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NanoMaja: A Hands-on Educational Program to Enhance Nanotechnology Understanding among High School Students at SMA Gotong Royong Kota Bangun

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A B S T R A K

Nanotechnology has become a vital field in modern science and technology; however, its integration into secondary education remains limited, leading to low student understanding of nanoscale concepts. Therefore, this study aims to evaluate the effectiveness of the NanoMaja Educational Program in improving students' understanding of nanotechnology. This study employed a descriptive quantitative approach using a one-group pretest–posttest design. The program was conducted at SMA Gotong Royong, Kutai Kartanegara, involving 85 students from grades 10–12. The intervention consisted of two sessions: interactive learning on nanotechnology concepts using visual and contextual approaches, and a hands-on experiment involving simple green synthesis of nanomaterials. Data were collected through multiple-choice pretest and post-test instruments and analyzed using mean score comparison and normalized gain (N-gain). The results showed a significant improvement in students' understanding, with the average score increasing from 48.2 to 82.6, and an N-gain value of 0.66, categorized as moderate to high. This improvement indicates that interactive, contextual, and experiment-based learning effectively enhances conceptual understanding and student engagement. In conclusion, the NanoMaja program is effective in introducing nanotechnology at the secondary school level. Future studies are recommended to involve larger samples, control groups, and long-term assessments to strengthen the findings

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INTRODUCTION

The rapid advancement of science and technology has significantly influenced various aspects of human life, particularly through the emergence of nanoscience and nanotechnology. Nanotechnology, which involves the manipulation of materials at the nanoscale (1–100 nm), has become a key area of innovation in fields such as medicine, energy, materials science, and environmental applications. Its interdisciplinary nature integrates principles from physics, chemistry, biology, and engineering, making it highly relevant to contemporary scientific and technological development (Yıldız, 2024; Yıldız & Karataş, 2017).

Due to its wide-ranging applications, nanotechnology has been recognized as an important component of science education. Introducing nanotechnology concepts can enhance students' scientific literacy by helping them understand fundamental ideas such as size and scale, structure–property relationships, and the interaction between science and society (Stavrou et al., 2015). Furthermore, early exposure to nanotechnology can foster students' curiosity and improve their ability to think critically and solve problems, which are essential skills in science learning (Spyrtou et al., 2021).

However, nanotechnology is still not widely integrated into secondary school curricula. Many students have limited opportunities to learn about nanoscale phenomena in a structured and meaningful way. As a result, their understanding of modern scientific developments remains incomplete (Mallmann, 2008). This condition highlights the need for innovative educational approaches that can introduce nanotechnology concepts in a simple, engaging, and contextually relevant manner.

Previous studies have shown that interactive and inquiry-based learning strategies are effective in improving students' understanding of complex scientific concepts, including nanotechnology. Learning activities that involve real-life applications, visual representations, and simple experiments can help students grasp abstract nanoscale concepts more easily (ACS, 2019). Such approaches also increase student engagement and motivation during the learning process.

In response to these challenges, the NanoMaja educational program was developed as a community-based initiative to introduce nanotechnology concepts to high school students. The program emphasizes contextual learning, interactive explanations, and simple demonstrations to make abstract concepts more accessible. Through this approach, students are expected to better understand the role of nanotechnology in everyday life and develop a stronger interest in science.

Therefore, this study aims to evaluate the effectiveness of the NanoMaja program in enhancing students' understanding of nanotechnology concepts. The results of this study are expected to contribute to the development of innovative science education strategies, particularly in introducing advanced scientific topics at the secondary school level.

IMPLEMENTATION AND METHOD

Type of Activity

This study employed a community service (Pengabdian kepada Masyarakat/PKM) approach with a descriptive quantitative design, aimed at evaluating the effectiveness of the NanoMaja Educational Program in improving students' understanding of nanotechnology concepts. A pretest–posttest design was used to measure students' learning outcomes before and after the educational intervention.

Location and Time of Implementation

The NanoMaja program was conducted at SMA Gotong Royong, located in Kota Bangun, Kutai Kartanegara, Indonesia. The activity took place on November 28, 2025.

Participants

The participants of this program consisted of: 85 high school students from grade 10 to grade 12, Teachers and the school principal. The activity was also supported by the Department of Chemistry, involving: The Head and Secretary of the Department, Lecturers, Students from the Chemistry Student Association (HIMAKIM). The involvement of multiple stakeholders aimed to create a collaborative and engaging learning environment.

Session 1: Concept Introduction and Material Presentation

In the first session, students were introduced to fundamental concepts of nanotechnology, including: Definition and scale of nanotechnology, Unique properties of nanomaterials, Types of nanomaterials (e.g., nanoparticles, nanotubes, quantum dots), Applications of nanotechnology in daily life (health, environment, energy, and food industry). The delivery method included: Interactive lectures, Visual presentations (images and diagrams), Contextual examples related to students' daily experiences.

Session 2: Simple Nanotechnology Experiment

The second session involved a hands-on chemistry experiment, where students conducted a simple synthesis of nanomaterials using a green synthesis approach. This activity aimed to: Provide direct experience in nanotechnology processes, Enhance students' understanding through observation and experimentation, Increase engagement and interest in science learning, The experiment was designed to be safe, simple, and suitable for high school students, using easily accessible materials.

Data Collection Techniques

To evaluate the effectiveness of the program, data were collected using: pretest, administered before the material presentation. Post-test, administered after the completion of all sessions. Both tests consisted of multiple-choice questions designed to assess students' understanding of: Basic nanotechnology concepts, Applications of nanotechnology, Fundamental principles of nanomaterials

Data Analysis

The data were analyzed using a descriptive quantitative approach by comparing pretest and post-test scores. The analysis included: Calculation of average scores, Measurement of score improvement, Interpretation of learning gains. The increase in students' scores from pretest to post-test was used as an indicator of the effectiveness of the NanoMaja Educational Program in enhancing students' understanding of nanotechnology.

Implementation Flow

The overall implementation of the activity followed these stages: (1) Preparation and coordination with the school; (2) Administration of pretest; (3) Delivery of nanotechnology material (Session 1); (4) Hands-on experiment (Session 2); (5) Administration of post-test; (6) Evaluation and documentation

Ethical Considerations

The activity was conducted with permission from the school, and all participants were informed about the purpose of the program. The data collected were used solely for educational and research purposes.

RESULTS AND DISCUSSION

Pretest and Post-test Results

The effectiveness of the NanoMaja Educational Program was evaluated using a pretest and post-test administered to 90 students. The tests aimed to measure students' understanding of basic nanotechnology concepts before and after the intervention. The summary of the results is presented as follows in Table 1

Table 1. The Result of Pretest and Post-test NanoMaja Educational Program

Assessment	Mean Score	Highest Score	Lowest Score
Pretest	48.2	70	30
Post-test	82.6	100	60

The results show a significant increase in the average score, from 48.2 in the pretest to 82.6 in the post-test. This indicates that students experienced substantial improvement in their understanding of nanotechnology concepts after participating in the NanoMaja program. To further examine learning improvement, the normalized gain (N-gain) was calculated using the formula:

$N = (Post – Pre)/(100 – Pre)$

Based on the average scores:

$N = (82.6 - 48.2)(100 - 48.2) = 0.66$

The calculated N-gain value of 0.66 falls into the moderate to high category, indicating effective learning improvement. According to Hake (1998), N-gain values between 0.3 and 0.7 are classified as moderate, reflecting meaningful conceptual gains in educational interventions. The bar graph shows a comparison of students' average pretest and posttest scores after participating in the NanoMaja program. There is a clear increase from an average score of 48.2 (pretest) to 82.6 (post-test) (Figure 1).

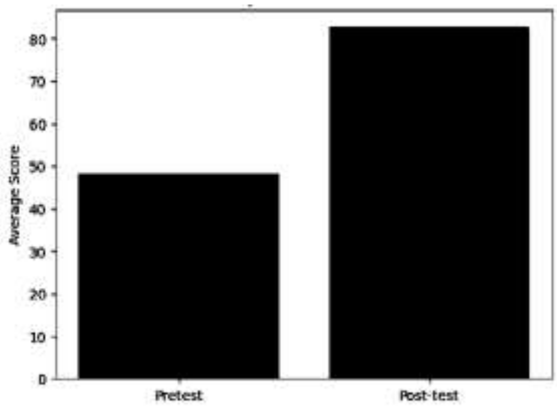

Figure 1. Student Score Improvement (pretest and post-test)

This increase indicates that before the program, students' understanding of nanotechnology concepts was relatively low. This is understandable, as nanotechnology is a topic that is not commonly taught in depth at the high school level. However, after participating in the program, there was a significant increase in understanding. The contrasting heights of the bars in the graph indicate that the learning intervention had a strong impact. This is supported by several key factors: First, the learning approach used was interactive and contextual, enabling students to relate nanotechnology concepts to everyday life. Second, the use of simple hands-on experiments helped students understand abstract concepts more concretely through direct experience. Third, the use of nanoscale visualizations and analogies made it easier for students to visualize dimensions and phenomena that cannot be directly observed. When associated with the N-gain value of 0.66, this increase falls into the medium to high category, which indicates that the NanoMaja program is effective in improving student understanding.

Improvement in Students' Understanding

The improvement in students' scores suggests that the NanoMaja Educational Program successfully facilitated learning. Before the intervention, many students had limited knowledge of nanotechnology, particularly regarding nanoscale size, applications, and properties of nanomaterials. This is reflected in the relatively low pretest scores.

This finding is consistent with previous studies indicating that interactive learning enhances students' conceptual understanding and engagement (Stavrou et al., 2015). Visual representation is particularly important in nanotechnology education because nanoscale phenomena cannot be observed directly, requiring conceptual visualization tools.

After the program, students demonstrated a better understanding of: The concept of nanoscale and its comparison with everyday objects, The unique properties of nanomaterials, Real-life applications of nanotechnology (e.g., sunscreen, nano silver, water filtration). This improvement can be attributed to the interactive and contextual learning approach used in the program.

Effectiveness of Learning Approach

The significant increase in learning outcomes can be explained by several key factors:

a. Interactive Material Delivery

The use of visual aids, real-life examples, and simple explanations helped students understand abstract concepts more easily. Nanotechnology concepts, which are typically difficult to visualize, became more accessible through diagrams and analogies (Figure 2).

Figure 2. Presentation nanotechnology and nanomaterial

b. Hands-on Experimentation

The second session, involving a simple nanomaterial synthesis experiment, played an important role in reinforcing students' understanding. Through direct observation, students were able to connect theoretical knowledge with practical experience. Hands-on and inquiry-based learning approaches have been shown to significantly improve students' comprehension and retention of scientific concepts (American Chemical Society, 2019). Practical activities enable students to actively construct knowledge rather than passively receive information (Figure 3).

Figure 3. Practical Experience

c. Contextual Learning

Relating nanotechnology to everyday products (e.g., sunscreen, masks, smartphones) increased students' interest and motivation. Students were more engaged because they could see the relevance of the material to their daily lives. This approach increases student motivation and relevance perception, as students are more engaged when they understand how scientific concepts apply to real-life situations (Spyrtou et al., 2021). Context-based learning has been widely recognized as an effective strategy in science education.

Student Engagement and Participation

During the implementation, students actively participated in both sessions. In the first session, they were engaged through discussions and questions. In the second session, students showed high enthusiasm during the experiment, particularly when observing changes in material properties. This active participation contributed positively to learning outcomes, as students were not only passive listeners but also directly involved in the learning process.

CONCLUSION AND RECOMMENDATIONS

The results indicate that the NanoMaja Educational Program was effective in improving students' understanding of nanotechnology concepts. The combination of interactive lectures, contextual examples, and hands-on experiments proved to be an effective strategy for introducing advanced scientific topics at the high school level.

Previous studies have highlighted that early exposure to nanotechnology enhances scientific literacy and prepares students for future scientific and technological challenges (Yıldız, 2024). Therefore, programs such as NanoMaja can serve as an effective model for integrating emerging scientific topics into secondary education. The findings support the idea that introducing modern scientific concepts, such as nanotechnology, can be successfully implemented through well-designed educational programs. Moreover, such initiatives can help bridge the gap between scientific advancements and school-level education (Figure 4)..

Figure 4. Documentation of participants and facilitators of the NanoMaja Educational Program at SMA Gotong Royong, Kutai Kartanegara, showing active engagement of high school students during the implementation of nanotechnology learning activities.

FURTHER STUDY

Although the results show significant improvement, several limitations should be noted: The study used a one-group pretest–post-test design without a control group, The assessment focused on short-term learning outcomes, The sample was limited to one school. These limitations suggest that further studies with broader samples and experimental designs are needed.

REFERENCES

ACS. (2019). Guided-inquiry nanotechnology learning activities. Journal of Chemical Education.

American Chemical Society. (2019). Inquiry-based nanotechnology learning activities. Journal of Chemical Education.

Hake, R. R. (1998). Interactive-engagement vs traditional methods: A six-thousand-student survey. American Journal of Physics, 66(1), 64–74.

Mallmann, M. (2008). Nanotechnology in school. Science in School.

Spyrtou, A., et al. (2021). Educational significance of nanoscience–nanotechnology. Education Sciences, 11(11), 724.

Spyrtou, A., et al. (2021). Educational significance of nanoscience–nanotechnology. Education Sciences, 11(11), 724.

Stavrou, D., et al. (2015). Teaching high-school students nanoscience and nanotechnology. LUMAT Journal.

Stavrou, D., et al. (2015). Teaching high-school students nanoscience and nanotechnology. LUMAT Journal.

Yıldız, M. (2024). Review of studies conducted in nanotechnology education. Discover Education.

Yıldız, M. (2024). Review of studies conducted in nanotechnology education. Discover Education.

Yıldız, N. K., & Karataş, H. (2017). Nanotechnology in the curriculum: A review. International Journal of Physics and Chemistry Education.