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Development of Digital Comic Media on Atomic Structure Material for Grade X to Enhance Quality Education

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Abstract: This study aims to develop a digital comic as a learning medium for year 10 students on the topic of Atomic Structure, as a solution to the low interest and understanding among students regarding abstract chemistry concepts. The method used is Research and Development (R&D), based on a modified Borg and Gall model consisting of seven stages. The developed digital comic was validated by three experts-subject matter, media, and language-with validation scores of 92%, 87%, and 95% respectively, falling within the appropriate to highly appropriate category. Small-scale and large-scale trials were conducted with Year 10 students at SMA Taman Mulia, resulting in practicality scores of 74% and 84%, which indicate very positive responses to the media. The digital comic proved to be engaging, communicative, and effective in helping students understand the concept of atomic structure. Therefore, the digital comic is deemed suitable for use as an innovative alternative learning medium in chemistry lessons.

Keywords: Atomic structure; Development; Digital comic; Learning media

Introduction

Chemistry is one of the lessons that has its own characteristics and requires skills in solving chemical science problems in the form of theories, concepts, laws, and facts. One of the goals is for students to understand chemical concepts, as well as interrelated applications in solving problems of daily life and technology (Hapsari et al., 2014). Chemistry subjects are often considered difficult by students because of the understanding of basic chemical concepts that are abstract (Adu-Gyamfi et al., 2023; Nufus et al., 2023). One of the abstract chemistry subjects is atomic structure material. Atomic structure is class X material in the Merdeka Curriculum. Atomic Structure material has complex characteristics with quite a lot of concepts, requires memorising skills, and requires students' activeness to really understand the concepts (Melani, 2024). This is because Atomic Structure material is one of the prerequisite materials for understanding further material, namely chemical bonds, periodic systems, and properties of elements consisting of the concept of electron configuration, orbital filling, and the relationship between Atomic Structure and chemical properties of elements (Borotan, 2022). The lack of understanding of Atomic Structure material makes students experience difficulties such as atomic models, determining electron configurations, and relating Atomic Structure to the periodic system (Hendrawani et al., 2025). Students' difficulties in learning Atomic Structure are not caused merely by the need for rote memorisation, but rather by their limited ability to visualise microscopic concepts that cannot be directly observed. Within the context of the Merdeka Curriculum, chemistry learning emphasises the strengthening of conceptual understanding, scientific reasoning, and visual representation skills; therefore, memorisation-based learning approaches are considered less relevant and less effective.

Information obtained based on interviews with chemistry teachers on 24 September 2024 explained that it is difficult to visualise teaching materials due to limited equipment, materials and costs. The use of teaching materials at Taman Mulia High School uses package books, and Student Worksheets (LKS) and

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powerpoints. Observations in class XB SMA Taman Mulia showed that students were less focused on learning, some were busy playing with friends and some looked lethargic. Some students are also still focused and active when the teacher explains the material with the LKS. From the observation, students showed low response and interest in learning from the teaching materials used.

Based on the results of the students' questionnaire, 61.9% stated that the teaching materials used such as package books or worksheets have language that is difficult to understand. Learners also think that the chemistry book used has unattractive pictures and colours. The students' incomprehension and disinterest in chemistry books resulted in students being lazy and bored to read them. Students are also difficult to understand the material so that it affects their interest in learning. One solution that can overcome these problems is with interesting and innovative learning media.

Learning media is one of the supporting factors in learning activities because it functions as an intermediary to transfer knowledge to students (Kendek, 2023; Susilawati et al., 2025). Effective learning media is media that can stimulate the thoughts, feelings, attention and willingness of students so that it can encourage the learning process in learners (Fatiah, 2024; Susilawati et al., 2023). Interesting learning media in the learning process that can make students not feel bored during the learning process. One of the learning media that is interesting and in accordance with the character of generation Z learners.

Generation Z is a generation born and raised in the midst of technological advances so that students have distinctive characteristics that are able to adapt to various technological advances (Krisdiyansah et al., 2023). As it is known that high school students are included in the generation Z category so that they can utilise learning media effectively and actively use social media. Social media provides many opportunities for generation Z to connect to students who also tend to spend a lot of time in front of gadget screens (Pujiono, 2021). The presence of social media allows learners to get information and knowledge more quickly and accurately, even when compared to teachers who still use conventional methods (Krisdiyansah et al., 2023). Therefore, social media that can be utilised as learning media is digital comic media.

Digital comics is a story that is presented systematically and regularly with visualism or pictorial illustrations, making it easier for readers to follow and understand the contents of comics (Sugawara et al., 2014). Digital comics can create a more fun and interactive learning atmosphere. The advantages of digital comics are flexible, paperless because they are already in digital form and timeless because of the durability across time which may not be done by easily damaged paper. In addition, it can help students understand chemical concepts through the role of characters in the comic storyline, so that it can attract attention in science learning (Kanti et al., 2018) and is also very effective with a good category for improving (Dewantara, 2020). The use of digital comics is expected to provide a new atmosphere in the teaching and learning process and has great potential to facilitate students' understanding of the material presented because it presents information visually and interestingly.

Some previous studies that support comic media in chemistry subjects have proven valid and practical results. Research has used comic media on Hydrocarbon Compound material which shows material validation results of 100%, media validation of 92% (Pasaribu et al., 2024). Comics on Redox Reaction material with the results of practicality analysis in terms of teacher and student response questionnaires both obtained a percentage of 87.50% (Nurhafiza, 2017). In addition, the results of research from Fatiah (2024) also show that the validity of digital chemistry comics on Chemical Compound Name System material is 96.51% very valid, and the student response questionnaire is 98.27%.

Based on the facts above, the researcher will develop digital comic-based learning media on Atomic Structure material. Digital comics can make it easier for students to understand concepts through characters in the story so that they can attract attention in science learning. Therefore, researchers are interested in conducting a study entitled 'Development of Digital Comic Media on Atomic Structure Material for Class X at Taman Mulia High School.

Method

The research method used in this study is the research and development method (R&D). Product results. The stages of this comic research refer to the opinion of Sugiyono (2020), which was then modified based on guidelines from Borg and Gall to produce educational learning resources. Although the process in this method is relatively simple, it still requires precision. There are ten steps that must be passed in this process. An illustration of the stages of the development research is shown in Figure 1.

Adapted from research (Nurhafiza, 2017) which carries out Borg and Gall research steps with seven research steps, namely: (1) Research and data collection, (2) Planning, (3) Product draft development, (4) Initial field trial, (5) Revising the results of the initial field trial, (6) Main field trial, and (7) Refinement.

Figure 1. Stage of the Borg and Gall method (Nurhafiza, 2017)

In the early stages of this research, researchers conducted a needs analysis, literature review, and problem identification to formulate the basis for developing new learning media. The needs analysis shows that the Atomic Structure material in the Independent Curriculum Chemistry LKS is still abstract and requires independent learning tools to improve student learning outcomes. The literature review reinforces the importance of comic media as a learning tool that can increase reading interest, enrich vocabulary, and facilitate understanding of abstract concepts. Problem identification at Taman Mulia High School shows that chemistry learning still feels monotonous due to limited media and lack of student motivation, so innovation is needed in the form of learning media that is more interesting and interactive (Borotan, 2022).

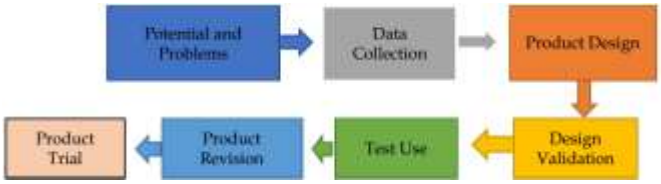

Figure 2. Seven stage of the Borg and Gall method (Nurhafiza, 2017)

The planning stage of comic development on Atomic Structure material, starting from collecting books related to Atomic Structure material to be developed, selecting the right design, writing interesting comic strips to preparing materials as comic evaluation. The development stage of the initial draft of the product begins with the preparation of comics on Atomic Structure material and research instruments, then validated by three media, language, and material experts to assess the validity of the product. The formula for calculating the average score.

$$p\frac{f}{N}x100\% \quad (1)$$

Description:
P = Percentage number and questionnaire
f = Number of scores obtained
N = Maximum number of score (Widoyoko, 2014)

The results of the percentage of media validation can be grouped in the score interpretation criteria according to the Likert scale so that conclusions will be obtained about the feasibility of the media, the score feasibility interpretation criteria can be seen in table 1 below (Sugiyono, 2020).

Table 1. Interpretation of Feasibility

Value (%)	Criteria
80 < - ≤ 100	Very Appropriate
60 < - ≤ 80	Appropriate
40 < - ≤ 60	Moderately Appropriate
20 < - ≤ 40	Inappropriate
0 ≤ - ≤ 20	Very Inappropriate

The validation results are used as the basis for revision, especially if the content validity value is ≤ 0.60 or the student response in the initial trial is < 60 (Alfiyani, 2015). In addition, teacher and student response questionnaires were also validated to assess the practicality of the comic media developed. After the comic product was developed, an initial field trial was conducted to measure its practicality involving 10 grade X students. Data were collected through questionnaires distributed after the trial, to assess students' responses to the use of the media. Recapitulating student assessment data based on scoring guidelines in table 2 (Fatiah, 2024).

Table 2. Questionnaire Score

Answer options	Statement
Strongly Agree	4
Agree	3
Disagree	2
Strongly Disagree	1

Calculating the percentage of questionnaire responses with the equation (Fatiah, 2024).

$$p = \frac{maximum\ number}{maximum\ score} x\ 100\% \quad (2)$$

Matching the response assessment with the results of the average total score given with the criteria in table 3 (Fatiah, 2024):

Table 3. Student and Teacher Response Criteria

Value	Criteria
80% < - ≤ 100%	Very Feasible
60% < - ≤ 80%	Feasible
40%< - ≤ 60%	Fairly Feasible
20% < - ≤ 40%	Inappropriate
0%≤ - ≤ 20%	Very Inappropriate

The main product revision was carried out based on the results of the first stage product trial. The developer revised the comic, according to the shortcomings and

errors after validation and field trials. By analyzing the shortcomings encountered based on validation and during the product trial. This field trial was carried out in the even semester of the 2024/2025 school year, at SMA Taman Mulia in class X with 19 students. To test the practicality of comic media, at this stage the teacher was given a teacher response questionnaire when conducting the trial and all students who became research samples were given a student response questionnaire after completing the trial. Product revision is always carried out after the product is applied or trialled. This is done especially if there are new obstacles that have not been thought of at the time of design. Feedback and suggestions in the main field trial can be taken into consideration in revising comic products. Comic media needs to be revised when the response value from teachers and students is less than 60. The practicality of the applied media must get at least good criteria with a value range of 60-80 (Faroh et al., 2014).

Result and Discussion

The results of this study are in the form of Digital Comic Learning Media on Atomic Structure material for class X Chemistry subjects that can be accessed via Smartphone and computer. This comic can be accessed with an internet connection (online) and without using the internet (offline). Offline comics are in file format.

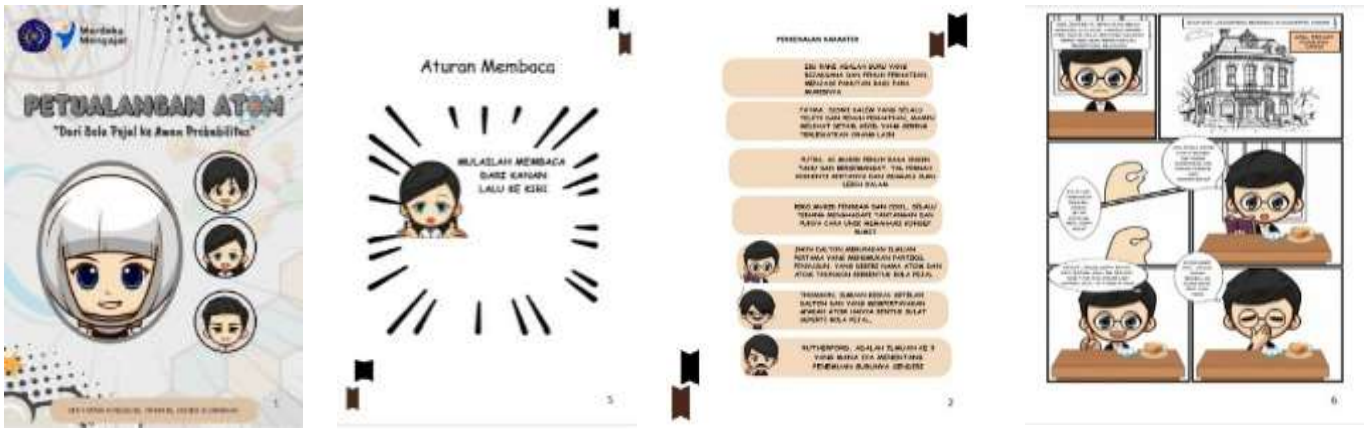

Figure 3. Comic visuals

To determine the feasibility of the developed media, validation is carried out by people who are experts in their fields. The results of this validation create an assessment in the form of comments and suggestions related to the media to be produced and can help in media improvement. The results of the assessment by severe experts can be seen in table 4.

Table 4. Expert Assessment Results

Expert	Percentage (%)	Criteria
Language	95	Highly Feasible
Media	87	Highly Feasible
Material	92	Highly Feasible

Validation of digital comic media products was carried out by three experts, namely linguists, media experts, and material experts to determine the feasibility of comics as learning media. validation from linguists obtained a percentage of 95% with very feasible criteria. The language used in the dialogue and narration in the comics is considered in accordance with the cognitive ability level of high school students. The sentence structure and selection of terms have fulfilled the rules of good and correct Indonesian language and are able to convey information communicatively. Comics are considered to encourage students to think critically through the delivery of dialogical and contextual material according to students' daily lives.

Validation from media experts showed a percentage of 87%, included in the highly feasible criteria. Visual aspects of comics such as character design, colouring, illustrations, and page layout are arranged in an attractive and interactive manner. Comics are prepared by considering visual comfort and aesthetics so as to increase students' interest in reading. The arrangement of comic parts such as cover, table of contents, glossary, and instructions for use have also fulfilled the criteria for complete learning media. Thus, the overall validation results show that this digital comic media is suitable for use in learning atomic structure in class X SMA.

The results of validation by material experts obtained a percentage of 92% with very feasible criteria. This assessment shows that the content of the material in the comic has met the eligibility criteria, including the accuracy of the concept, relevance to the curriculum, and usefulness in strengthening understanding of the concept of atomic structure. The material expert also

said that the presentation of information through the storyline and characters in the comic was able to describe the process of concept formation well and attract students' interest in learning.

Table 5. Product Trial

Trial	Percentagee (%)	Criteria
Small Scale	74	Feasible
Large Scale	84	Very Feasible

Students' responses to digital comic media were obtained through two stages of trials, namely small-scale trials and large-scale trials, which were carried out after the media were validated by material experts, linguists, and media experts. The purpose of this trial was to assess the practicality and effectiveness of digital comics as chemistry learning media, especially on atomic structure material.

Some aspects that were analysed at both stages of the trial included the suitability of the material content, language clarity, the benefits of the media for understanding concepts, as well as the visual quality and presentation of information in comics. In the small-scale trial, 7 grade X students were involved to provide an initial assessment of the practicality of the product. The results of this stage showed that the comic obtained a score of 74%, which was included in the feasible category. Meanwhile, the large-scale trial involved 15 grade X students and aimed to assess the effectiveness of the media on a wider range of users. At this stage, the media scored 84%, which is included in the feasible category.

These results indicate that the digital comic media developed can be well received by students and can be used as an alternative learning media that is interesting and effective. The difference in scores between the small and large scale trials indicates the variability in students' preferences and experiences of the media, which is an important input for revision and improvement of the product before it is implemented more widely.

Conclusion

The development of digital comic media on class X Atomic Structure material was carried out as a solution to the problem of low interest and understanding of students of abstract chemical material. Based on the results of validation by experts, digital comics are declared very feasible to use as learning media, with a percentage of validity of 95% (linguists), 92% (material experts), and 87% (media experts) respectively. The results of small and large scale trials also showed a positive response from students with a percentage of 74% (very feasible) and 84% (feasible). Digital comics are proven to be able to attract students' attention, present information in an interesting visual way, and help in understanding chemical concepts more effectively. Therefore, this digital comic media has great potential to be used as an innovative learning alternative in chemistry materials in high school.

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The authors declare no conflict of interest.

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