it easier to visualise ideas, and make it more orderly in the process of making learning videos. The next step is to create a script, the preparation of this script is to facilitate the video making process. Scipt is arranged using 2 columns containing scenes and scenarios. The following is an example of a script in a green chemistry interactive learning video can be seen in Table 4.

Table 4. Sample Script

Scene 1	Explanations related to the creation of the earth that is so beautiful with abundant natural resources, and the positive and negative impacts related to the development of development. One of them is waste, hence the need for green chemistry.
Scene 2	An explanation of green chemistry, and the benefits of green chemistry

The next step is to design the material and cover developed on the Canva platform which can be accessed at the following link https://www.canva.com. The design results can be seen in the following image:

Image 2. Design of Green Chemistry Materials Using Canva

Image 3. Green Chemistry Cover Using Canva

Development Stage

The development stage of green chemistry learning videos includes making videos and looking for suitable videos, looking for images that can help illustrations, editing through the CapCut application and then filling in the sound and adjusting to the predetermined video duration. The next step is to review the video from start to finish, if it is appropriate then proceed with the download process on the CupCut application. The last step is to upload the video to the YouTube platform and provide a brief video description related to the video content. The video results can be accessed through the following YouTube link: https://youtu.be/4VPz6vOpxag?si=lc6kYMyf9asLTUgA

Image 4. Display of Green Chemistry Interactive Video on YouTube Platform

- **Validation of Research Instruments**
  The research instruments have been validated by 2 material experts and media experts, namely chemistry education lecturers in University Musamus. The results of the validation of research instruments can be seen as follows:

Table 4. Validation Test Results

Validation Test	%	Category
Material Expert Validation	90	Very Valid
Media Expert Validation	88	Very Valid
Validation of the Lecturer Response Questionnaire instrument	88	Very Valid
Validation of Student Response Questionnaire	90	Very Valid
Instrument validation of Pretest-Posttest	92	Very Valid

The following are some of the suggestions and feedback from the validators. 1) Revision of the material validator, namely the need to add text at the beginning, not just sounds and images, 2) The media validator's revision is to provide additional illustrations such as videos that can help illustrate the meaning of what is discussed in the material. All revisions from the validators have been made, then the green chemistry interactive video learning media can be used at the implementation stage. Validity is an important requirement for the development of this green chemistry interactive learning video. Learning media that have been declared valid can be continued at the next stage. Learning videos can be used in the next step after the material validation test, media (Fadillah et al., 2022). This is in line with research Sumanik et al., (2021) that expert validation is needed to improve the developed product.

Implementation Stage

The implementation stage is the stage of testing learning media in the form of interactive green chemistry videos. At this stage, practicality tests were carried out through small group tests and large group tests.

- **Product Trial (Small Group Trial)**
  Product trials in small groups were conducted on 5 students. The results of the small group product trial can be seen in the following table:

Table 5. Small Group Trial Results

Assessment Aspect	%	Category
Ease of Use	95	Very Practical
Time efficiency	88	Very Practical
Usability	85	Very Practical
Attractiveness	88	Very Practical
Average	89	Very Practical

Practicality test data, namely green chemistry interactive learning video learning media, is very practical to use. This is in line with the research of (Sumanik & Natsir, 2024) which states that the practicality test is needed to find out the product is practical to use so that it can be continued with a large group trial. The results of the small group trial contained several revisions to improve the green chemistry video in accordance with the suggestions and input provided from the practitioner's response. The

improvements include adding a closing section with more examples of the application of green chemistry principles accompanied by illustrations in the form of pictures.

- **Field Trial (Large Group Trial)**
  The next step after the small group trial is the field trial on 20 students. This trial was conducted to confirm the data and know the product widely.

Table 6. Large Group Trial Results

Assessment Aspect	%	Category
Ease of Use	94	Very Practical
Time efficiency	80	Very Practical
Usability	88	Very Practical
Attractiveness	88	Very Practical
Average	90	Very Practical

The data from the large group trial results have an average of 90% in the very practical category, this shows that green chemistry learning video products are practical and easy to use by users. This is in line with Parera et al., (2022) research explaining that the large group test was conducted to determine the feasibility of the product on a larger scale.

- **Effectiveness Test**
  The effectiveness test was carried out on a large group of pretest with critical thinking questions, it aims to determine the initial ability of students. Next is the application of the learning process in the classroom using interactive learning videos of green chemistry. The learning process ended by giving posttest critical thinking questions to 20 students. The next step is to analyse the results of student pretests and posttests. The increase in student learning outcomes is calculated using the normalised gain (N-Gain) formula, the results of the N-gain calculation can be seen in the following table:

Table 7. N-gain Results

Effectiveness Test	Description	Category
N-Gain	0.77	High
% Effectiveness	77%	Effective

The N-gain result of 0.77 shows that the interactive video learning media of green chemistry has a high category. If the results are interpreted in % effectiveness of 77% with an effective category, it shows an increase in student learning outcomes after learning using interactive videos of green chemistry. Interactive learning videos on green chemistry materials are designed not only to present information, but also to stimulate students in critical thinking. Through the critical thinking questions given, students are encouraged to analyse information in depth by finding facts or evidence and analysing then drawing conclusions. Learning video media is suitable to be developed for teachers with innovations to make it more interesting during the teaching and learning process (Salutri et al., 2022).

Evaluation Stage

The last stage is the evaluation of interactive learning video products. After the product was tested in a large group, product revisions were made to improve the chemistry learning

video so that it could be used as a learning media that could also be used by all parties in need and could help the learning process. In the large group trial, some students gave suggestions to share to other social media such as tik tok, Instagram and Facebook.

Understanding concepts in chemistry is very important, so the video developed needs 21st century learning pedagogy and the suitability of the concept of (Pasha et al., 2024). The use of learning media is a good means of transferring knowledge because it is easy to understand. In line with this (Arham, 2020). Explaining that the use of YouTube as a means of learning media can increase knowledge, help get information, know world developments, deepen material studies and know technical matters. Therefore, efforts to create an attractive learning environment are one of them with the help of learning media

The advantages of using learning videos integrated on the YouTube platform are broad accessibility because the YouTube platform has many users, so that videos can be utilised and accessed by anyone in need, and can be accessed anywhere and anytime via smartphone, computer, leptop or tablet so that students can learn anytime and anywhere. On the other hand, the interactive feature provides interaction because students can provide responses, ask questions through the comments column, the like and dislike features can make feedback on video development and make evaluation material. The YouTube platform is also equipped with a subtitile feature so that students who have difficulty understanding spoken language can adjust.

YouTube's potential to reach a wider audience because the use of videos can be shared through various social media so that collaboration with learning communities can occur in a wider scope. Through proper optimisation, students who search for material in the search field can find it so that they can reach students independently. The attractive visualisation will arouse students' interest and enthusiasm for learning with high quality, informative and dancing videos with added sound effects or appropriate music will make the learning videos developed more lively and fun. The YouTube platform in developing learning media has the potential to be used in developing other learning materials, especially chemical materials that require visuals. Utilisation of the features on the platform makes learning more effective to improve the quality of learning and achieve good educational goals. The interactive video product developed can help students understand green chemistry material better so that it is declared to have a quality that is feasible to use as a chemistry learning media.

CONCLUSION

Interactive learning media becomes a bridge between students and lecturers in the transfer of knowledge in the learning process. The development of interactive learning videos on green chemistry material has been declared valid, practical and effective. The learning video has been validated by material experts and media experts. The applications used in developing learning videos in this study include Canva and CapCut. Furthermore, the video is published on YouTube, the selection of this platform is due to its easy access and the discussion feature facilitates interaction.

The things that need to be considered in making interactive videos are the need to compile material with language that is easy to understand, use images, animated videos that can help clarify concepts, can also add animation. Make the duration of the video into several parts

so as not to be boring, and need to consider the ability of students or students. Through interactive video products, elemental chemistry is proven to be effective in improving critical thinking, this is shown by the increase in the average score of students on the critical thinking test after participating in learning. besides that students give positive responses related to interactive videos because they are easy to understand and more interesting.

The suggestions given for further research are that interactive videos can be implemented more widely in schools or universities, especially in chemistry learning. Interactive videos can be developed by adding interactive features to increase student involvement. Interactive videos can be integrated in learning models such as problem-based learning, project-based learning, cooperative learning, inquiry-based learning.

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