

Exploring Differentiated Learning Strategies to Respond to Differences in Students' Level of Understanding of Metal Inorganic Chemistry Course

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Abstract. Differentiated learning refers to educational schemes and materials individually developed about the varied needs of each student to improve knowledge understanding as individuals, as well as participation involvement. The study applied differentiated learning in the metal inorganic chemistry class of chemistry education to address student understanding variability. These strategies and their effect on student performance were studied through observations, surveys, and interviews in a mixed-method design. The findings portrayed that the application of differentiated learning helps boost the student's performance in understanding the concepts inorganic chemistry of metals. Additionally, the students showed higher satisfactions and engagements when the instructor incorporated different teaching modes, materials (videos, presentation materials, and books), and practical use of examples. Group discussion and collaborative learning among the students helped them better understanding and retention of the knowledge of metal inorganic chemistry.

Keywords: Differentiated learning, inorganic chemistry, learning strategies, diverse methods.

Introduction

As an integral part of the chemistry curriculum, the inorganic chemistry of metals plays an essential role in shaping students' understanding of the basic concepts of complex chemistry. However, the diversity of levels of knowledge among students is often an obstacle to achieving optimal learning goals. Some factors that cause differences in students' level of understanding in the metals inorganic chemistry course may come from different educational backgrounds (Sattin-Bajaj et al., 2023), previous experience (Malmberg & Martin, 2019), interests (Wang et al., 2015), and learning styles (Vizeshfar & Torabizadeh, 2018). Students with different educational backgrounds or levels of ability may respond to the learning material in various ways, leading to gaps in understanding the concepts of the inorganic chemistry of metals. Previous learning experiences at a particular educational unit will significantly influence the student's conception of the chemistry lesson material (Al Gifary et al., 2023)

Conventional learning approaches (Tatachar & Kominski, 2017) are often less able to adapt to individual differences in student understanding. A lack of responsive strategies

(Kumar et al., 2019) for individual learning needs can impede student academic progress and reduce overall learning effectiveness. As a result, developing and implementing differentiated learning strategies for learning the inorganic chemistry of metals becomes critical (Lim & Park, 2022). This strategy allows educators to adapt teaching methods (De-Abreu et al., 2022), learning approaches, and teaching materials (Flesca et al., 2024) to the individual learning needs of students, thereby improving their chances of understanding and mastering the learning material better.

Considering its significance, this research digs into the potential of differential learning strategies in responding to differences in student levels of understanding in an inorganic chemistry course on metals, which is becoming highly relevant and urgent. We anticipate that this research will significantly enhance the efficacy of chemistry education in universities, tackling the difficulty of fostering a comprehensive understanding among students with diverse backgrounds and skills.

Metal inorganic chemistry is a course that deals with metal elements' properties, structure, and reactivity. The materials taught include the concepts of metallurgy, metal reactions, complex compounds of metals, and the uses or applications of elements. (Holme, 2023). Metallurgy is the branch of science that studies metals' production, purification, and application (Liu & Rehren, 2024). In the study of the inorganic chemistry of metals, the concept of metallurgy encompasses the processes of metal extraction from mineral ore, metal refining, and metal manufacturing processes. It involves understanding the chemical reactions involved in the process, such as reducing metals from oxide or sulphide compounds, electrolysis, and the physical processing of metal (Morita et al., 2024). Metal reactions include various chemical reactions between a metal and another substance, whether it's another element, compound, or environment. Examples include a metal reacting with an acid to produce hydrogen gas, a metal reacting with water to produce metal hydroxide and hydrogen gas, and a metal reacting with oxygen to form metal oxide (Abdelkareem et al., 2024). Understanding these reactions is essential to understanding metals' chemical properties and uses.

A metal complex compound is a complex molecule consisting of central metal ions coordinated by molecules or other ions called ligands (Özkılıç, 2024). Metals have a wide range of applications in everyday life and industry. Some metals are used to manufacture construction materials, such as steel, aluminium, and copper (Yerasimou et al., 2023). Understanding the usefulness or application of the utilisation of these elements is essential to knowing the relevance and role of metals in various areas of human life.

Differential learning is an approach that tailors the learning process to the unique needs and characteristics of each student (Napitupulu et al., 2023). Its primary objective is to ensure that each student gets access to a curriculum that matches their ability and potential, as well as to enhance student motivation and involvement in learning (Langelaan et al., 2024). Differential learning strategies in higher education have attracted attention as an effective way to overcome differences in student understanding in complex courses such as inorganic chemistry of metals (Gómez-Tejedor et al., 2020).

Some principles underlying differential learning are recognition and respect for students' differences and diversity in their learning styles, needs, interests, and cultural backgrounds (Rugambuka & Mazzuki, 2023). Considering the above differences, the teacher adapts the teaching methods or strategies (Napitupulu, et al., 2020), the material, and the assessment to meet the student's needs (Walanda et al., 2022). The challenge for teachers is to be able to use a variety of teaching approaches and strategies that are flexible and responsive to the needs of students (Do et al., 2023). Teachers can also provide additional academic and emotional support to students who need it to ensure their learning success (Shen et al., 2024).

The differential pursuit strategy has a positive influence that distinguishes teaching critical reading learning from reading interest, as it allows the student to have a deep

insight into the target language, learn to see its abilities in new ways, and increase confidence in the learning objectives in English subjects (Sahril & Nur, 2021). Differentiated learning also positively impacts attitudes and learning outcomes in mathematics (Febriana et al., 2023). Differentiation strategies are an excellent way to improve the quality of learning at all levels of students (Am et al., 2023). However, specific contexts and educational environments influence the effectiveness of teaching applications. Earlier studies (Ju et al., 2023) have demonstrated the efficacy of differentiation learning strategies in improving student understanding and the importance of using flexible and responsive approaches to individual learning needs in complex chemistry learning contexts. This research explores differentiated learning strategies to overcome the different levels of knowledge of fourth semester students in metal inorganic chemistry courses.

Methods

The study uses a combination of qualitative and quantitative approaches (mixed methods) to explore differential learning strategies in response to differences in students' understanding of inorganic chemistry courses. The subjects of this study were students who took the metal inorganic chemistry course in the Chemistry Education Study Program at Tadulako University in the even semester of 2023/2024 academic year. The sample will be categorized based on course grades from odd-semester learning in non-metallic inorganic chemistry courses, diagnostic assessment scores in metal inorganic chemistry courses, and student learning preferences.

The instruments used in this study include a pre-research questionnaire which is used to identify students' initial level of understanding and learning preferences. The questionnaire was distributed to students before the start of teaching. Classroom observation sheet used to observe the implementation of differentiated learning strategies by lecturers. Classroom observations were conducted during the teaching period to observe the implementation of differentiated learning strategies. After the teaching process a written comprehension test used to measures students' understanding before and after implementing differentiated learning strategies. A comprehension test is conducted before and after implementing a differentiated learning strategy to measure the change in students' knowledge.

The researcher implemented the differentiated learning strategy as a lecturer of the metal inorganic chemistry course. The strategy implementation included providing additional materials for students with a low understanding of using several teaching methods, such as cycle learning, cooperative learning, and project learning. In addition to teaching methods, educational technologies such as online platforms and multimedia were actively used in learning metal inorganic chemistry. Individual feedback was given to students at the end of implementing differentiated strategies.

Data from questionnaires, observations, and comprehension tests were analysed qualitatively to interpret the results and linked to relevant theories and literature. Findings were discussed in terms of practical and academic implications.

Results and Discussion

Table 1 explains student preferences and choices for metal inorganic chemistry learning methods. Lecturers use this data to adjust learning strategies to be more effective according to student preferences and help improve student understanding of metal inorganic chemistry materials.

Students can develop a deeper understanding of the concepts and content by teaching metal inorganic chemistry in various ways. Different methods can provide new perspectives or additional explanations that help understand complex concepts in metal inorganic chemistry. Varied learning can also be more exciting and intellectually challenging for students as it can increase student engagement in the learning process and maintain their interest in the material being taught (Nordahl-Pedersen & Heggholmen, 2022).

Table 1. Student Learning Preferences

Student's opinion	SD	D	N	A	SA
I prefer to have the material taught differently, according to my understanding.	2	1	0	60	14
I feel more comfortable learning by using visualizations (videos, graphs, diagrams, etc.).	1	11	0	52	13
I understand the material better when the lecturer gives practice questions that vary in difficulty.	1	18	0	55	3

SD=strongly disagree, D=disagree, N=neutral, A=agree, SA=strongly agree

According to Table 1, the majority of students (60 individuals) express a preference for teaching the material at a level that aligns with their understanding level. Fourteen students strongly agree, and two students strongly disagree. Fifty-two students felt more comfortable learning with visualizations such as videos, graphs, or diagrams. 13 strongly agreed, and one strongly disagreed. Most students (55 people) decided they understood the material better when the lecturer gave practice questions that varied in difficulty. However, 18 students strongly agreed, while three students strongly disagreed.

The different levels of understanding of 77 students in learning inorganic metal chemistry are shown in Figure 1 below, where the experience level is scored from 10-100. The level of understanding is divided into 3: low level with a score of 10-49, medium level with a score of 50-69, and sound level with a score of 70-89.

Figure 1 illustrates the disparity in students' comprehension of metal inorganic chemistry content, particularly in relation to metallurgical materials and transition metal elements. Of the 25 questions or quizzes with a maximum score of 100, 14% of students with a low level of understanding scored between 20-49, or below 50% of the maximum achievement. Meanwhile, the moderate level, with scores between 50-69, is 35%, and the high level of understanding is 41% of 77 students, with scores between 70-89

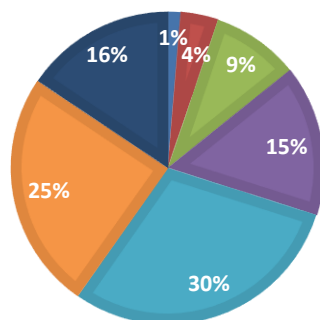


Figure 1. Initial student's level of understanding of the metals inorganic chemistry

Every student has a different learning style and level of understanding. Teaching the material with various methods helps to reach different learning styles, such as auditory, visual, or kinesthetic (Walanda et al., 2023). This allows students to find the most effective way of learning for themselves. By practicing problems with different difficulty levels, students can hone their problem-solving skills. Students learn different strategies and techniques to deal with various issues, allowing them to deal with varying difficulty levels, from easy to complex, and choose problems that match their current level of understanding (Willamo et al., 2018).

An observer monitored the implementation process of differentiated learning, observing the activities of both the instructor and students, as detailed in Table 2.

Table 2. Differentiated Learning Observation

Observer opinion	N	R	S	O	A
Lecturers often use different learning methods to explain the same concept.					√
Students are more interactive and collaborative in learning					√
Lecturers use various media (videos, presentations, books, and questions) to explain course materials.					√

N=never, R=rare S=sometimes, O=often, A=always

Implementing the differentiated learning model provides different learning outcomes for the initial assessment, as described in Figure 2.

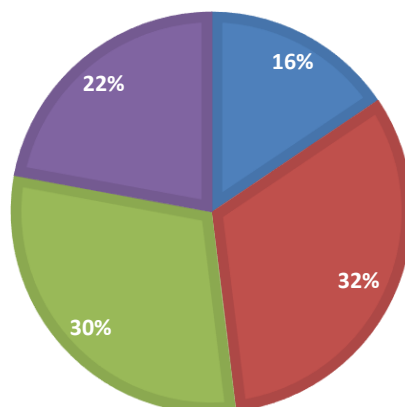


Figure 2. Student's level of understanding of metal inorganic chemistry after implementing differentiated learning.

Figure 2 shows that the level of understanding of students after the implementation of differentiated learning is at only four levels; namely, the level of experience is moderate (score 60–69), high (70–89), and very high (90–99). Table 3 below summarises students' opinions on the effectiveness of differentiated learning.

Various media (videos, presentations, books, and quizzes) can enrich the material presented, making it more exciting and easier to understand. It can also accommodate all learning styles, help students remember information for extended periods, and facilitate active and participatory learning (Chen & Wu, 2015).

Interaction and collaboration help students develop social skills such as communication, cooperation, and empathy. Discussion and collaboration can help students

deepen their understanding of the material by exchanging ideas and opinions, as well as increasing student motivation and engagement in learning. Students learn to work in teams, an essential skill in the working world (Dukuzumuremyi & Siklander, 2018).

Table 3. Effectiveness of Differentiated Learning Strategies

Students opinion	SD	D	N	A	SA
I find it easier to understand the material when the lecturer gives real examples or practical applications.	2	1	0	50	24
The use of group discussions in class helps me understand the material better.	1	8	0	63	5
Lecturers often give assignments appropriate to each student's level of understanding.	2	13	0	60	2

SD=strongly disagree, D=disagree, N=neutral, A=agree, SA=strongly agree

Table 3 shows that most students (50 agreed and 24 strongly agreed) felt it was easier to understand the material when the lecturer gave real examples or practical applications. Most students (63 agreed and five strongly agreed) felt that group discussions helped them understand the material better, although some disagreed (8 people). Most students (60 people) agreed that lecturers frequently gave assignments that were appropriate to each student's level of understanding, although some disagreed (13 people). The few students who disagreed with some statements indicate that there may still be room for improvement in applying these strategies. Table 4 depicts the satisfaction level of 77 students towards differentiated learning in metal-inorganic chemistry courses.

Lecturer can create a more dynamic, inclusive, and effective learning environment by frequently using different learning methods and various learning media and encouraging student interaction and collaboration (Stollman et al., 2019). This improves understanding and retention of the material and helps students develop a range of essential skills that benefit their academic and professional lives.

During group discussions, students can learn from the explanations and perspectives of their classmates, who may use language or modes of delivery that are easier to understand. Group collaboration allows students to share ideas, clarify understanding, and help each other solve problems. Group discussions encourage students to think critically, evaluate arguments, and develop solutions collectively. Discussions also allow students to resolve disagreements or confusion, helping to deepen their understanding of metal-inorganic chemistry materials (Jacobs et al., 2022).

Table 4. Differentiated Learning Recommendations and Satisfaction

Student's opinion	SD	D	N	A	SA
I am satisfied with how the lecturer manages different levels of understanding in class.	2	4	0	65	6
I feel that differentiated learning strategies should be applied more often in lessons.	1	7	0	64	5
I would recommend differentiated learning methods to other lecturers.	2	2	47	22	4

SD=strongly disagree, D=disagree, N=neutral, A=agree, SA=strongly agree

The data in Table 4 shows that most students (65 agreed and six strongly agreed) are satisfied with how lecturers manage different levels of understanding in class. The majority of students (64 agreed and five strongly agreed) expressed a strong belief in the frequent application of differentiated learning strategies. Most students (47 neutral) did not seem to have a strong opinion about recommending this method, but some agreed (22) and strongly agreed (4).

Differences strongly influence differences in students' understanding of metal inorganic chemistry in students' cognitive and intellectual abilities. Mental and intellectual abilities affect students' understanding of metal inorganic chemistry material (Halevi, 2004). Students with high analytical skills may more quickly understand complex concepts, while others may need more time and help understanding them. In addition, motivation and interest in specific topics also affect student understanding. Students interested in metal inorganic chemistry will tend to have a better experience due to their involvement in learning and are more eager to explore the topic. The availability of learning resources, such as textbooks, online materials, laboratories, and support from lecturers or tutors, can affect students' ability to understand and master metal inorganic chemistry materials (Reeves et al., 2021).

After knowing the level of student understanding of metal inorganic chemistry, learning was implemented with a differentiation model using the project-based learning method (Guo et al., 2020). We divided the students into three groups based on their understanding level: low, medium, and reasonable. The low-level group receives a project that covers the general properties of metals, including thermal and electrical conductivity, metal bonding properties, and the correlation between structure and properties. The medium level assigns projects that explore the reactivity of metals with non-metals, metal processing, the magnetic and optical properties of metals, metal complexation and coordination, and the industrial applications of specific metals. Projects at the excellent level focus on the physical and chemical properties of organometallic compounds, the synthesis of metal complex compounds, homogeneous and heterogeneous catalysis, and the applications of metals in nanomaterial technology and materials science. Each of these difficulty levels allows students to build a strong foundation in metal inorganic chemistry, ranging from basic understanding to applying more complex concepts in various application areas (Reeves et al., 2021). These difficulty levels also reflect the skills and knowledge expected of students at a specific stage of their lectures and advanced studies.

The implemented differentiated learning has been successfully carried out, demonstrating that lecturers frequently (score 5) employ diverse learning methods and media to elucidate the same concept, specifically metallurgy in inorganic chemistry. Various learning methods help students understand concepts from multiple perspectives, prevent boredom, maintain interest and motivation to learn, meet diverse learning needs, and encourage students to think critically and solve problems (Zen et al., 2022).

After implementing differentiated learning, low levels with scores between 20 and 59 no longer exist. This is because students learn according to their learning ability level. Lecturers adjust teaching materials and methods according to the needs and abilities of individual students, ensuring that students who need more help receive additional support. Conversely, lecturers provide additional challenges to students who grasp the material more quickly. Various media, such as videos, simulations, and electronic books, enrich learning resources and clarify complex concepts; interactive media, such as simulation software, help students better understand the structure and chemical reactions of inorganic metals. Methods that actively involve students, such as group discussions and collaborative projects, increase learning engagement and motivation and link the material with real-world applications and practical experiments, making learning more relevant and exciting, thus improving learning outcomes (Matzembacher et al., 2019)

Real examples or practical applications link the theory to real-life situations, making the material more relevant and simple to understand because abstract material becomes more concrete when explained through real examples, making it easier for students to understand complex concepts (Cenk et al., 2016). Students gain first-hand experience in applying the theory, thereby enhancing their memory and comprehension. Active engagement in practical learning helps to strengthen understanding as students are hearing, reading, and doing.

Customised tasks ensure that the challenge is appropriate to the individual's ability and neither easy nor difficult. Students are not frustrated by tasks that are too difficult, which can hinder their motivation and confidence. Tasks tailored to students' understanding levels allow students to gradually develop their knowledge, building concepts from primary to higher levels. Lecturers can emphasise areas where students need more practice, helping them to strengthen their understanding of weak areas (Musengimana et al., 2022). When students feel the task is challenging yet achievable, they feel rewarded for their efforts, which increases motivation. Students feel more satisfied with their learning when they see tangible progress through tasks matching their abilities.

The high level of satisfaction indicates that students appreciate the lecturer's efforts in managing different levels of understanding in class, and students feel that their individual learning needs are well taken care of and accommodated (Bosch, et al., 2021). Strong support for the more frequent application of differentiated learning strategies suggests that students see tangible benefits from this method, and it reflects that students feel that differentiated learning enhances their learning experience (Stollman et al., 2019). The high number of neutral responses may indicate that students are not yet fully confident about recommending this method or have not seen enough examples of successful implementation. It may also suggest that, although they are satisfied with their experience, they are not convinced that the method would work equally well in other classes or with different lecturers (Malmberg & Martin, 2019).

Factors that support students' satisfaction level in learning are tasks and methods tailored to each student's level of understanding, making them feel cared for and supported in their learning (Ahlstrom et al., 2023). The collaborative learning atmosphere can also increase learner satisfaction, allowing students to learn from their peers and deepen their understanding of the material. On the lecturer's side, providing immediate and relevant feedback helps students improve and better direct their learning (Cai et al., 2023). Students' desire to see these differentiated learning strategies and models applied more often in lessons indicates their high level of satisfaction with differentiated learning, particularly in how lecturers manage different levels of understanding.

The use of differentiated learning strategies in metal inorganic chemistry can have significant implications for teaching and learning practices in higher education. Differentiation strategies can increase learners' engagement in learning because students will be more motivated to learn when the learning material is relevant and appropriate to their needs (Aldalur & Perez, 2023). Learner engagement is defined as working in groups or teams with interests or abilities that engage in collaborative learning (Lapitan et al., 2023). Differentiation can also accommodate individual needs, allowing teachers to customise learning instructions to meet individual learning needs. Appropriate instruction will enable learners to learn at a level appropriate to their abilities, thus reducing the risk of learning gaps (Loibl & Leukel, 2023).

Teachers can provide more targeted and relevant feedback by understanding learners' needs and readiness levels. Feedback helps learners understand their strengths and areas for improvement in individualised learning (Cai et al., 2023). Differentiation strategies also help reduce students' frustration levels (Novak et al., 2023) by providing alternatives that match their abilities and interests, so that they are not overly stressed or overwhelmed by the learning material. Learning experiences at a level that matches

personal abilities will promote increased academic achievement (Basarkod & Marsh, 2023). With these implications in mind, educators can design and implement differentiation strategies more effectively, thus creating an inclusive and supportive learning environment for all learners (Walanda et al., 2023).

Conclusion

Differentiated learning strategies improved students' understanding of metal inorganic chemistry. Tailoring teaching methods to individual levels of understanding helps students better master the concepts taught. The majority of students were satisfied with the way lecturers managed different levels of knowledge in class. They appreciated using various teaching methods, including real-life examples, practical applications, and diverse learning media. The differentiated approach increased students' active involvement in the learning process by participating in discussions and completing tasks appropriate to their level of ability. Students feel more motivated when given tasks that match their level of understanding, making them feel challenged but not too difficult. Thanks to the support they receive through differentiated learning, they show increased confidence in understanding and mastering metal inorganic chemistry materials. Students support the application of differentiated learning strategies more frequently in learning. This approach enhances their learning effectiveness and warrants widespread adoption in the teaching of metal-inorganic chemistry. Although many students were satisfied, most were neutral about recommending the method to other lecturers. This suggests that, despite the perceived benefits, we need more evidence and consistent experiences to encourage wider adoption.

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