JoSSEd
Journal of Science and Science Education
ISSN: 2774-1869 eISSN: 2774-2105

Development of Teaching Modules Using the Understanding by Design (UbD) Approach on Class X Chemical Bond Material

Nurli Yanti Rumahorbo[1*], Dewi Syafriani[1], Husna Sari Agustina[2]

[1] Department of Chemistry Education, Faculty of Mathematics and Natural Sciences, Universitas Negeri Medan, Indonesia
[2] SMA Negeri 4 Medan, Medan, Indonesia

Received: March 17, 2025
Revised: September 21, 2025
Accepted: October 25, 2025
Published: October 31, 2025

Corresponding Author:
Nurli Yanti Rumahorbo
Yantinurli240@gmail.com

DOI: 10.29303/jossed.v6i2.10904

Abstract: This study aims to develop a teaching module based on the Understanding by Design (UbD) approach for 10th-grade students at SMA Negeri 4 Medan, with the specific objective of enhancing students' conceptual understanding of chemical bonding. The research employed the ADDIE development model, which consists of five stages: analysis, design, development, implementation, and evaluation. The subjects involved included 36 students of class X and one chemistry teacher. The instruments used in this study were expert validation sheets, teacher and student response questionnaires, and pretest-posttest assessments. Content and media validity were assessed by experts, resulting in validity percentages of 87% and 86%, respectively. Practicality was evaluated through teacher and student questionnaires, obtaining average scores of 93% and 93%, indicating the module is easy to use and well-received. Effectiveness was measured using the N-Gain formula, yielding a score of 73.58%, categorized as quite effective in improving students' understanding. Data were analyzed descriptively to determine the module's feasibility, practicality, and effectiveness. In conclusion, the UbD-based teaching module on chemical bonding is valid, practical, and effective in supporting students' conceptual mastery of chemistry.

Keywords: ADDIE Model; Chemical Bonding; Module Development; Understanding by Design (UbD).

Introduction

Chemistry has many benefits in daily life, but the interesting problem to pay attention to is many facts that show that chemistry is seen as a difficult and uninteresting science to study. Chemical bonds shape and determine the properties of substances we use every day, such as the formation of water, salt, soap, and detergent molecules, so understanding chemical bonds is essential for application in health, food, and home life (Danin & Kamaludin, 2023).

In chemistry learning activities, there are still many students who find it difficult to solve problems in relating chemical concepts to real life. Many students are fixated on the formula without understanding the concept. This causes low chemistry learning outcomes for students (Suswanti, 2021). Many students have difficulty in connecting chemical concepts to real life, for example when it comes to explaining why table salt has a salty taste due to ionic bonds, why sugar is sweet and water-soluble due to polar covalent bonds, or why water has a high boiling point due to hydrogen bonds. This difficulty arises because the concept of chemical bonds is abstract and often not directly associated with everyday phenomena, so students need innovative learning media that can bridge their understanding (Afrianti et al., 2024).

One of the chemical materials studied in phase E class X is chemical bonding. Chemical bonds are one of the materials that contain basic concepts in chemistry learning. Chemical bonds have a big role in the discussion of chemistry both at the high school and university levels (Hunter et al., 2022). This topic requires an understanding of important details and complex reasoning, making it complex and difficult for most learners. Different types of bonds (metallic, ionic, covalent, polar and nonpolar, intermolecular) pose conceptual difficulties and lead to the formation of many misconceptions (Tsaparlis et al., 2020). In the process of learning and learning chemical bonds, students are

How to Cite:
Rumahorbo, N. Y., Syafriani, D., & Agustina, H. S. (2025). Development of Teaching Modules Using the Understanding by Design (UbD) Approach on Class X Chemical Bond Material. *Journal of Science and Science Education*, *6*(2), 115–123. https://doi.org/10.29303/jossed.v6i2.10904

required to understand these abstract concepts and various models and representations. This is what causes students' difficulties in understanding chemical bonding materials (Hendrawani, 2023).

Based on the results of an interview with one of the chemistry teachers at SMA Negeri 4 Medan, students' difficulties in understanding the chemistry material taught are influenced by abstract materials and low student interest in learning. The low interest of students is influenced by material that is difficult to understand and the learning process is less interesting and seems to be watching like just listening to the teacher's explanation without the active involvement of the students. The use of teaching media by teachers also has an impact on students' interest in learning. In the learning process, teachers have used learning design by implementing several learning models that are not only teacher-centered but student-centered. The teaching media used by teachers are standard media such as books and Power Point. With the learning design applied by teachers, it is hoped that students' learning outcomes on chemistry can achieve above-average scores. But in reality, with the models and media applied by teachers, the learning outcomes of students are not as expected. This is evidenced by the results of the Mid-Semester Assessment of students who still have not achieved the desired results. Based on the Mid-Semester Assessment data, it is known that as many as 45% of students have not reached the Minimum Completeness Criteria set by the school, which is 75. In addition, there are some misconceptions that often arise, such as the assumption that ion bonds only occur between metals and noble gases, or that all covalent bonds are non-polar.

To achieve learning goals and improve students' understanding, there are several factors that can influence, one of which is learning media. Teaching modules are a type of teaching media that contains learning implementation plans, to help direct the learning process to achieve Learning Outcomes. UbD, also known as "*Understanding by Design*", is a concept closely related to an educational framework called Understanding by Design (Wan et al., 2023). UbD is a design model that focuses on student understanding and accepts learning as a process (Altun et al., 2021).

UbD according to Wiggins & McTighe (2005) is an approach to the learning process that aims to improve students' understanding in depth and actively engage them. This learning design is certainly oriented to the final result of a learning or thinking about how students think about a subject matter concept and placing the learning process at the end of the design sequence. The fundamental difference between UbD and other learning designs is in the order of designing learning evaluations and learning steps. Usually, teachers design learning starting from determining learning objectives, then learning steps, then learning evaluation. However, in UbD, the design starts from the learning objectives, then prepares a learning evaluation and then only plans the learning steps (Pertiwi et al., 2019). One of the hallmarks of UbD is that this framework requires that the learning objectives must lead students to understand the big ideas related to the topic being studied. The main idea means the most essential idea related to the topic being studied. The basic question when determining the main idea is, "What are the most important ideas on this topic that students need to keep in mind, in case all the other ideas are forgotten?" (Ramli & Argaswari, 2023).

UbD, also known as *the Backward Design* model, focuses on learning objectives as a result of a teaching before planning learning activities and teaching methods. While it is important to think about what material will be taught and how to teach it, the main focus should be on the desired outcome of the learning. Using an upside-down design offers a concrete way to communicate learning expectations. Creating a clear set of learning expectations by using UbD often creates higher student achievement because an organized approach outlines what to learn at the end of a lesson or activity (D'angelo et al., 2019).

UbD has three stages: 1) identifying what students want and what knowledge students should have, 2) determining acceptable evidence of learning, i.e. how to know that students have achieved the desired outcomes, 3) designing learning experiences and instructions, i.e. determining what activities must be done so that all desired goals can be achieved. UbD design aims to form aspects of understanding, which consist of explaining, interpreting, applying, having perspective, empathizing, and having self-knowledge (Gloria et al., 2019).

Here is a description of the three stages of UbD (Wiggins & McTighe, 2005):

Identify desired results

This first stage in the design process requires clarity about learning priorities. UbD emphasizes that any learning should focus on transfer goals that determine what students should be able to do with their learning in the long run. Then, the faculty identified the "Big Ideas" they wanted the students to understand as a result of the unit. These important concepts frame *essential questions* as companion material—open-ended thought-stimulating questions that aim to involve students in creating meaning. Thus, stage 1 includes three levels (transfer, meaning, and acquisition) that encourage deep conceptual understanding**.**

To keep those big ideas in mind during the early part of the planning process, Wiggins & McTighe (2005) suggest that designers include 'essential questions' that may be answered (perhaps only partially) during the learning sequence Essential questions are questions that

can encourage inquiry, understanding, and transfer of learning. The characteristics of essential questions are (Wiggins & McTighe, 2005): Raise meaningful and relevant questions to the big ideas and core discussions; Encourage deep thinking, lively discussion, continuous inquiry and new understandings and questions; Requires students to consider alternatives, gather evidence, support their ideas and justify their answers; Stimulate important and sustained rethinking of big ideas, hypotheses, or previous lessons; Triggering meaningful connections with previous learning and daily life; and Repetitive naturally, creating opportunities to transfer to other situations and subjects

Determine Acceptable Evidence

The second stage of this design encourages teachers to act as assessors before planning lessons and learning activities in the third stage. In other words, think about how the evidence of assessment will show how far the student has achieved the targeted learning goals in the first stage. Traditional tests, quizzes, and skills exams can assess students' mastery of science knowledge and proficiency in basic skills. However, UbD proposes that conceptual understanding requires stronger evidence, which is obtained through performance assessments that encourage students to apply (i.e., transfer) their learning to new situations and explain the understanding they have acquired. It is recommended that performance tasks be created in a meaningful and authentic context (e.g., related to a phenomenon) where possible.

Plan learning experiences and instruction

The third stage is the daily learning planning stage. It was found that when teachers have set clear learning objectives in the first stage and have carefully considered the evidence of assessment required in the second stage, teaching and learning plans will become sharper. Wiggins and McTay compiled a set of criteria known as WHEREETO elements.

W (Where is it going): The teaching objectives of each unit should be clearly communicated to all students to ensure their understanding.

H (Hook & Hold): Effectively engage students from the start and consistently grab their attention.

E (Equip & Experience): Aims to equip students with the experience, means, knowledge, and specific skills necessary to achieve their learning goals.

R (Rethink & Experience): Aim to rethink, review and improve their understanding.

E (Evaluate): Students engage in the evaluation of their learning process through various means such as conducting assessments, conducting self-assessments, and making necessary adjustments based on formative assessments.

T (Tailor): Implement a variety of units for a diverse student population, with a study plan that includes differentiation and personalization strategies while maintaining the integrity of phase 1 and phase 2.

O (Organize): The first step in optimizing engagement and effectiveness is to organize units in a logical order.

Previous research entitled The Impact of Using Understanding by Design (UbD) Model on Class 10 Student's Achievement in Chemistry, stated that there was a significant difference between the learning outcomes of the control group and the experimental group. There was an increase in the average learning outcomes of the experimental group taught using the UbD model compared to the control group. This illustrates that the use of the UbD Model in learning can improve student learning outcomes (Tshering, 2022). Therefore, this study focuses on finding out how effective the teaching modules developed are on improving student learning outcomes.

Method

Research subjects

The subjects in this study are 36 students in grades X-6 of SMA Negeri 4 Medan who will use an *Understanding by Design (UbD)-based teaching module* on chemical bonding materials. The subject was chosen because at this level the chemical bonding material began to be taught and often caused difficulties in understanding, so it was suitable to be used as a trial of the developed teaching module.

research Objects

The object of this research is a chemistry teaching module with *an Understanding by Design (UbD)* approach to chemical bonding materials. The focus of the research object includes the module development process, the feasibility of the module based on the validation results, and the response and learning outcomes of students after using the module.

Expert Validators

In this study, three expert validators were used consisting of Chemistry Education lecturers at the State University of Medan (UNIMED) with the academic qualification of Master of Education in the field of chemistry education. The selection of such expert validators is based on academic competence and relevant professional experience, so that the results of the assessment can be accounted for academically. The expert validators are in charge of assessing the feasibility of the *Understanding by Design (UbD)* based teaching module on chemical bonding materials, both from the material feasibility aspect and the media aspect (presentation, language, and graphics).

General Procedure

This study will use the Reasearch and Development (R&D) method which is a research method that is carried out in a structured manner to improve existing products or develop a new product through testing, so that the product can be accounted for (Rustamana et al., 2024). This study uses the ADDIE model which is an acronym for Analyze, Design, Develop, Implement and Evaluate. The concept of the ADDIE model is applied to build basic performance in learning, namely the concept of developing a learning product design (Hidayat & Nizar, 2021).

Analysis

In the analysis stage, it focuses on understanding learning needs. This analysis is important to ensure that the teaching modules developed are relevant to the needs of students and the curriculum used. This stage consists of gap analysis, analysis of student characteristics, analysis of material and references and formulation of learning objectives. At this stage, the analysis is carried out using an interview questionnaire and an observation questionnaire. To find out the needs and characteristics of students, an interview questionnaire is used, while for material analysis and reference, an observation questionnaire is used. There are 5 books from various publishers that are used as references and materials in the modules to be developed.

Design

The design stage involves the creation of a UbD-based teaching module design with planning focused on the desired learning outcomes, as well as the design of assessments and learning activities that support it. The stages of planning include setting the expected results, compiling essential questions, designing assessments and assessments, designing learning activities and designing forms.

Development

This stage is the process of creating a teaching module based on the design that has been designed. This stage consists of module prototype development, validation, and revision. At this stage, it is hoped that the modules that have been developed can be tested. The formula used to calculate the data from the results of filling out the questionnaire by the validator as follows Formula 1 (Arikunto, 2010).

Table 1. Categories Interpretation of Module Eligibility

Percentage Interval %	Eligibility Criteria
81 - 100	Highly feasible
61 - 80	Proper
41 – 60	Quite feasible
21 – 40	Not eligible
< 21	Very unworthy

$$P = \frac{\sum f}{\sum N} \times 100\% \quad (1)$$

Implementation

At this stage, the modules that have been developed are implemented in real learning situations. The module is implemented in a sample in the form of 1 experimental class. This implementation will be carried out in the even semester in class X-6 SMA Negeri 4 Medan. In the initial stage of implementation, a pre-test was given to the sample to find out the initial ability to have chemical bonds, then it was treated by being taught using the module that had been developed.

Evaluation

At this stage, the researcher tested the students' achievement of understanding related to chemical bonding material after using the module by providing a posttest. Designed 25 multiple-choice questions according to learning outcomes with cognitive levels C1-C5 that have been validated by expert validators. In addition, the practicality of the modules that have been developed will be measured by filling out a practicality sheet by 36 students dan teacher at SMA Negeri 4 Medan. The practicality sheet is in the form of a questionnaire consisting of an assessment of aspects of language, appearance and learning.

Data Analysis

There are several data analyses used in this study. The data from the interview results in the early stages were analyzed by qualitative descriptive methods. This is useful for determining the need for module development which is expected to have the potential to help students in improving learning outcomes. The data from the questionnaire was analyzed by descriptive statistical methods. This is useful for measuring the validity and feasibility of the module. Meanwhile, the data from the pretest and posttest results were analyzed by the N-gain test. According to Maryani et al. (2022) The normalized gain (N-gain) is calculated using the Formula 2.

$$N - Gain = \frac{Skor\ Posttest - Skor\ Pretest}{Skor\ Maximum - Skor\ Pretest} \times 100\% \quad (2)$$

Table 2. Categories Interpretation of N-Gain Effectiveness

Percentage	Interpretation
> 76	Effective
56 - 75	Quite Effective
40 – 55	Less Effective
< 40	Ineffective

Research Procedure

Based on the explanation of the research method above, the research procedure can be designed in the form of a flow chart as follows Figure 1.

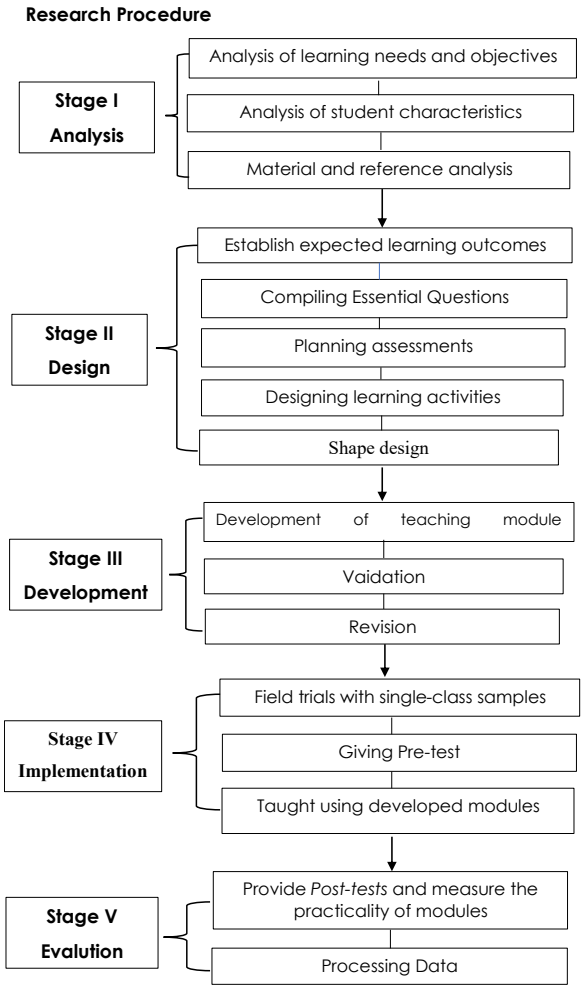

Figure 1. Research Procedure

Result and Discussion

This research was carried out at SMA Negeri 4 Medan which is located at Jalan Gelas No. 12, Sei Putih Tengah, Medan Petisah District, Medan City, North Sumatra with the postal code 20118 which involves one class with the procedure of giving a pretest first to find out the initial ability of students and then treating students by learning with teaching modules using the Understanding by Design (UbD) approach on chemical bonding materials that have been developed for the semester even the 2024/2025 school year.

Analysis stage

At this stage of analysis, it was carried out using interview and observation instruments. 16 questions are provided for teachers with indicators of how the chemistry learning process is and the need for modules. Meanwhile, for interviews with students, 10 questions with the same indicators are provided. Interviews were conducted with 10 students representing students of high, medium and low academic scores. Interviews need to be conducted with students from low, medium, and high academic levels so that the data obtained reflect the variation in students' abilities, as done by Khairun Nisa & Baidowi (2023) who selected interview subjects based on the initial ability category, and by Baharunnisa et al. (2023) who selected subjects based on the high, medium, and low categories of each personality type.

This stage is carried out to find out the problems and gaps that can occur in the learning process both from the teaching staff, students and the teaching materials used so that relevant modules can be developed, according to needs and in accordance with the curriculum applied. Based on the results of interviews with teachers and students, it was concluded that learning in the classroom still uses teaching materials in the form of package books provided by the school.

However, students find it difficult to understand the content of the book because the language used is difficult to understand so that students' understanding of chemical concepts is not optimal. According to Ramadhani et al. (2024), sentences that are considered appropriate are sentences that are easy for the human mind to understand. The application of effective sentences is very necessary when writing reading texts because the text conveys a message to the reader. The structure, pattern, and effectiveness of sentences in a text need to be considered so that the message contained can be conveyed clearly to the reader. A well-valued reading text consists of sentences that are in accordance with grammatical rules.

An analysis of the material and references that will be used in the development of teaching modules and an analysis of learning objectives is also carried out. The materials and references used are adjusted to be able to overcome existing gaps while the learning objectives are adjusted to the learning outcomes that have been set in the Learning Objectives Flow. Edelson et al. (2021) states that well-designed materials can support changes in teaching and learning practices, so alignment between the material and the learning objectives to be achieved is very important. The learning objectives are as follows: Students can understand the concept of elemental stability based on octet rules; Students are able to describe the Lewis symbol as a representation of valence electrons in the formation of chemical bonds; Students can analyze the concept of ionic bonds, how electrons move from one atom to another to form ionic bonds and the properties of ionic bonds; Students are able to use the Lewis symbol to describe the process of forming ionic bonds; Students can understand the concept of covalent

bonds, how electron pairs are shared between atoms to form covalent bonds and the properties of covalent bonds; and Students could use the Lewis symbol to describe the process of forming a covalent bond.

In this study, material analysis and references were carried out on 6 books from different publishers. Analysis was carried out on the completeness of the book's identity, book components and the content of the book. Analysis of books as references and materials in module development needs to review the completeness of identity, book components, and book content, as explained by Suryani et al. (2024) that the components of teaching modules include module identity, learning objectives, teaching materials, evaluation, and reference materials.

Design stage

At the design stage, several aspects are determined that must be present in the module to be developed. At this stage, several important data were produced, namely: Modules are packaged in accordance with the UbD stages, namely determining expected outcomes, designing assessments and assessments and designing learning activities that are able to encourage the achievement of expected learning outcomes; At the stage of determining the expected results, it is equipped with transfer, namely the ability of students to use their understanding, meaning consisting of essential questions and understanding and acquisition consisting of knowledge and skills; The assessment stage is equipped with performance tasks, evaluation criteria and evidence assessment. UbD's assessment emphasizes more on student performance. The results to be achieved in UbD are not directly on the highest ability but are arranged gradually because what is most expected in UbD-based learning is the understanding of students (Natala, 2023); Learning activities in the form of discussions, comprehension tests, analysis, activities and student worksheets that are done in groups and presented in front of the class. According to Saputra et al. (2024) the presentation of sample questions is an important part of teaching materials. Sample questions serve as exercises that can be done by students, thus helping them in understanding the material being taught; The modules developed have presented material that has an attachment to real-world situations and is able to encourage students to make connections between their knowledge and real-life application. Contextual teaching materials not only serve as a means of learning, but also guide students to analyze cases and apply the theories learned. This aims to increase student engagement and make learning more relevant to their daily experiences (Saputra et al., 2024).

Development stage

At the stage, modules are obtained that have been validated by Expert validator and can be tested. The modules that have been developed are validated by three (3) expert validators who simultaneously assess for material and media validation. The results of the analysis of the expert validator's assessment on the material aspect consisted of an assessment of the feasibility of the content, the feasibility of presentation, the contextual assessment and the assessment of the UbD aspect. In addition to the material aspect, expert validators also provide an assessment of the media aspect which consists of an assessment of the feasibility aspect of graphics and the feasibility aspect of language.

The important data obtained at this stage are presented practically by: The results of the validation of the subject matter experts on the developed modules obtained an average score of 87% with the category of "very feasible"; The results of the validation of media experts on the developed modules obtained an average score of 86% with the category of "very feasible"

The results of the assessment of the subject matter obtained an average score of 87%. The material experts gave an assessment of the modules developed and presented material that was in accordance with the learning objectives. In addition, the material presented is also in accordance with the development of chemistry and is presented with examples and cases in daily life. The development of learning materials that are relevant and contextual to students' daily lives is the key to creating meaningful learning. The alignment of teaching materials with learning objectives, as well as the updating of content in accordance with scientific developments, is an important foundation to support the paradigm shift from conventional teaching to student-centered learning and encourage high-level thinking skills (Suranti, 2022).

Meanwhile, the results of the assessment of the feasibility of the media obtained an average score of 86%. Media experts assessed that the modules developed were in accordance with the module size provisions with ISO standards. In addition, the module covers have consistently displayed layout elements on the front and back covers. The module cover is also designed with illustrations that describe the entire content of the material with a harmonious shape, color and size so that it can attract students' reading interest. This is in line with Winingsih (2021) stating that the design on the cover of the book must be as attractive as possible so that people's interest in reading is higher, not only that the cover design must be able to adjust the image to be conveyed and must be in accordance with the content of the book. By paying attention to the cover design that is made that is easy for readers to understand and easy to understand for its purpose and purpose, the

design must also be able to adjust the design of the book to the criteria of the target reader.

Based on the results of the analysis, it can be concluded that the *Understanding by Design* (UbD) based Chemical Bonding module that has been developed is suitable for use in learning activities.

Implementation Stage

At the implementation stage, a pretest was given to find out the initial abilities of students by providing 25 multiple-choice questions with a cognitive level of C1-C5 that had been validated in advance with questions with a level of C1 as many as 1 question, C2 as many as 7 questions, C3 as many as 9 questions, C4 as many as 3 questions and C5 as many as 5 questions. The questions presented have been adjusted to the learning objectives that must be achieved by the students. From the questions that have been designed, it is found that several questions must be improved to maximize the achievement of learning objectives. Based on the validated grid of test instruments, it can be concluded that it is necessary to improve the quality of the questions in learning objectives 2, 4 and 6 by adding questions in accordance with the learning objectives and the required cognitive level.

Then they are treated by learning students using the modules developed. The teaching and learning process is carried out five (5) meetings with a time allocation of 3 x 45 minutes. At the first meeting, students were introduced to the UbD-based chemical bonding module that had been developed. In this activity, students were given a brief explanation of what UbD is and how systematic UbD is. In the second to fourth meetings, learning began using the modules that had been developed. In the learning process using the UbD-based chemical bonding module, students showed enthusiasm in learning. Learning always begins with an explanation of the first stage (expected results) and the second stage (evidence collection/assessment and evaluation criteria) of UbD so that students understand what must be achieved and how the criteria prove that they have achieved it.

Evaluation stage

At the evaluation stage, a posttest is given with the same questions as the pretest to find out the final ability of the students. The data of the pretest and posttest results were then analyzed using the N-Gain test to obtain the percentage of N-Gain to determine the effectiveness of the module. In addition, an analysis of the practicality of the module was also carried out by asking for the responses of teachers and students to the developed modules. Based on the results of the analysis, the teacher's response with a score of 93% and the student's response with an average score of 93% with the category of "very practical" was obtained. Based on this data, it can be concluded that the modules developed are very practical to be used in the learning process.

Effectiveness of UbD-based modules

The effectiveness of the module was measured using pretest (30.11) and posttest (81.44) data. Table 1 shows the data where the posttest score is higher than the pretest score. From this data, the N-Gain percentage was obtained at 73.58% with a fairly effective category.

Table 3. Data Analysis of Module Effectiveness Results

Average	Value	N-Gain (%)	Category
Pre-test	30.11±SD	73.58	Quite Effective
Post-test	81.44±SD		

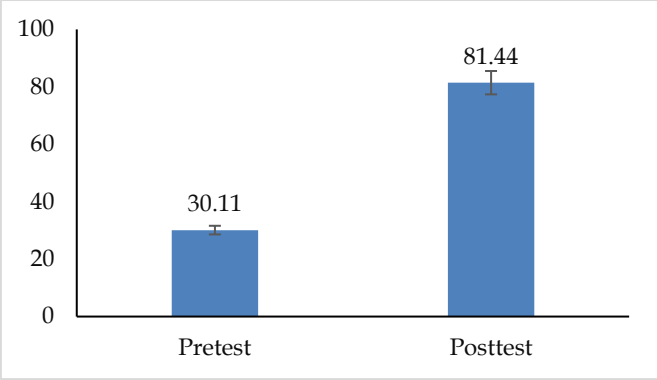

Figure 2. Module Effectiveness Graph.

From the results of the data above, it can be concluded that UbD-based modules are quite effective in improving student learning outcomes. This is in line with previous research which stated that the increase in students' academic achievement was higher in classes taught using the UbD principle (Erdağı & Dündar, 2024). Agree with the results of this study, Ozyurt et al. (2021) conducted a study on the effectiveness of the teaching model with UbD on science teaching and concluded that the application of the UbD model in science teaching effectively improved the academic achievement of students. Aslam et al. (2024) also reported that the implementation of UbD-based teaching significantly improved students' science learning achievement. The results of the module's effectiveness as shown in Figure 1.

Conclusion

The Understanding by Design (UbD)-based teaching module on chemical bonding material produces quality results, meeting the criteria of validity, practicality and effectiveness. The UbD-based module has very feasible validation criteria with material feasibility of 87% and media feasibility of 86%. The

teacher's response to the module obtained a score of 93% and the student's response obtained an average score of 93% with very practical criteria that showed the practicality of the module to use. Understanding by Design (UbD) based teaching modules developed for chemical bonding materials have proven to be of high quality and worthy of use. Based on the validation results, this module has excellent material and media feasibility. The level of practicality of the module is also very high, as evidenced by the positive responses of teachers and students who show that this module is easy and practical to implement in learning. A significant increase in student understanding is shown by an N-Gain score of 73.58% with the criteria of being quite effective. This improvement occurs because the UbD framework in the module facilitates more structured and centered learning on deep understanding. The module is designed with a "backward design" approach that emphasizes clear learning objectives, authentic performance assessment, and relevant learning activities. These features help students not only memorize, but also build a more meaningful understanding of chemical bond concepts through performance tasks and essential questions that encourage critical thinking.

Acknowledgments
The author would like to thank all validators who have validated the module developed in this study. Furthermore, the author would also like to thank all participants, namely students of class X-6 SMA Negeri 4 Medan and Chemistry Education Lecturers of UNIMED who have been willing to be the subjects of this study and fully participated in the data collection process.

Author Contributions
Developed the research instrument, conducted the research, and wrote the review of the research article, author R. N. Y.; supervised the research and writing of the article, authors S. D. and A. H. S. All authors have read and approved the published version of the manuscript.

Funding
This research received no external funding

Conflicts of Interest
The authors declare no conflict of interest.

References

Afrianti, N., Al Idrus, S. W., & Sari, D. P. (2024). Effectiveness of Discord instructional media integrated with chemical bond material. *Jurnal Penelitian Pendidikan IPA (JPPIPA)*, *10*(4), 1962–1970. https://doi.org/10.29303/jppipa.v10i4.6385

Altun, S., Yabaş, D., & Nayman, H. B. (2021). Teachers' experiences on instructional design based professional development: A narrative inquiry. *International Electronic Journal of Elementary Education*, *14*(1), 35–50. https://doi.org/10.26822/iejee.2021.227

Arikunto, S. (2010). *Prosedur penelitian: Suatu pendekatan praktik*. Jakarta: Rineka Cipta.

Aslam, A., Ahamd, S., Siller, H.-S., & Nasreen, A. (2024). Impact of the Understanding by Design Model on the Science Academic Achievement of Fifth Grade Students in Pakistan. *Asia-Pacific Science Education*, *10*(1), 113–153. Retrieved from https://brill.com/view/journals/apse/10/1/article-p113_5.xml

Baharunnisa, N., Suryani, S., & Baidowi, B. (2023). Efektivitas pendekatan pembelajaran berbasis proyek terhadap hasil belajar siswa. *Jurnal Penelitian Dan Pembelajaran IPA*, *5*(1), 85–94. https://doi.org/10.29303/jcar.v5i1.2800

D'angelo, T. L., Thoron, A. C., & Bunch, J. C. (2019). What is Understanding by Design (UbD. *EDIS*, *1*, 1–5. Retrieved from https://edis.ifas.ufl.edu

Danin, V. J., & Kamaludin, A. (2023). Development of Google Sites Based Learning Media on Chemical Bonds with Multilevel Chemical Representation. *Jurnal Penelitian Pendidikan IPA*, *9*(9), 6727–6733. https://doi.org/10.29303/jppipa.v9i9.1552

Edelson, D. C., Reiser, B. J., McNeill, K. L., Mohan, A., Novak, M., Mohan, L., Affolter, R., McGill, T. A. W., Buck Bracey, Z. E., Deutch Noll, J., Kowalski, S. M., Novak, D., Lo, A. S., Landel, C., Krumm, A., Penuel, W. R., Horne, K., González-Howard, M., & Suárez, E. (2021). Developing Research-Based Instructional Materials to Support Large-Scale Transformation of Science Teaching and Learning. *Journal of Science Teacher Education*, *32*(7), 780–804. https://doi.org/10.1080/1046560X.2021.1877457

Erdağı, T., & Dündar, H. (2024). Investigation of the Effects of Understanding by Design Model on Problem-Solving, Collaboration, and Academic Achievement in Social Studies Course. *Erzincan University Journal of Education Faculty*, *26*(2), 330–338. https://doi.org/10.17556/erziefd.1451042

Gloria, R. Y., Sudarmin, W., & Indriyanti, D. R. (2019). Applying Formative Assessment through Understanding by Design (UbD) in the Lecture of Plant Physiology to Improve the Prospective Teacher Education Students' Understanding. *Journal of Turkish Science Education*, *16*(3), 350–363. https://doi.org/10.12973/tused.10287a

Hendrawani, H. (2023). Katalog Miskonsepsi dalam Pembelajaran Ikatan Kimia. *Empiricism Journal*, *4*(2), 648–656. https://doi.org/10.36312/ej.v4i2.1729

Hidayat, F., & Nizar, M. (2021). Model Addie (Analysis, Design, Development, Implementation and

Evaluation) Dalam Pembelajaran Pendidikan Agama Islam Addie (Analysis, Design, Development, Implementation and Evaluation) Model in Islamic Education Learning. *JIPAI: Jurnal Inovasi Pendidikan Agama Islam*, *1*(1), 28–37. Retrieved from https://shorturl.asia/i0SyV

Hunter, K. H., Rodriguez, J. M. G., & Becker, N. M. (2022). A review of research on the teaching and learning of chemical bonding. *Journal of Chemical Education*, *99*(7), 2451–2464. https://doi.org/10.1021/acs.jchemed.2c00034

Khairun Nisa, L., & Baidowi, B. (2023). Deskripsi kemampuan pemecahan masalah siswa ditinjau dari kemampuan awal matematis. *Jurnal Penelitian Dan Pembelajaran IPA*, *5*(1), 65–74. https://doi.org/10.29303/jcar.v5i1.2639

Maryani, M., Nisak, M. S., & Supriadi, B. (2022). Implementasi media pembelajaran berbasis web google sites untuk meningkatkan kemampuan memecahkan masalah siswa SMA pokok bahasan gelombang bunyi. *Jurnal Penelitian Pendidikan IPA*, *8*(4), 2430–2438. https://doi.org/10.29303/jppipa.v8i4.2037

Natala, V. E. D. (2023). Implementasi Understanding By Design dalam Kegiatan Pembelajaran: Literatur Review. *Prosiding Seminar Nasional Ilmu Pendidikan FKIP Unila*, *2*(1). Retrieved from https://shorturl.asia/xgatm

Ozyurt, M., Kan, H., & Kiyikci, A. (2021). The Effectiveness of understanding by design model in science teaching: A quasi-experimental study. *Eurasian Journal of Educational Research (EJER)*, *94*. Retrieved from https://shorturl.asia/eTxY5

Pertiwi, S., Sudjito, D. N., & Rondonuwu, F. S. (2019). Perancangan Pembelajaran Fisika tentang Rangkaian Seri dan Paralel untuk Resistor Menggunakan Understanding by Design (UbD. *Jurnal Sains Dan Edukasi Sains*, *2*(1), 1–7. https://doi.org/10.24246/juses.v2i1p1-7

Ramadhani, A., Sustiani, D., Hardiansah, I. P., Fitri Maharani, K., Farradina, N. D., Purwo, A., Utomo, Y., & Madyaningtyas, R. S. (2024). Analisis Keefektifan Kalimat pada Teks Laporan Hasil Observasi di Modul Pembelajaran Bahasa Indonesia Tingkat SMA Kelas X. *Jurnal Ilmu Pendidikan*, *2*(6). https://doi.org/10.61132/morfologi.v2i6.107

Ramli, D. P. S., & Argaswari, D. P. A. D. (2023). Praktik Mengajar Understanding by Design (UbD) bagi Calon Guru Pendidikan Matematika di Universitas Sampoerna. *Edukatif: Jurnal Ilmu Pendidikan*, *5*(3), 1492–1504. https://doi.org/10.31004/edukatif.v5i3.4865

Rustamana, A., Sahl, K. H., Ardianti, D., & Syauqi, A. H. (2024). Penelitian dan Pengembangan (Research & Development) dalam Pendidikan. *Jurnal Bima : Pusat Publikasi Ilmu Pendidikan Bahasa Dan Sastra*, *2*(3). https://doi.org/10.61132/bima.v2i3.1014

Saputra, A., Asmidar, A., Putra, A., & Haq, C. (2024). Pengembangan Bahan Ajar E-Book Dalam Meningkatkan Literasi Siswa Pada Kurikulum Merdeka. *Dharmas Education Journal*, *5*(2), 890–899. https://doi.org/10.56667/dejournal.v5i2.1445

Suranti, T. (2022). *Pengembangan E-Modul Matematika Berbasis Etnomatematika pada Materi Persamaan Dan Pertidaksamaan Linier Satu Variabel* [Doctoral Dissertation: Institut Agama Islam Negeri Metro]. Retrieved from https://repository.metrouniv.ac.id/id/eprint/5847/

Suryani, E., Baidowi, B., & Ramdani, A. (2024). Pengembangan modul ajar berbasis outdoor learning untuk meningkatkan keterampilan berpikir kritis mahasiswa. *Jurnal Penelitian Dan Pembelajaran IPA*, *5*(1), 1–10. https://doi.org/10.29303/jcar.v5i1.8015

Suswanti, U. (2021). Penerapan Problem Based Learning (PBL) Meningkatkan Hasil Belajar Kimia. *TEACHING: Jurnal Inovasi Keguruan Dan Ilmu Pendidikan*, *1*(3), 127–136. https://doi.org/10.51878/teaching.v1i3.444

Tsaparlis, G., Pappa, E. T., & Byers, B. (2020). Proposed pedagogies for teaching and learning chemical bonding in secondary education. *Chemistry Teacher International*, *2*(1). https://doi.org/10.1515/cti-2019-0002

Tshering, S. (2022). The Impact of Using Understanding by Design (UbD) Model on Class 10 Student's Achievement in Chemistry. *IJCER (International Journal of Chemistry Education Research)*, *6*(1), 29–33. https://doi.org/10.20885/ijcer.vol6.iss1.art4

Wan, Q., Zuo, S., & Liu, Z. (2023). A case of reverse instructional design based on Ubd theory: take" set" as an example. *International Journal of New Developments in Education*, *5*(15), 114–118. Retrieved from https://shorturl.asia/Jeitu

Wiggins, G., & McTighe, J. (2005). *Understanding by Design*. United States of America: ASCD Publications.

Winingsih, N. (2021). Analisis Sampul Buku Tema " Udara Bersih Bagi Kesehtan" Book Cover Analysis Theme "Clean Air For Health. *Journal of Education and Culture (JEaC)*, *1*(2), 1–7. https://doi.org/10.47918/jeac.v2i2.1066