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# Development of Digital Atlas with Multiple Intelligences on the Materials of Cell Structure and Function to Improve Cognitive Thinking Ability of Senior High School Students

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## Abstract

Cell Structure and Function is one of the biology topics in senior high schools that needs to be concretized, as students cannot directly observe cellular structures and organelles without supporting tools. Learning this material requires observation of illustrations, logical reasoning, collaboration, and independent study. Relying solely on textbooks as the main learning source is considered less effective in mastering the concepts, which results in students' incomplete cognitive understanding. Therefore, an additional teaching supplement that visualizes the material while accommodating students' learning styles is necessary. This study aims to describe the characteristics of the developed atlas, analyze its validity, examine teachers' and students' responses, and evaluate the effectiveness of the atlas in improving students' cognitive abilities. This research employed a Research and Development (R&D) design with eight stages: identifying potentials and problems, data collection, product design, expert validation, design revision, product trial, product revision, and usage trial. The subjects were XI MIPA A and XI MIPA E students at SMA N 1 Batang in the 2021/2022 academic year. Research instruments included interview sheets, validity sheets, teacher and student response questionnaires, and a 25-item multiple-choice test. Data were analyzed using descriptive quantitative percentages. The results showed that the developed atlas presented schematic illustrations and varied microscopic observations, linked cellular phenomena, encouraged logical reasoning through "let's reason" prompts, facilitated discussions, and supported independent learning via YouTube videos. The validity test obtained a score of 96.6% (very good) from material experts and 87.5% (very good) from media experts. Teachers' and students' responses reached 90.7% and 91.2%, respectively, both categorized as very good. Effectiveness testing indicated improvements in cognitive thinking skills with the following N-Gain scores: remembering (C1) = 0.93 (high), understanding (C2) = 0.80 (high), applying (C3) = 0.76 (high), analyzing (C4) = 0.57 (moderate), and evaluating (C5) = 0.71 (high). Based on these results, the digital atlas incorporating multiple intelligences is proven effective in enhancing students' cognitive thinking skills.



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## INTRODUCTION

The use of textbooks in teaching Biology, particularly the topic of Cell Structure and Function in senior high schools, has not been able to thoroughly explain the essential aspects of the material. This is because cellular structures and functions cannot be directly observed with the naked eye without the aid of supporting tools; therefore, the material must be concretized. This aligns with Setiawati (2018), who stated that students often perceive cell biology as a difficult subject because it presents numerous cellular anatomical details that cannot be observed directly. The basic competency (KD 3.1) to be achieved by students in this material requires them to explain the structure and function of cellular organelles. To make these concepts easier to understand, teachers must employ media that can effectively visualize them.

In the context of teaching, media can be interpreted as the teacher's dialect, both verbal and non-verbal (Munadi, 2013; Setiawati, 2018). One type of media capable of presenting a wide range of visual information is the biological atlas. A biological atlas serves as supplementary teaching material containing images, explanations, and descriptions designed around a specific learning theme. Such an atlas can be produced either in printed form or electronically/digitally. According to Wulansari et al. (2015), the advantages of using an atlas in learning include: (1) assisting students in understanding the material without direct observation, (2) increasing student enthusiasm for learning activities, (3) stimulating curiosity about the subject matter, (4) helping overcome the limitations of laboratory facilities and equipment, (5) being practical, easy to develop, and flexible, and (6) aligning with learning objectives.

Learning Cell Structure and Function can also be integrated with the concept of Multiple Intelligences, particularly four types: visual–spatial, logical–mathematical, interpersonal, and intrapersonal intelligences. Multiple Intelligences refer to the various inherent intelligences possessed by individuals, enabling educators to identify students' potential strengths (Ahsan et al., 2015). According to Yaumi and Ibrahim (2013) and Fikriyah & Aziz (2018), visual–spatial intelligence is the ability to understand images and shapes, including interpreting spatial dimensions not directly visible. Logical–mathematical intelligence, often referred to as numerical insight, also encompasses scientific reasoning and critical thinking. Interpersonal intelligence refers to learning through collaboration and discussion with peers (Fikriyah & Aziz, 2018). Meanwhile, intrapersonal intelligence relates to self-focus, self-regulation, intrinsic motivation, and perseverance in achieving goals (Wilson, 2018). Students engaged in learning activities based on multiple intelligences tend to have stronger awareness and higher motivation in their learning environment (Syafra et al., 2018).

The appropriate selection of instructional media, combined with the concept of multiple intelligences, will facilitate students' mastery of material concepts through the development of their cognitive abilities. Anderson (2002, in Nabilah et al., 2020) stated that cognitive ability refers to students' mastery within the cognitive domain. This domain covers intellectual aspects such as knowledge and thinking skills, which are categorized into lower-order thinking skills (LOTS)—remembering (C1), understanding (C2), and applying (C3)—and higher-order thinking skills (HOTS), which include analyzing (C4), evaluating (C5), and creating (C6), based on the revised Bloom's taxonomy.

Observations and interviews with teachers and students at SMA N 1 Batang revealed that students experience difficulties in understanding the topic of Cell Structure and Function. The learning resources used in this school were still limited to textbooks and PowerPoint slides, without any supplementary

teaching materials for this subject. Consequently, students were inclined to rely solely on reading and memorizing textbook content without engaging in deeper conceptual analysis. However, in terms of learning facilities, students at SMA N 1 Batang are allowed to use smartphones to browse learning materials.

Based on these findings, there is a need to develop supplementary teaching material in the form of a digital atlas that incorporates multiple intelligences (visual, logical, interpersonal, and intrapersonal). Such a digital atlas would serve as a learning supplement that combines essential concepts with accessible and clear visualizations of cellular structures.

## RESEARCH METHOD

This type of research is research and development (R&D) by producing a teaching supplement product in the form of a digital atlas containing multiple intelligences on the material of Cell Structure and Function. The research steps are: (1) Potential and Problems, (2) Data Collection, (3) Product Design, (4) Design Validation, (5) Design Revision, (6) Product Trial (small scale), ( 7) Product Revision, and (8) Usage Trial (wide scale). Atlas product design using Microsoft Office Word 2010 and Canva. Atlas validation was carried out by material experts and media experts at Semarang State University. The small-scale and large-scale tests were carried out at SMA N 1 Batang. The small-scale test sample consisted of 20 students from class XI Mipa A and XI Mipa E and a biology teacher to be asked for comments regarding the developed atlas, while the large-scale test sample consisted of 70 students consisting of 36 students from class XI Mipa A and 34 students from class XI Mipa E to answer the test questions of 25 questions with a research design using One Group Pre-test and Post-test Design. The purpose of the large-scale test is to determine the effectiveness of using atlas in improving students' cognitive abilities. The sampling technique in this study used a simple random sampling technique. The research instruments used were interview sheets, validity sheets, teacher and student response questionnaire sheets, and 25 multiple choice test questions that were valid and reliable. Data analysis in this research is descriptive quantitative percentage. The steps for using the atlas in learning are presented in Chart 1.

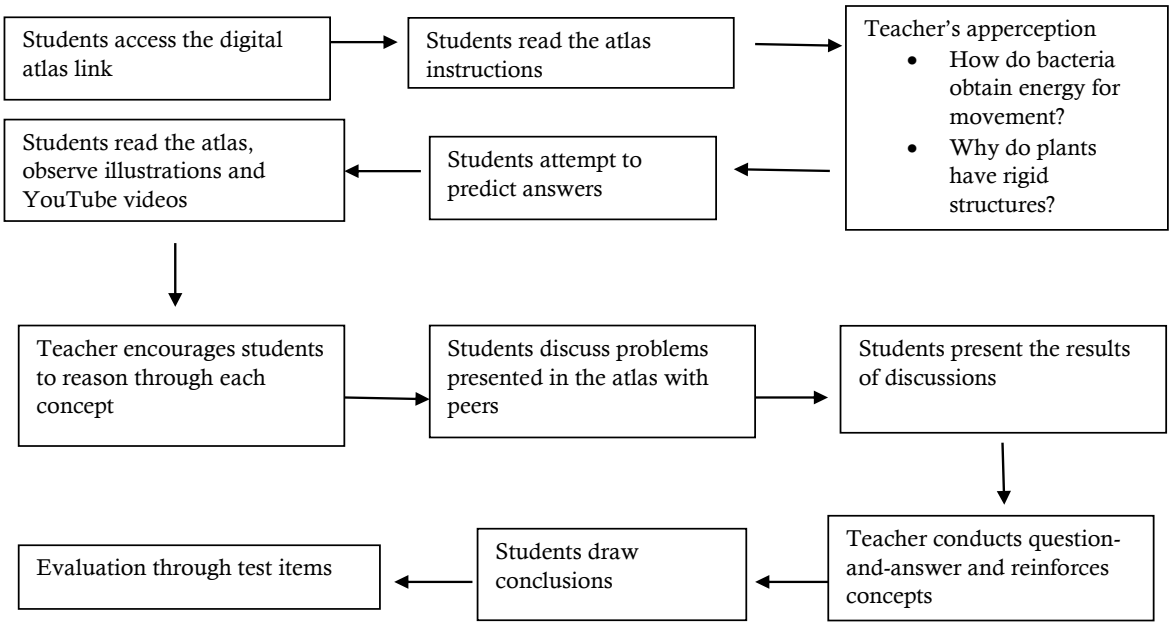


**Chart 1.** Steps of digital atlas implementation in learning.

## RESULTS AND DISCUSSION

### Characteristics Digital Atlas of Development Results

In general, the digital atlas consists of a cover, introduction, table of contents, instructions for using the atlas, contents, evaluation page, and bibliography. The main characteristics of the digital atlas containing multiple intelligences that have been developed include: 1) having clear and more varied images when compared to images in textbooks with proportional image sizes, 2) presenting examples of microscopic images of direct observation, 3) presenting material that discusses phenomena related to the shape of cells that are connected with causation, 4) have material information that explains causal relationships through logical invitations, 5) there are invitations to discuss to discuss a problem, and 6) have independent study instructions via youtube links/addresses and evaluation via gform . These six characters are a form of applying the concept of learning with multiple intelligences in visual, logical, interpersonal and intrapersonal types. This character atlas has been validated by media experts and material experts on the validation instrument in the aspects or indicators of the atlas character with 23 points from a maximum of 24 points or 95.8%. The results of the validation of the characteristics of the atlas are presented in **Table 1**.

**Table 1.** Characteristics of the Atlas Result of Development of

| Indicators | Assessment | |
|---|---|---|
| | Material Experts | Media Experts |
| ● Clear and varied images differ from the text books used as teaching materials, making it easier to understand the material. | 4 | 4 |
| ● The linkage of examples of images from direct observations that are in accordance with the material discussed. * | 4 | - |
| ● Image proportional as needed is not too small. ** | - | 4 |
| ● Has explanatory information relating causal phenomena related to the characteristics and functions of a cell organelle. | 3 | 3 |
| ● Atlas develops students' academic skills by thinking logically on each material concept through an invitation to let's be logical. | 4 | 4 |
| ● Atlas provides a web address/link for self-study through relevant YouTube animated videos to clarify the material and evaluation materials through a gform at the end of the page. | 4 | 4 |
| ● Atlas develops emotional skills in group learning through an invitation to discuss with discussion materials that are relevant to the material. | 4 | 4 |
| Score | 23 | 23 |

*Indicators are intended for material experts only.
**Indicators are intended for media experts only.

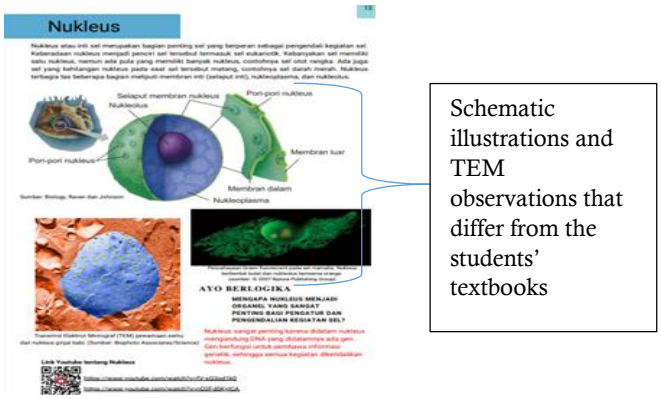


Figure 1.

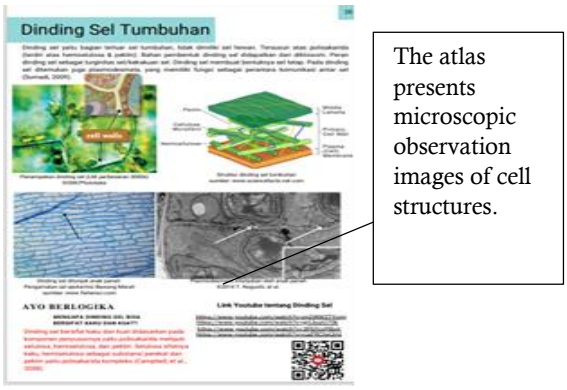


Figure 2.

Figure 1. Atlas with varied and proportional images

Figure 2 The atlas presents examples of direct observation images with a microscope.

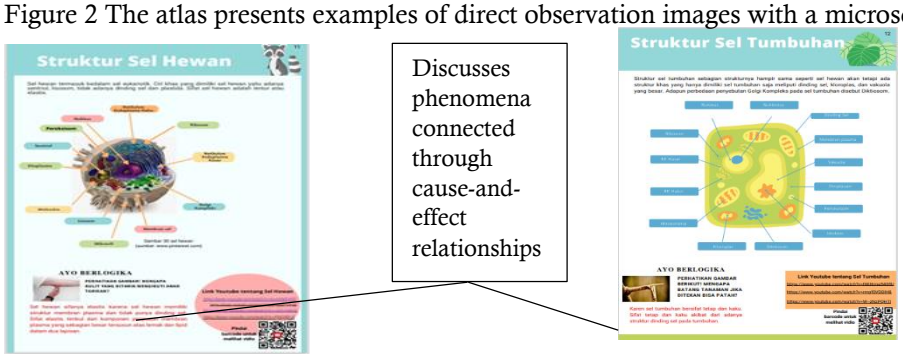

Figure 3. Atlas presents material phenomena related to cell shape which are related to cause and effect .

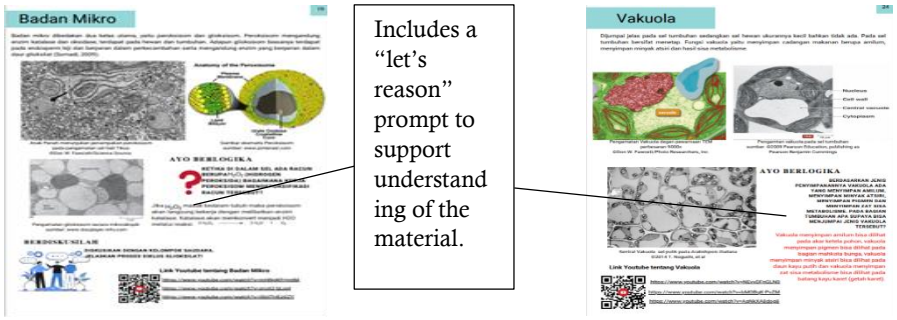


Figure 4. Atlas presents material related to cause and effect through an invitation to let's be logical.

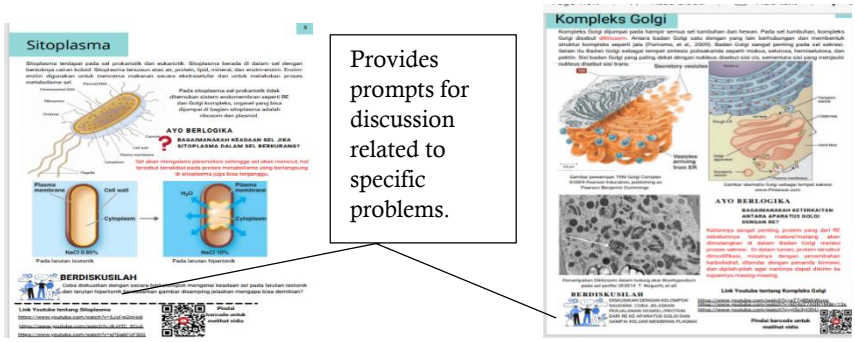


Figure 5. Atlas presents an invitation to discuss related problems.

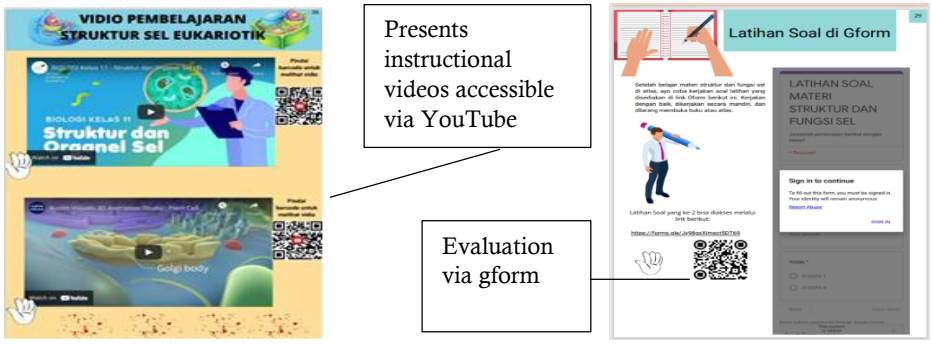


Figure 6. Atlas presents a video from the youtube link and evaluation via gform link.

**Material Validation Digital Atlas with Multiple Intelligences**

The purpose of material validation was to assess the accuracy, scope, and clarity of the content presented, as well as its ability to stimulate students' curiosity. Validation was conducted by a cell biology expert and assessed based on content feasibility and atlas characteristics. The results of material validation are presented in **Table 2**.

**Table 2**. Atlas Validation Results by Material Experts

| Assessed Aspects | Number of Items | Score max. | Score | Percentage (%) |
|---|---|---|---|---|
| Eligibility Content coverage | | 36 | 35 | 97.2 |
| material accuracy | 3 | | | |
| material clarity | 2 | | | |
| stimulates student curiosity | 2 | | | |
| | 2 | | | |
| Character Atlas | 6 | 24 | 23 | 95.8 |
| Total | 15 | 60 | 58 | 96.6 |

The results showed a total score of 58 out of 60 (96.6%), categorized as "very good." The content covered the curriculum competencies (KD), learning objectives, and depth of the subject matter, while maintaining conceptual accuracy and relevance of phenomena. Furthermore, the sequence of material combined with clear illustrations encouraged curiosity and deeper exploration.

In terms of the character aspect of the atlas, material experts agree that this atlas has a strong character in different images from textbooks as well as strengthening concepts through multiple intelligences. The concept of learning by involving multiple intelligences makes it easier for students to master the material according to the type of learning. Overall on material validation, the atlas is in the very valid category or very feasible to be used as a teaching supplement. The feasibility of the material presented will encourage students to understand more deeply. This is in accordance with the opinion of Rahmawati & Lisdiana (2021) which states that the presentation of a material in an atlas can arouse students' curiosity and encourage students to study and seek other information thoroughly.

**Media Validation Digital Atlas with Multiple Intelligences**

Media validation aimed to evaluate the design and presentation of the atlas. Three components were assessed: language, presentation, and atlas characteristics. The results of media validation by experts are presented in **Table 3**.

**Table 3**. Atlas Validation Results by Media Experts

| Assessed Aspects | Number of Items | Score max. | Score | Percentage (%) |
|---|---|---|---|---|
| Language Component | 5 | 20 | 13 | 65 |
| Presentation Component | 9 | 36 | 34 | 94.4 |
| Character Atlas | 6 | 24 | 23 | 95.8 |
| Total | 20 | 80 | 70 | 87.5 |

Based on Table 3, it can be seen that the total assessment score obtained was 70, or 87.5% in percentage terms. This total score falls into the "very good" category. In the language component, several indicators were evaluated by the media expert. These indicators included the appropriateness of the language with students' level of thinking, the suitability of the language with students' emotional development, the logical and communicative use of language, the use of language that encourages learning motivation, and the accuracy of Indonesian grammar. Septiana et al., (2020) stated that the linguistic aspect of an instructional medium is one of the essential elements to be considered, as it serves as a supporting factor in students' comprehension.

Of the five indicators, three received appropriate assessments, while two were rated less satisfactory. These two were the use of language to encourage learning motivation and the accuracy of Indonesian grammar. According to expert feedback, the motivational aspect was not fully achieved because inconsistencies in wording within the atlas disrupted comprehension of the material. In addition, the accuracy of Indonesian grammar was also not fully met, as many images contained captions in foreign languages. Nevertheless, the use of foreign-language captions could still be tolerated, since the images were different from those typically presented in textbooks frequently used by teachers.

The presentation component received a "very good" rating. This component was divided into two aspects: display quality (6 indicators) and the practicality of using the atlas (3 indicators). The quality of the

atlas display was rated highly appropriate because the atlas had an attractive design, well-placed images, clear illustrations, harmonious backgrounds, and appropriate font styles and sizes. Likewise, in terms of practicality, two indicators were rated "very good," namely the completeness of the usage instructions and the presentation format of the atlas, which was available both online via links and offline in PDF format. However, one indicator was rated less satisfactory, namely the use of the atlas in all conditions of time and place. This was because the atlas was presented in digital format and required internet access; however, when these conditions were met in the research setting, the atlas could be effectively applied.

**Teacher and Student Responses to the Use of the Atlas**

**1. Teacher's Response**

The biology teacher at SMA N 1 Batang assessed the feasibility of the atlas across four aspects: basic competencies and learning objectives, practicality, effectiveness, and appearance. The overall score was **90.7%**, categorized as "very good." The teacher confirmed that the atlas was practical, effective, and visually appealing, and that it supported logical reasoning and collaborative learning. The results of the teacher's responses regarding the feasibility of the atlas are presented in **Table 4**.

**Table 4**. Recapitulation of the Results of Biology Teachers' Responses

| Assessed Aspects | Number of Items | Score max. | Score | Percentage |
|---|---|---|---|---|
| KD and Learning Objectives | 2 | 10 | 8 | 80 |
| Practicality | 5 | 25 | 23 | 92 |
| Effectiveness | 3 | 15 | 14 | 93.3 |
| Display | 5 | 25 | 23 | 92 |
| Total | 15 | 75 | 68 | 90.7 |

In the aspect of basic competencies (KD) and learning objectives, the teacher responded positively, agreeing that the atlas had already presented relevant competencies and objectives. In terms of practicality, the teacher gave a very good response, agreeing with the clarity of atlas usage, its format, the organization of the material, and the ease of use of the atlas within the learning environment. Furthermore, regarding effectiveness, the teacher agreed that the use of the atlas could help students master the subject concepts by engaging in logical reasoning and discussion activities. The teacher also provided a positive response to the presentation aspect, noting that the atlas displayed clear images that differed from those in textbooks, accompanied by an attractive design.

**2. Students' Response**

Student responses were obtained from a checklist questionnaire after the small-scale trial involving 20 students. All students rated the atlas as "very good," with an average score of **91.2%**. Student responses to small-scale trials are presented in **Table 5**.

**Table 5**. Recapitulation of Student Responses to Small-Scale Trials

| No. | Criteria | Number of Students |
|---|---|---|
| 1. | Very Good | 20 |
| 2. | Good | 0 |
| 3. | Fair | 0 |
| 4. | Less | 0 |
| 5. | Poor | 0 |
| | Total Number of Students | 20 |
| | Average Score (max score 75) | 68.4 |
| | Percentage (%) Average Score | 91 ,2% |
| | Criteria | (applicable) |

Based on Table 5, it can be seen that all students provided assessments in the "very good" category. The average score given by all students was 68.4, or 91.2% of the maximum score. These results indicate that the atlas received a positive response in the limited trial. The checklist questionnaire consisted of three assessment aspects with a total of 15 items. The aspects assessed included: the practicality of the atlas, the ease of concept mastery, and the presentation aspect. The recap of student responses for each aspect is presented in **Table 6**.

**Table 6**. The results of the recapitulation of student responses on each aspect

| No. | Aspect | Percentage (%) | Criteria |
|---|---|---|---|
| 1. | Practicality | 93.6 | Very Good |
| 2. | Easy Concept Mastery | 90.5 | Very Good |
| 3. | Presentation | 91.3 | Very Good |

Based on Table 6, student responses for each aspect were categorized as "very good." The practicality aspect obtained a percentage of 93.6%, indicating that the atlas was easy for students to use in learning the topic of Cell Structure and Function. In the aspect of ease of concept mastery, students also gave a very good response with a percentage of 90.5%. This ease of concept mastery was reflected in students' agreement that the atlas helped them to remember, understand, apply, analyze, and conclude the essential concepts of the material. Furthermore, in the presentation aspect, the atlas received a percentage of 91.3%, also categorized as very good. Students gave positive responses regarding the design and appearance of the atlas, noting that it contained clear and proportional images, language appropriate to their level of thinking, harmonious selection of colors and fonts, and a well-structured presentation of the material that encouraged their motivation to learn.

**Analysis of the Effectiveness of the Digital Atlas with Multiple Intelligences**

The determination of the effectiveness of the atlas is based on the results of a wide-scale test on the use of the product, namely by looking at the increase in students' cognitive abilities. In the test of using this product, it involved a total sample of 70 students. The increase in cognitive ability was measured based on the results of the pretest and posttest on each indicator C1, C2, C3, C4, and C5 which was then measured the value of N-Gain. The results of the average achievement of indicators of cognitive ability and the results of N-Gain are presented in **Table 7**.

**Table 7**. Average Results of Achievement of Indicators and N-Gain

| No. | Cognitive Indicator | Ability | | Average | Achievement | | | N-Gain |
|---|---|---|---|---|---|---|---|---|
| | | Pretest | Max. | % | Posttest | Max score. | % | |
| 1. | Remembering (C1) | 3.88 | 5 | 77.6 | 4.92 | 5 | 98.4 | 0.93 |
| 2. | Understanding (C2) | 3.34 | 5 | 66.8 | 4.67 | 5 | 93.4 | 0.80 |
| 3. | Applying (C3) | 2.27 | 5 | 45.4 | 4.34 | 5 | 86.8 | 0.76 |
| 4. | Analyzing (C4) | 2.0 | 5 | 40 | 3.72 | 5 | 74.4 | 0.57 |
| 5. | Evaluating (C5) | 1.25 | 5 | 25 | 3.90 | 5 | 78 | 0.71 |

Based on Table 7, it can be observed that the average percentage of correctly answered questions for each cognitive skill indicator increased. The increase in the percentage of indicator achievement from pretest to posttest, ranked from the highest to the lowest, was as follows: (1) evaluating skills (C5), which increased by 53%; (2) applying skills (C3), which increased by 41.4%; (3) analyzing skills (C4), which increased by 34.4%; (4) understanding skills (C2), which increased by 26.6%; and (5) remembering skills (C1), which increased by 20.8%. It is evident that understanding (C2) and remembering (C1) were the lowest, indicating that prior to the use of the digital atlas in the research class, students' cognitive knowledge of Cell Structure and Function concepts was still limited to remembering and understanding, which belong to the category of Lower-Order Thinking Skills (LOTS).

The effectiveness of the atlas can also be measured by the N-Gain values of the average achievement of each cognitive thinking indicator. For the remembering indicator (C1), the N-Gain was 0.93 (high), meaning that the atlas helped students recall material, such as explaining the characteristics of prokaryotic and eukaryotic cells, identifying cell structures, and naming the functions of organelles. For understanding (C2), the N-Gain was 0.80 (high), indicating that the atlas improved students' ability to differentiate between cell structures, comprehend the functions of organelles, and categorize cell types based on their structures and organelles. For applying (C3), the N-Gain was 0.76 (high), showing that the atlas helped students apply theories of structure and function to real-life phenomena.

For analyzing (C4), the N-Gain was 0.57 (moderate), suggesting that students' ability to analyze the material did not increase significantly. Some students still experienced difficulty analyzing cause-and-effect relationships related to organelle functions, explaining the function of organelles, and connecting relationships among organelles. Such difficulties in analysis are closely related to logical reasoning skills needed to formulate answers, which require repeated practice. This is consistent with Saptono et al. (2013), who stated that analytical thinking (C4) is a higher-order cognitive skill characterized by the ability to connect concepts and provide arguments, a skill that can be trained through relevant learning programs.

For evaluating (C5), the N-Gain was 0.71 (high), meaning that the atlas enhanced students' ability to assess whether a statement was consistent with cell biology concepts or not, while also encouraging them to draw conclusions from those concepts.

The high N-Gain values demonstrate the effectiveness of the atlas as a supplementary teaching material in the sample classes. This finding is in line with Iswanti (2019), who stated that the use of atlas media in learning can improve detailed conceptual understanding through comprehensive visual

representation of the material. Overall, the cognitive test results indicate that the atlas was effective in enhancing students' cognitive thinking skills

## CONCLUSION

Based on the results of the study, it can be concluded that the digital atlas incorporating multiple intelligences is characterized primarily by its use of more varied illustrations, integrated with visual, logical, interpersonal, and intrapersonal learning types. The atlas was also validated as highly appropriate in terms of both content and media, which was further supported by the positive responses from teachers and students. Therefore, the digital atlas supplement incorporating multiple intelligences is considered suitable as a learning resource for the topic of Cell Structure and Function, as evidenced by the improvement in students' cognitive abilities.

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