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Design of Innovative Non-Routine Learning Strategies in Chemistry Learning

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Abstract

Traditional teaching methods in chemistry have been insufficient in helping students master problem-solving and conceptual understanding across the three levels of chemical representation: macroscopic, submicroscopic, and symbolic. Innovative strategies are needed to address these challenges and improve learning outcomes. This study evaluates the feasibility, practicality, and effectiveness of a non-routine learning strategy as an innovative approach to teaching chemistry. The research adopts the Gall and Gall Research and Development (R&D) model with a 3D design framework (Define, Design, Develop). The study involved chemistry education students from UIN Ar-Raniry Banda Aceh and UIN Sultan Syarif Kasim Riau. Data collection instruments included validation sheets to assess feasibility, observation sheets for practicality and effectiveness, as well as tests and related documents. The findings demonstrate that the non-routine learning strategy is valid, practical, and effective. It significantly enhances students' ability to solve problems and explain chemical concepts using the macroscopic, submicroscopic, and symbolic levels of representation. This non-routine learning strategy represents a feasible and effective innovation in chemistry education, providing a practical tool for improving students' problem-solving skills and conceptual understanding. Its implementation offers valuable insights for advancing chemistry teaching practices.

Keywords: chemistry education, non-routine learning, teaching strategy

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1. Introduction

Chemical materials are generally viewed from two properties: physical and chemical. In its application and study, chemistry is divided into five parts: basic chemistry, physical chemistry, inorganic chemistry, organic chemistry, and analytical chemistry. In its development, chemistry can be viewed from three levels of representation, which are macroscopic, symbolic, and microscopic levels of representation (Justi et al., 2009). Three levels of representation are used because most chemical concepts are abstract concepts. Based on this developmental study, learning activities must be carried out simultaneously to explain between levels. These levels are crucial for explaining abstract chemical concepts, and recent studies emphasize the need to integrate them simultaneously to enhance students' conceptual understanding and problem-solving abilities (Almeida & Gonçalves, 2022; Peters et al., 2022). This integrated approach bridges the gap between theoretical knowledge and practical application, fostering deeper learning experiences and improving student engagement. During the current pandemic disaster, many effective strategies are sought to be used in the learning process, so that educators can easily convey material to students so that it can make it easier for students to absorb the material they learn.

The systems used also vary, some use online, offline, or blended learning, which combines online and offline systems. This condition will require educators to innovate continuously in designing their learning more practically and effectively (Sabekti et al., 2020). Blended learning, has proven effective, combining interactive tools like simulations and real-time feedback to enhance chemistry education (Cho et al., 2023; Adedoyin & Soykan, 2023). High-level thinking is one of the supporting factors in producing a practical, effective, and efficient learning design. This is very much needed to make students more directed, and motivated to gain knowledge from the material studied in learning activities. However, many obstacles are experienced so the government and practitioners continue to innovate to minimize these obstacles.

The results of the initial study found that lecturers still find it difficult to find more effective steps in delivering chemistry learning materials, let alone learning activities carried out online. Educators are still lacking in making innovations related to designing learning. Further asked about the learning tools used in learning activities, and obtained quite varied information, some used printed books photograph some material and assignments, some made powerpoint (PPT), made their videos, did live activities (proof of concept), and so on. Of the several ways, PPT usually dominates video demonstrations (Adnan et al., 2023; Zhao et al., 2022). Non-routine learning strategy is one of the innovations to facilitate teaching concepts for prospective chemistry teacher students. This design describes a series of typical learning activities and has an element of novelty in teaching chemistry material. So that the social interaction that takes place makes it easier for students and educators to explain, and practice problem-solving and concept mastery. In effect, students can achieve the competencies they must have. The achievement of these competencies is one of the accompanying effects for students after carrying out the learning process using non-routine learning strategies. The non-routine learning strategy is designed based on Polya's problem solving method. This was chosen with the consideration that the steps developed by Polya can help students' mathematical abilities in mastering concepts, and solving chemical problems.

2. Research Method

2.1. Research Design

The research conducted belongs to the type of development research (research and development). Development research must be able to produce products based on needs, from the results of these products used as a tool to test the quality of these products so that they can function properly (Sugiyono, 2011). The final product is evaluated based on the specified product quality aspects. A developed product is called quality if it meets three criteria, which are valid, practical, and effective (Nieveen, 1999). This research also developed learning tools including RPS, student teaching materials, student activity sheets, and student competency assessment sheets as a support system for the implementation of the developed strategies, and the necessary instruments. This research was conducted to produce a non-routine learning strategy that has three criteria according to Nieveen (1999). The research and development design used is a research and development design adapted from Gall et al. (1996), which includes three stages, which are Define, Design, and Development.

2.2. Location and Research Subject

The research was conducted at PTKIN, which has a chemistry education department, and at UIN Ar-Raniry Banda Aceh and UIN Sultan Syarif Kasim Riau. The subjects of this research were Chemistry education students at FTK UIN Ar-Raniry and Chemistry education students at FTK UIN Sultan Syarif Kasim Riau.

2.3. Data Collection Instrument

To measure the validity, practicality, and effectiveness of non-routine learning strategies, research instruments were compiled and developed consisting of: (1) a validation sheet of the developed strategy; (2) validation sheet of learning devices including syllabus validation sheet, RPS validation sheet, student teaching materials validation sheet, and student worksheet validation sheet; (3) observation sheet of the implementation of non-routine learning strategy; (4) observation sheet of student activities; (5) record sheet of obstacles during the implementation of learning; (6) learning outcomes assessment sheet; (7) student response questionnaire.

3. Result and Discussion

3.1. Validation of Learning Tools Supporting Non-Routine Learning Strategies in Chemistry Learning

The validation results show a score range between 3.00 and 4.00. The aspect of the suitability of objectives with indicators is in the valid category with a score of 3.00, while other aspects are in the very valid category with scores of 3.33, 3.67, and a score of 400. The reliability coefficient is in the range of 85.71% to 100%; each aspect in all components assessed is included in the reliable category.

Table 1. Table of Learning Tools Non-Routine Learning Strategies in Chemistry Learning

No	Component Assessed Validation	Score Validity	Criteria Reliability	Coefficient Reliability (%)	Reliability
1	Rationale for Learning Strategy.	3.33	highly valid	84.21	Reliable
2	Theoretical and Empirical Support.	3.50	highly valid	92.68	Reliable
3	Steps of non-routine learning strategy	3.35	highly valid	91.60	Reliable
4	Learning Planning.	3.58	highly valid	89.66	Reliable
5	Instructions for Implementing Learning with the developed strategy.	3.50	highly valid	85.71	Reliable
6	Support System.	3.78	highly valid	99.22	Reliable
7	Instructional impact and nurturant impact	3.70	highly valid	98.51	Reliable

The validation results were improved based on suggestions and input from the three validators. Some suggestions from the validators are; (1) indicators need to use operational verbs that contain C4, C5, and C6, (2) the word writing is replaced with the word writing, (3) the preparation of objectives in learning devices needs to follow the format of A (audience), B (behavior), C (condition), and D (degree).

3.2. Validation of Student Teaching Materials

The results of the validation of student teaching materials as shown in Table 1 are in very valid criteria with a range of scores between 3.33 to 4.00. The reliability coefficient of 85.71% to 100% of all aspects falls into the reliable category. The results of validations of student teaching materials that have been carried out by validators are revised based on suggestions and input from validators. Some suggestions and input from the validators are (1) illustrations need to be made more interesting, (2) the breadth and depth of the material need to be added, (3) it needs to be made more provocative, and (4) creating interactive communicative is less visible.

3.3. Validity of Non-Routine Learning Strategy

Non-routine learning strategies are developed to teach chemistry as proposed by (Gilbert & Treagust, 2009; and Kozma, 2003) so that students can connect one level of representation with another in solving and explaining chemical concepts. The development of non-routine learning strategies is also supported by social constructivist theory related to the Zone of

Proximal Development (ZPD), scaffolding, cognitive apprenticeship, and cooperative learning (Santrock, 2011), scaffolding (Wass et al., 2011), problem-solving according to Polya (Akyüz, 2020) and problem solving according to Huffman (Ayoola & Bileya, 2024) which says that the strategy developed has the characteristics and feasibility as suggested by Plomp (2013), which is a product is said to be valid if it meets the criteria of valid content and construct. Content validity is the element of novelty and construct validity is the consistency between the components of the strategy and the consistency between the theories that underlie it and the strategy developed.

3.4. Validity of Learning Tools Supporting Non-Routine Learning Strategies

Based on these results, the developed MFI can be used in learning activities to support the implementation of the developed non-routine learning strategy. This shows that the student worksheet that has been prepared has met the requirements as a quality student worksheet. This activity is by the process standards set out in SNPT, that student worksheets are used as a medium to assist students in understanding the material, solving problems, and discussing problems (Demoin & Jurisson, 2013). Student worksheets can also be used as a guide to monitor the development of students' ability to solve problems (Choo et al., 2011). This is in line with the views of Kibar and Ayas (2010) who say that student activity sheets are used to direct learning activities for the achievement of learning objectives.

3.5. Practicality and Effectiveness of Non-Routine Learning Strategy

Based on the observation of activities when working on student worksheets, novice-novice category students have difficulty connecting between submicroscopic, macroscopic, and symbolic levels of phenomena so that in solving and providing explanations for the answers that have been done are less precise (Harrison & Treagust, 2002; Gilbert, 2006; Justi et al., 2009; Meijer, 2011) because the submicroscopic level is abstract (Wiser & Smith, 2009; Rappoport & Ashkenazi, 2008; Gilbert & Treagust, 2009), Sukmawati (2019) emphasizes the importance of presenting macroscopic, submicroscopic, and symbolic representations in helping students in concept construction. Based on the three research results, the researcher uses the research results (Corradi et al., 2012; Yakmaci-Guzel & Adadan, 2013) as a support for the results of the research that has been carried out, and the results of Maries' research, (2013) are used as a study material in the process of improvement and refinement, Ijtihadah & Ardhana (2024) to improve students' understanding, it is necessary to be given different representation skills to explain abstract concepts.

This research is development research or Research and Development (R&D), which is a research method used to produce products and test their effectiveness (Sugiyono, 2011). The resulting product must be valid, practical, and effective (Nieveen, 1999). Based on this statement, the findings in this study are related to the validity, practicality, and effectiveness of the non-routine learning strategy as a product of this study.

Non-routine learning strategies are proven to be valid, both in terms of content and construct. Content is valid because there is novelty in the developed strategy and construct is valid because there is consistency between the steps of the strategy and consistency between the developed strategy and its supporting theories. Non-routine learning strategies are new compared to the strategies used to solve previous problems or DECSAR developed by Chaudhry and Rasool (2012) because non-routine learning strategies have fewer steps. DECSAR has 6 steps in practicing problem solving skills, while the non-routine learning strategy has 3 steps. The non-routine learning strategy in the routine practice step and the non-routine Learning strategy Learning strategy are proven to be able to train students' problem-solving and representation skills. Steps 1 and 2 can support students in gathering information related to solving problems to be used in explaining concepts and can train students to be more thorough and careful in solving the problems asked. This proves that students feel able to follow the learning process with non-routine learning strategies in practicing the ability to solve problems and explain chemical concepts.

The non-routine learning strategy has met the practical criteria because it can be implemented by lecturers and students. The results showed that operationally, the three steps of non-routine learning strategies that have been developed in the RPS and MFI can be carried out by lecturers and students.

Overall, students' ability to solve problems and explain concepts increased. This proves that the three steps of non-routine learning strategies are effective. The findings are supported by the answers to the questionnaire responses, which show that students find it easy to understand the language, material, pictures, graphs, formulas, symbols, and example problems presented in the MFI. In addition, students also felt that they could practice their problem-solving skills and explain chemical concepts.

The three steps of non-routine learning strategies, which include analyzing problems, finding ways to solve problems, and explaining concepts, can improve students' ability to solve problems and explain concepts. These activities are based on the theory proposed by Vygotsky about two main concepts in student cognitive development: scaffolding and Zone of Proximal Development (ZPD). Research conducted by Wass et al. (2011) proved that scaffolding in the ZPD can develop problem-solving skills.

The implementation of non-routine learning strategies can provide instructional impact and accompanying impact for students (Sutherland, 2002). Students are trained to solve problems and explain concepts, visualize microscopic-level phenomena, and students are trained to integrate the three levels of representation in solving problems.

Students who have less initial ability of representation but good academic ability can develop the ability to solve problems and represent non-routine Learning strategies in the novice category to expert, but for students who have less initial ability and academic ability, the ability to solve problems and explain concepts only increases slightly, that is, it remains in the novice category.

The results show that expert students have the characteristics of (1) Able to integrate the three levels of representation in answering problems and explaining the answers that have been done, (2) Describing submicroscopic phenomena first to visualize the problem before planning how to solve the problem and explain the answer, (3) Linking prior knowledge with the problem to be solved (4) Expressing ideas in different ways, which is, building the ability to solve problems with non-routine learning strategies in the order of interpreting, planning, then using features different from those presented in the problem. For example, if a symbolic representation level is presented, then in choosing how to solve the problem using the submicroscopic representation level or macroscopic representation level (5) Starting with visualizing the problem then doing concept analysis, planning the steps before applying the planned way of solving chemical problems (Karous et al., 2022; Levy & Wilensky, 2011). Based on the response questionnaire answers given, students gave a positive response to learning activities with non-routine learning strategies.

The findings demonstrate that the developed strategy serves as an effective alternative learning method to train students in solving problems and explaining chemical concepts, regardless of their initial abilities—low, medium, or high. This highlights the versatility and inclusiveness of the approach, ensuring that students with varying academic starting points can benefit and make progress.

Learning achievement is not solely determined by previous academic abilities; other factors, such as the quality of instruction, the learning environment, individual talents, and the time available for learning, also play significant roles (Joyce et al., 2009). These aspects emphasize the importance of designing teaching strategies that address diverse needs and maximize student engagement.

By providing a well-structured learning environment, non-routine learning strategies help both expert and novice pre-service teachers enhance their problem-solving and chemical representation skills. This improvement is particularly evident when focusing on the three levels of representation—submicroscopic, symbolic, and macroscopic—ensuring comprehensive mastery of chemical concepts essential for effective teaching and future professional practice.

4. Conclusion

The developed non-routine learning strategy is valid, practical, and effective, making it a feasible approach to train students in solving chemical problems and explaining concepts across the three levels of chemical representation (submicroscopic, symbolic, and macroscopic). Content validity ensures the strategy is novel and relevant, while construct validity confirms consistency with theoretical principles.

The implementation of the strategy through well-designed teaching materials, such as Semester Learning Plans and Student Worksheets, successfully encouraged student-centered learning and active participation. Although some technical obstacles were encountered, adjustments improved the learning outcomes in broader tests.

Prospective teacher students' abilities in chemical problem-solving and representation were generally in the medium category, with some reaching expert levels. Expert students demonstrated advanced skills, including effective use of all representation levels, integrating prior knowledge, and employing diverse problem-solving approaches. Students and lecturers responded positively to the non-routine strategy, highlighting its potential to enhance teaching and learning in chemistry.

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