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Implementation of the Discovery Learning Model Assisted by Simple Molecular Teaching Aids to Support In-Depth Learning of Functional Groups at SMA Negeri 2 Maginti

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Abstract
This study examined the implementation and learning improvement associated with the discovery learning model assisted by simple molecular teaching aids in supporting in-depth learning of functional groups among grade XII students at SMA Negeri 2 Maginti. In-depth learning in this study refers to students' ability to visualize molecular structures, distinguish functional groups, and explain the relationship between functional group structure and compound characteristics rather than merely memorize names or formulas. The study employed a quasi-experimental one-group pretest-posttest design involving 29 students. The intervention used low-cost molecular models made from cork and satay skewers to represent atoms and chemical bonds during the discovery-learning stages of stimulation, problem identification, data collection, data processing, verification, and generalization. Data were collected through conceptual understanding tests, student activity observation sheets, student response questionnaires, and classroom documentation. Data analysis was conducted descriptively by calculating the mean score, mastery percentage, student activity percentage, student response percentage, and normalized gain (N-Gain). The findings showed that the average pretest score of 46.00 increased to 85.00 in the posttest, while learning completion improved from 10.34% to 89.66%. The N-Gain value reached 0.72, which falls into the high category. Student activity during learning was high to very high, particularly in constructing molecular structures (96.55%), discussing differences among functional groups (89.66%), and drawing conclusions from observations (86.21%). Student responses also showed high agreement that the teaching aids helped visualize molecular structures and clarify functional group concepts. These results indicate that discovery learning assisted by simple molecular teaching aids can support conceptual improvement and active participation in functional group learning, especially in schools with limited facilities; however, the findings should be interpreted within the limits of a one-group design without a control class.

Keywords: Discovery Learning; Functional Groups; In-Depth Learning; Molecular Teaching Aids; 3T Regions

INTRODUCTION

Chemistry learning is a branch of natural science that requires students not only to understand concepts theoretically but also to relate these concepts to observable phenomena in everyday life. In chemistry education, conceptual understanding is commonly built through three interconnected levels of representation: the macroscopic level, which refers to observable phenomena; the microscopic level, which refers to atoms, molecules, and bonds; and the symbolic level, which refers to formulas, equations, and structural representations (Astuti, Saputro, & Mulyani, 2023). Functional groups in carbon compounds represent one topic where these three representations must be connected simultaneously. Students are expected to identify the functional group symbol, visualize its molecular arrangement, and relate the structure to the properties of a compound. This makes the topic conceptually demanding, especially when learning is dominated by memorization rather than visualization and inquiry (Ahmad & Sari, 2022; Arifin & Lestari, 2022; Mahardika & Sumarti, 2022).

The difficulty of learning functional groups is often strengthened by students' limited ability to visualize microscopic molecular forms. When students only receive verbal explanations or two-dimensional formulas, they may recognize the names of -OH, -COOH, -CHO, and -NH2 groups but fail to understand how atoms are arranged and how bonds define the identity of each functional group. This condition is critical in science education because functional group learning should help students move from symbolic memorization toward conceptual understanding that connects molecular structure with chemical behavior (Handayani & Prasetyo, 2024; Karimah & Widodo, 2022).

These problems tend to be more pronounced in schools located in remote and 3T regions, where laboratories, commercial molecular kits, visual media, and stable internet access are often limited. SMA Negeri 2 Maginti is located on Maginti Island, Maginti District, West Muna Regency, Southeast Sulawesi Province. In this context, chemistry learning cannot depend heavily on expensive laboratory kits or digital simulations. Learning resources must be economical, locally available, and easy to construct. Classroom conditions also indicate that teacher-centered instruction and lecture-based explanation may cause students to memorize functional group names without understanding the relationships among molecular structures, atom positions, and compound properties (Oktavia & Supardi, 2022; Sari & Kasmui, 2022; Wulandari & Budijastuti, 2022).

One alternative to address these issues is the discovery learning model. Discovery learning encourages students to participate actively through observation, problem identification, hypothesis formulation, data collection, verification, and conclusion drawing (Amelia & Kurniawan, 2023; Erlina & Putra, 2022). Through this learning sequence, students do not merely receive concepts from the teacher; they are guided to construct concepts through direct interaction with learning objects. In chemistry learning, this model is relevant because students can explore molecular structures, compare functional groups, and verify their findings through discussion and symbolic abstraction (Maulida, Nurhayati, & Sriyono, 2023; Putri, Rusilowati, & Pamelasari, 2024; Suryani, Ahda, & Ernawati, 2023).

To support discovery learning, simple molecular teaching aids can function as concrete representations of microscopic entities. In this study, the teaching aids were made from cork and satay skewers. Cork pieces represented atoms, while skewers represented chemical bonds. The novelty of this study lies in the integration of discovery learning, low-cost locally available molecular teaching aids, functional group content, and the remote-school context of SMA Negeri 2 Maginti. Unlike commercial molecular kits, the aids can be produced by teachers and students using inexpensive materials, adapted to the functional groups being studied, and used directly in group exploration. Therefore, this study contributes to science education by presenting a contextual chemistry learning strategy for schools with limited facilities.

Based on the background above, this study focused on three questions. First, how does students' conceptual understanding of functional groups change after the implementation of discovery learning assisted by simple molecular teaching aids? Second, how active are students during the implementation of the model? Third, how do students respond to the use of simple molecular teaching aids in functional group learning?

METHODS

Research Design, Setting, and Participants

This study used a quasi-experimental method with a one-group pretest-posttest design. This design was selected because the study aimed to observe changes in students' conceptual understanding and learning activity before and after the implementation of the discovery learning model assisted by simple molecular teaching aids, without involving a comparison group. The design is appropriate for an initial classroom-based evaluation in a remote-school context, although it cannot fully control threats to internal validity such as testing effect, maturation, teacher effect, and history effect. Therefore, the findings are interpreted as class-level learning improvement associated with the intervention rather than definitive causal evidence.

The study was conducted at SMA Negeri 2 Maginti in the even semester of the 2025/2026 academic year. The research participants were 29 students of class XII MIPA who studied functional groups as part of organic chemistry content. The school minimum mastery criterion used in the study was 80.

Learning Materials and Teaching Aids

The treatment consisted of discovery learning supported by molecular models made from cork and satay skewers. Cork pieces were used to represent atoms and were colored according to simplified CPK conventions: black for carbon, white for hydrogen, red for oxygen, and blue for nitrogen. Satay skewers represented chemical bonds. Students used these materials to model alcohol (-OH), carboxylic acid (-COOH), aldehyde (-CHO), and amine (-NH2) groups. The teaching aids were designed to help students connect symbolic formulas with three-dimensional molecular structures in a concrete and economical way.

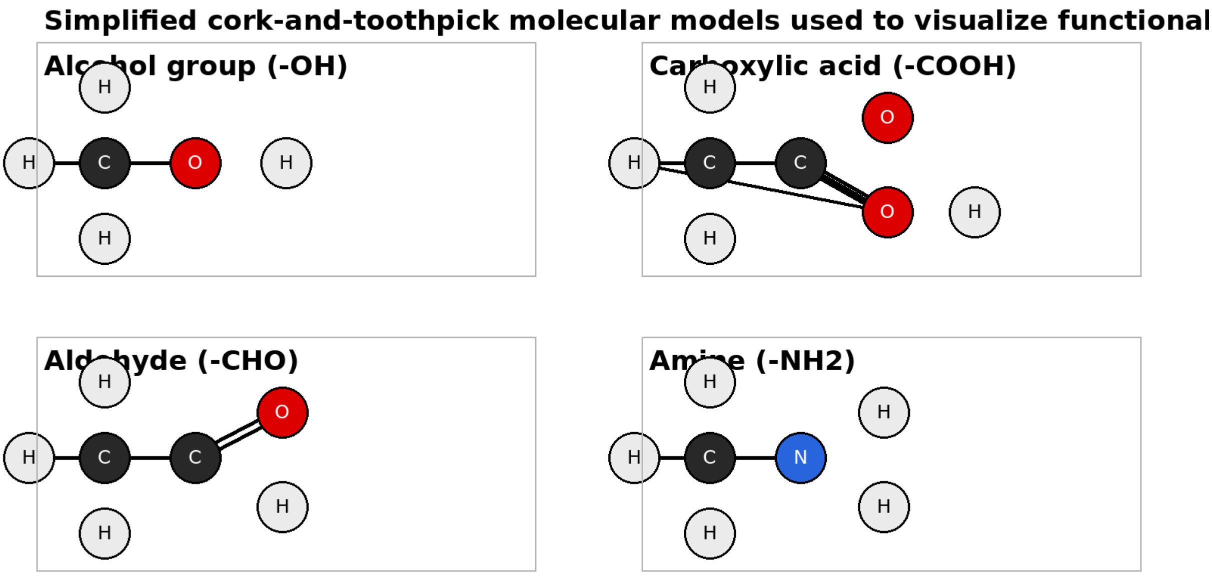

Figure 1. Schematic Representation of Simple Molecular Teaching Aids for Functional Groups

Implementation Procedure

The intervention was implemented as a functional-group learning sequence consisting of pretest, discovery-learning activities, and posttest. Students worked in small groups to construct molecular models, compare atom arrangements, identify functional groups, and present their findings. The teacher acted as a facilitator who provided guiding questions, verified students' molecular structures, and connected students' concrete models to symbolic structural formulas on the board. The discovery-learning syntax used in the lesson is summarized in Table 1.

Table 1. Discovery-Learning Syntax and Implementation In Functional-Group Learning

Discovery-learning stage	Classroom implementation in functional-group learning
Stimulation	The teacher presented examples of carbon compounds and asked students to observe differences in their structures and properties.
Problem identification	Students identified why compounds with similar carbon skeletons may have different characteristics because of different functional groups.

Data collection	Students constructed molecular models of -OH, -COOH, -CHO, and -NH2 using cork and skewers.
Data processing	Students compared atom positions, bond patterns, and group characteristics in their models.
Verification	Students discussed their models with peers and the teacher, then matched them with symbolic structural formulas.
Generalization	Students concluded the relationship between functional group structure and compound properties.

Figure 2. Classroom Documentation of Discovery Learning Activities Using Molecular Teaching Aids

Data Collection Techniques and Instruments

Data were collected using conceptual understanding tests, student activity observation sheets, student response questionnaires, and documentation. The conceptual understanding test was administered as a pretest and posttest to measure students' understanding of functional groups. The indicators covered recognition of functional groups, interpretation of molecular structures, distinction among functional groups, and explanation of the relationship between functional group structure and compound characteristics. Student activity was recorded using an observation sheet containing four observable indicators: asking questions, constructing molecular structures, discussing differences among functional groups, and drawing conclusions from observations. Student responses were obtained through a questionnaire consisting of closed agree-disagree statements about the usefulness of the teaching aids in visualizing molecular structures and clarifying functional group concepts. The instruments were aligned with the learning objectives and the functional-group indicators before implementation.

Data Analysis Techniques

The data were analyzed using descriptive quantitative techniques. Students' conceptual understanding scores were calculated using the formula: student score = (obtained score / maximum score) x 100. The mean pretest and posttest scores were calculated using the formula: mean score = total score of all students / number of students. Improvement in conceptual understanding was examined using normalized gain (N-Gain) based on Hake's formula: N-Gain = (posttest score - pretest score) / (maximum score - pretest score). Student activities and responses were analyzed using percentages. Because the study used a one-group design and did not report individual paired-score dispersion, no inferential statistical claim is made in this manuscript.

Table 2. N-Gain Index Criteria

Gain index (g)	Criteria
g >= 0.70	High
0.30 <= g < 0.70	Medium
g < 0.30	Low

Table 3. Student Activity Criteria

Percentage (%)	Criteria
80.1-100.0	Very high
60.1-80.0	High
40.1-60.0	Medium
20.1-40.0	Low
0-20.0	Very low

RESULT AND DISCUSSION

Result

Students' Conceptual Understanding of Functional Groups

The first finding concerns students' conceptual understanding before and after the implementation of discovery learning assisted by simple molecular teaching aids. The recapitulation of the pretest and posttest results is presented in Table 4. The school minimum mastery criterion was 80.

Table 4. Recapitulation of pretest and posttest results

Exam	Grade average	Number of students completing the standard	Completion percentage
Pretest	46.00	3 students	10.34%
Posttest	85.00	26 students	89.66%
Improvement	+39.00	+23 students	+79.32 percentage points

Based on data from 29 students, there was a substantial increase in conceptual understanding after the treatment. In the pretest stage, the average student score reached only 46.00, with 3 students, or 10.34%, achieving the minimum mastery criterion. This initial condition indicates that most students had difficulty understanding functional group material and tended to memorize group names or formulas without clearly understanding bonding structures, atom positions, and the relationship between molecular structure and compound properties.

After the implementation of discovery learning assisted by simple molecular teaching aids, the average score increased to 85.00. In addition, 26 students, or 89.66%, achieved or exceeded the mastery criterion. The N-Gain analysis showed a value of 0.72, calculated as N-Gain = (85 - 46) / (100 - 46) = 39 / 54 = 0.72. This value falls into the high category, indicating that the learning process supported meaningful improvement in students' understanding. The increase can be explained by the learning mechanism: students were not only told the names of functional groups, but were asked to construct the molecular forms, compare the differences among groups, and verify their structures through discussion. This process helped students bridge the microscopic and symbolic representations of chemistry.

This finding is consistent with the principle of discovery learning, which emphasizes that students develop stronger understanding when they actively construct knowledge through exploration and verification. In this study, the cork-and-skewer molecular models functioned as concrete mediators that transformed abstract functional-group concepts into manipulable objects. The use of simple models helped students move from memorization toward conceptual explanation, particularly in recognizing how the position of O, H, N, and C atoms forms different functional groups and contributes to compound characteristics.

Student Activity During Discovery Learning

Student activities during the learning process were observed through several indicators, including asking questions, building molecular structures, discussing differences among functional groups, and drawing conclusions about the relationship between structure and compound properties. The observation results are presented in Table 5.

Table 5. Results of student activity observation

Activity indicator	Number of active students	Percentage	Category
Asking questions related to the material	23 students	79.31%	High
Participating in building molecular structures	28 students	96.55%	Very high
Discussing the differences between types of functional groups	26 students	89.66%	Very high
Concluding the relationship between molecular structure and compound properties	25 students	86.21%	Very high

The observation data show a positive change in student learning behavior. Of the 29 students involved, 28 students, or 96.55%, actively participated in constructing molecular models using simple teaching aids. This finding indicates that the use of concrete teaching aids attracted students' attention and shifted their role from passive listeners to active learners. The indicator of discussing differences among functional groups reached 89.66%, showing that students exchanged opinions, compared molecular structures, and identified the characteristics of different functional groups.

The percentages for asking questions and drawing conclusions were 79.31% and 86.21%, respectively. These results indicate that students began to express curiosity and were able to draw conclusions from their observations. In accordance with the principles of discovery learning, these activities trained students to think analytically, solve problems, and construct knowledge through direct experience. The use of cork and satay skewer models helped bridge abstract microscopic concepts into concrete representations. This is especially important in remote schools, where commercial molecular kits or digital three-dimensional simulation tools may not be available.

Student Responses to the Use of Simple Molecular Teaching Aids

Student responses were collected through a questionnaire to determine how students perceived the use of simple molecular teaching aids during the learning process. The results are presented in Table 6.

Table 6. Student responses to the use of teaching aids

Statement	Agree	Disagree	Agree (%)
Teaching aids help visualize molecular structures	28 students	1 student	96.55%
Functional group material becomes clearer and is not limited to memorization	27 students	2 students	93.10%
It is easier to distinguish and understand the characteristics of each functional group	26 students	3 students	89.66%

The student response data indicate a high level of agreement with the use of simple molecular teaching aids. A total of 96.55% of students stated that the teaching aids helped visualize molecular structures that had previously seemed abstract and difficult to imagine. Students were able to distinguish carbon, hydrogen, oxygen, and nitrogen atoms and understand how bonding positions form functional groups. Furthermore, 93.10% of students stated that the material became clearer and was no longer merely memorized, while 89.66% of students found it easier to distinguish the characteristics of each functional group and relate them to the properties of compounds.

These responses should be interpreted as students' perceptions rather than direct evidence of effectiveness. Nevertheless, they support the observation data by showing that students perceived the teaching aids as useful and accessible. The positive response may also be influenced by the novelty of the activity and teacher involvement during the intervention. Therefore, response data are used in this study as supporting evidence for the acceptability and contextual relevance of the learning strategy.

Discussion

Contribution to Chemistry Education in Remote Schools

The findings of this study strengthen the view that functional group learning requires more than symbolic explanation. In chemistry education, students are expected to understand concepts through the interconnection of macroscopic, microscopic, and symbolic representations. Functional group material is difficult because students must identify symbolic formulas while also imagining invisible molecular structures and relating them to compound properties. This finding is consistent with Astuti, Saputro, and Mulyani (2023), who emphasized that chemistry learning becomes meaningful when students are able to connect the three levels of chemical representation. Similarly, Pratiwi, Sudarmin, and Pujiastuti (2023) stated that students' difficulties in chemistry often arise because they are unable to transform symbolic formulas into microscopic structural understanding. Therefore, the use of simple molecular teaching aids in this study helped bridge these representational gaps by allowing students to manipulate atom and bond models directly.

The use of cork-and-skewer molecular models enabled students to observe, construct, and compare the structures of -OH, -COOH, -CHO, and -NH_2 functional groups. Through this process, students did not merely memorize the names of functional groups but began to recognize that small differences in atom arrangement can produce different compound characteristics. This finding supports Handayani and Prasetyo (2024), who found that simple molecular teaching aids can improve students' visualization of abstract chemical concepts. It also aligns with Karimah and Widodo (2022), who reported that students often experience difficulty in visualizing molecular forms when learning organic chemistry. By transforming abstract structures into concrete three-dimensional models, the teaching aids in this study supported deeper conceptual understanding of functional groups.

The results also show that low-cost media can be pedagogically meaningful when integrated with an appropriate learning model. The cork-and-skewer teaching aids were not used merely as display objects, but as inquiry tools. Students observed, built, compared, verified, and concluded their findings through group activities. This distinguishes the strategy from conventional teacher demonstrations or ordinary molecular models that are only shown by the teacher. Discovery learning provides opportunities for students to construct concepts independently through exploration and verification. This is in line with Anggraini, Putra, and Lestari (2024), who reported that discovery learning increases student learning activity, and Ramadhani, Mulyani, and Bakti (2023), who found that discovery-based learning can improve students' conceptual understanding in science learning. In this study, the integration of discovery learning and molecular teaching aids encouraged students to become active learners rather than passive recipients of information.

In the context of 3T regions, this combination is particularly valuable because it does not require expensive materials, laboratory infrastructure, or internet access. Schools in remote areas often face limitations in laboratory facilities, visual media, and digital learning resources. This condition has also been reported by Budiarti and Wahyudi (2024) and Lestari, Sudarmin, and Sumarti (2024), who noted that limited facilities remain a major challenge in science learning in remote schools. The present study shows that these limitations can be addressed through locally available materials and pedagogically appropriate learning design. The cork-and-skewer models are inexpensive, easy to produce, and adaptable to classroom needs, making them relevant for chemistry teachers working in resource-limited settings.

This finding is also supported by Ojetunde et al. (2025), who argued that low-cost molecular model kits can function effectively as alternatives to commercial teaching aids, especially in contexts where schools lack access to modern laboratory equipment. Similarly, Dewi, Nugraha, and Permanasari (2023) showed that three-dimensional teaching aids help students understand microscopic concepts more clearly, while Fadilah, Wijaya, and Kurniawan (2024) emphasized that simple learning media can support science learning in schools with minimal facilities. Thus, the contribution of this study lies not only in improving students' learning outcomes but also in demonstrating a practical and replicable instructional strategy for chemistry education in remote schools.

The increase in students' conceptual understanding, as reflected in the improvement from the pretest to posttest and the high N-Gain score, indicates that discovery learning assisted by simple molecular teaching aids has strong potential to support in-depth learning. However, the improvement should not be interpreted solely as the effect of the media, but as the result of the interaction between the learning model, concrete representation, group discussion, and teacher guidance. This interpretation is consistent with Bruner's theory of discovery learning, which argues that students develop deeper understanding when they actively organize and reconstruct knowledge through direct experience. In this study, students were encouraged to connect molecular structures with functional group characteristics through active exploration, making the learning process more meaningful and less dependent on rote memorization.

However, this study has several limitations. First, the one-group pretest-posttest design does not allow strong causal claims because there was no control group. Second, the study was conducted in only one class with 29 students, so generalization should be made carefully. Third, individual score dispersion, reliability coefficients, and inferential statistics were not reported. Fourth, student response data may contain response bias because students may tend to provide positive answers after participating in an enjoyable learning activity. Therefore, future studies should involve comparison groups, larger samples, validated instruments, individual score distribution, and inferential analysis such as paired sample t-test or non-parametric alternatives when appropriate. Future studies may also examine long-term retention, students' misconceptions, and the effectiveness of similar teaching aids on other organic chemistry topics. Despite these limitations, the findings provide practical evidence that discovery learning assisted by simple molecular teaching aids is promising for improving chemistry learning in schools with limited facilities, especially in 3T regions.

CONCLUSION

This study concludes that the implementation of the discovery learning model assisted by simple molecular teaching aids was associated with improved conceptual understanding and active participation in functional group learning among grade XII students at SMA Negeri 2 Maginti. The average score increased from 46.00 in the pretest to 85.00 in the posttest, while the percentage of learning completion increased from 10.34% to 89.66%. The N-Gain value of 0.72 indicates a high level of class-level improvement. Student activity was also high to very high, particularly in constructing molecular structures, discussing differences among functional groups, and drawing conclusions from observations. Student responses showed strong agreement that the teaching aids helped visualize molecular structures, clarify functional group concepts, and reduce dependence on rote memorization. These findings suggest that discovery learning supported by simple, low-cost molecular teaching aids can serve as a contextual alternative for chemistry learning in schools with limited facilities, particularly in 3T regions. Nevertheless, because the study used a one-group design without a control class, the results should be interpreted cautiously as contextual learning improvement rather than definitive causal evidence. Future research should involve broader samples, comparison groups, and stronger measurement validation to confirm the effectiveness of this strategy.

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