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A Proposed Learning Design: Application of Differential and Integral Concepts By Modeling the Heating Process of Glucose Solution

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ABSTRAK

The concepts of differential and integral are important topics in chemistry mathematics courses. Based on the number of subtopics, differential and integral concepts cover, on average, more than 40% of chemistry mathematics textbooks. Several previous studies have reported that differential and integral concepts remain difficult for students to understand. This research aims to evaluate the previous lecture program and propose an alternative learning design to help students more easily grasp these concepts. In this study, we developed a practicum by adopting Plomp's model, which involves collecting, designing, trying, and revising the product. The practicum design was developed for the heating process of glucose solution. These chemicals were chosen because the materials are relatively easy to obtain, inexpensive, and safe, making it highly feasible to practice in the laboratory. We used Maple to model the heating process phenomenon. The results show that differential and integral concepts can be effectively applied to model the heating process of glucose solution using Maple. This research is limited to simulations; therefore, the suggestion for further research is to conduct field trials to determine the impact of implementing the learning design on increasing students' understanding of differential and integral concepts.

Keyword: chemistry mathematics, differential and integral, modeling, maple

INTRODUCTION

The ability to understand and apply mathematics is crucial in every branch of chemistry, including inorganic, organic, physical, biochemistry, and analytical chemistry (Akaygun & Aslan-Tutak, 2016; Çalış, 2020; Cunningham & Whelan, 2014; Havia et al., 2023; Özsoy-Güneş et al., 2012). In the Chemistry Education Program, the application of mathematics in chemistry is primarily concentrated in the chemical mathematics course. The fundamental objective of this course is to facilitate students in learning the application of mathematical concepts in chemistry. By having a good understanding of chemical mathematics, students are expected to grasp the concepts of subsequent chemistry courses more easily (Paristiowati et al., 2022; Yik et al., 2022).

We examined the lesson plan references and source books used in chemical mathematics lectures. Based on calculations of the number of subtopics and time allocation in the lesson plan from several universities in Indonesia, the coverage of differential and integral concepts averages around 37% in the chemical mathematics course. Some universities developed lesson plan with subtopic percentage compositions and time allocations above 50.0%. Similarly, the coverage of topics in differential and integral calculus in chemical mathematics books (Cunningham & Whelan, 2014; Steiner, 2008) ranges above 40% when calculated from the number of subtopics. This illustrates that mastery of differential and integral calculus material is crucial for students as a foundation for studying advanced chemistry. Therefore, a good understanding of differential and integral calculus material is highly important for students in the chemical mathematics course.

In the field, it is found that students still experience difficulties in understanding chemical mathematics material. This is evidenced by data showing that 56% of students' Final Semester Exam scores at one Teacher Training and Education Institution in Central Kalimantan were still below 70 for the Academic Year 2021/2022 in the chemical mathematics course. The percentage of students experiencing difficulties is still relatively high. Evaluation of the chemical mathematics program is necessary during the course activities (Yik et al., 2022). Therefore, the mathematical domain within chemistry requires program evaluation.

One of the program evaluations is conducted by understanding the opinions of education service users. Program evaluation should involve assessing the satisfaction and perceptions of students, parents, or other stakeholders regarding the education program. Evaluators will gather feedback and opinions from respondents directly involved in the program. This helps to understand the success of the program from the user's perspective and evaluate the extent to which the program meets the needs and expectations of respondents (Fitzpatrick et al., 2012). The consumer approach is an evaluation method that emphasizes the users or consumers of the program, such as students and teachers. In the context of academic programs, this approach can be used to obtain input from consumers or users of the program regarding their needs and expectations of the program.

This research aims to propose an alternative learning design to help students more easily understand complex scientific concepts. By developing a practical approach, we utilized a modified version of Plomp's model. This model typically consists of several steps, but for this particular study, we selected only a few crucial steps: collecting data, designing the practicum, trying it out, and revising the product as needed. This selective application was intended to streamline the development process and focus on the most impactful aspects of the practicum.

The practicum was specifically designed to explore the heating process of glucose solution. These particular chemicals were chosen due to their accessibility and affordability, as well as the fact that they pose minimal safety risks. This makes them ideal for use in a laboratory setting, providing a practical and safe environment for students to engage in hands-on learning. The choice of materials also ensures that the practicum can be easily replicated in various educational settings without requiring specialized equipment or resources. To enhance the understanding of the heating process phenomenon, we employed Maple, a computational tool, to model the process. This approach not only facilitated the visualization of the adsorption dynamics but also allowed for the analysis of different variables and conditions. By integrating computational modeling with practical experiments, the research aimed to provide a comprehensive learning experience, enabling students to grasp both theoretical and practical aspects of the topic. This blended approach is expected to foster a deeper understanding of scientific principles and improve students' problem-solving skills.

This study offers several significant benefits, both theoretically and practically. Theoretically, this research contributes to the development of innovative learning models in chemical mathematics by integrating mathematical modeling with real chemical phenomena. The application of Plomp's development model with the PEE'SI (Problem, Equations, Equations', Solution, Interpretation) approach also enriches the literature on educational design methodology, especially in the context of higher education. Practically, the proposed learning design provides an effective alternative for lecturers to teach differential and integral concepts in a more contextual and applicable manner. For students, this approach is expected to reduce learning difficulties, enhance understanding of abstract mathematical concepts, and improve data interpretation and mathematical modeling skills. Additionally, the use of accessible materials such as glucose solution and Maple software makes this learning design feasible to implement in various educational laboratories, supporting the dissemination and adoption of this method in other chemistry education institutions.

This study aims to develop an alternative learning model based on the analysis of the perceptions of 24 students regarding the chemical mathematics course program, particularly on the topics of differential and integral calculus. The main focus of this research is to understand how students perceive and respond to the existing teaching methods, as well as to find ways to improve the effectiveness of learning on topics that are often considered difficult by the majority of students.

RESEARCH METHOD

The two main stages conducted in this study were the evaluation of learning and the development of the proposed design. The learning evaluation used a consumer approach to understand students' perceptions after participating in the chemical mathematics course program. The second stage involved program development. Based on students' perceptions, the findings guided the design of alternative learning models. The learning design development adopted Plomp’s model, which includes collecting, designing, trying, and revising the product. This stage was limited to simulations conducted solely by the research team and was not implemented with students.

Participants were Chemistry Education students at a university in Central Kalimantan. A total of 24 students consented to participate. During the interviews, all participants were fourth-semester students who had completed the Chemical Mathematics course in their third semester. The research instrument was administered via Google Form, containing 28 closed-ended questions with answer options and open-ended sections for participants to express their opinions. The questionnaire was completed online within one week, and responses were automatically recorded.

Data were analyzed qualitatively using NVivo. The open-ended responses were processed following six stages of Interpretative Phenomenological Analysis (IPA) by Smith et al. (2009): reading and reviewing responses, coding transcripts, identifying emerging themes, examining thematic relationships, repeating the process for consistency, and summarizing to develop concept maps and diagrams interpreting respondents’ perceptions.

Participants confirmed the analysis results through feedback to minimize subjectivity and ensure findings reflected true interpretations. All confirmed and approved the results. NVivo was used to prevent errors during coding, and Google Form facilitated automatic data transcription.

The proposed learning design focused on differential and integral calculus topics in the chemical mathematics course and was based on issues identified in the learning evaluation phase. Following Plomp’s model, the design process began by analyzing evaluation findings and topic characteristics. Next, the learning program was developed to apply differential and integral concepts through modeling the heating process of glucose solution using Maple. The design was simulated internally during the trying stage without student involvement. Revisions were made based on evaluations conducted during this stage.

RESULTS AND DISCUSSION

The research results include findings from the learning evaluation and the proposed learning design development.

The Learning Evaluation Phase

In the closed-ended questionnaire results, respondents were asked to choose answers provided in the survey form. Answers are automatically recorded in the platform available within Google Form. Percentages exceeding 45% are reported in almost all aspects except for understanding notations and symbols. The highest aspect is found in the difficulty level of the material (87.5%) and recommendations to link phenomena to concepts (91.7%). To strengthen the findings, we conducted triangulation by providing an open-ended questionnaire that allowed students to provide perceptions in the form of reviews. Findings based on triangulated data show five major themes that can be grouped: difficulties, constraints, recommendations, learning, and initiatives. Themes related to difficulties, constraints, and recommendations are more dominantly expressed compared to other themes based on students' perceptions.

Difficulties

The first theme found is the difficulties experienced by students during their chemical mathematics lectures, especially in the topics of differential and integral calculus. Based on participants' responses, there are three categorizations of difficulties experienced by students when studying differential and integral calculus: mathematical operations, concept application, and interpretation. According to the analysis of perceptions provided by students, mathematical operations are the most dominant area of difficulty experienced by students.

Mathematical operations such as symbols, notations, and mathematical terms used in calculations become challenging factors for students. Symbol naming significantly influences students' learning of differential and integral calculus. Difficulty in distinguishing the correct symbols becomes a constraint as chemical formulas appear almost identical to students. Students' difficulty in interpreting symbols creates the perception that in chemical mathematics, especially in differential and integral calculus, many formulas with similar appearances have different meanings. This affects students' understanding in selecting the appropriate formulas in mathematical operations. Students admit to facing difficulties when working on formula derivations. Additionally, the abundance of formulas and lengthy solution steps also pose challenges for students. Another difficulty expressed by students is in visualizing data tables in the form of graphs or diagrams. Students feel confused when relating tables to graphs and vice versa. Some students also struggle to understand graphs. The difficulties experienced by students are related to their interpretation skills. These skills are linked to students' ability to translate empirical data into visual models.

Students should also have the ability to apply these skills to chemical problems. This serves as an indicator that students can apply mathematical concepts in the context of chemistry. Field findings indicate that students admit to facing difficulties when applying mathematical concepts to chemistry. Based on students' perceptions, differential and integral methods are considered lengthy problem-solving methods when applied in chemistry. Students express that these methods are challenging and complicated. The difficulties experienced by students are not only in mathematical operations but also in connecting them to chemistry.

Constraints

The second theme derived from students' perspectives can be categorized as constraints. Students provided opinions based on their experiences during lectures. Based on the questionnaire responses, the constraints experienced by students are grouped into six categories: lecturer explanations, learning activities, textbooks, learning motivation, and exam questions. Among these categories, lecturer explanations are most frequently mentioned as a factor hindering students in learning differential and integral topics.

The most dominant constraint experienced by students is related to the personal approach of lecturers in delivering the material. Based on the tendency of opinions expressed by students, lecturer explanations are acknowledged as the biggest constraint. Lecturers are perceived as emotionally distant, leading students to feel hesitant to ask questions when they do not fully understand the material. The lecturers' teaching style is also perceived as monotonous and merely following the textbook guidelines. Students feel that the teaching methods lack variety. Lecturers are also seen as assigning students to presentations but rarely providing feedback and linking the material to real-life situations.

Another factor that acts as a constraint is the learning activities. Students explain that lectures are conducted online and are predominantly in the form of presentations. Lecturers rarely provide feedback, so students only receive explanations from their peers during presentations. Moreover, lecturers are seen as rarely discussing exam questions and their explanations during the learning process. Students feel that such learning activities hinder their understanding of the lecture material. Students argue that topics in chemical mathematics lectures, especially differential and integral calculus, are less effective if taught solely through presentations and should also be linked to chemical phenomena. For students, lectures conducted online also pose a constraint in understanding the material.

Textbooks have the potential to be a hindrance for students. The formulas provided lack comprehensive explanations, causing confusion among students. The formulas presented are often direct equations without sufficient accompanying explanations. Students also explain that errors in writing are sometimes found in the modules provided. Personal issues are voiced by students as barriers for them to study differential and integral materials. These personal hindrances are related to motivation. In the questionnaire responses, many students admit that they are not particularly fond of calculations and rarely revisit differential and integral materials. This becomes a barrier for students to understand the material well and can trigger difficulties for them. Therefore, learning designs that can enhance students' learning motivation are highly necessary in lectures. Another potential hindrance is the exam questions provided by lecturers. During the chemical mathematics lectures attended by the participants, exam questions sometimes differ from the materials studied. Some students argue that some calculations tested in the questions are significantly different or have not even been explained in the lectures.

Recommendations

The third theme found in the questionnaire responses can be categorized as recommendations expected by students. These recommendations are provided by participants based on their experiences during chemical mathematics lectures, especially in the topics of differential and integral calculus. Based on the categorization conducted by ourself, there are 7 points of recommendations put forward by the participants. These recommendations represent the opinions given by students for differential and integral calculus lectures. Based on their experiences during the lectures, the main points obtained are as follows: (1) learning should not be conducted solely online, (2) teaching materials should be easily understandable, (3) a combination of theory and practice, (4) additional lecture hours and peer tutors, (5) more detailed explanations, (6) provided with examples of application, and (7) not solely relying on classmates' presentations.

Learnings

From the students' perspective, the fourth theme, based on the analysis of participant questionnaire data, is categorized as learning activities in the chemical mathematics course, specifically in the topics of differential and integral calculus. We then divides the learning theme into 3 categories: online lectures, presentations, and concept application. According to students' perceptions, the form of concept application provided by lecturers is mainly limited to solving problems. Lecturers relatively seldom relate concepts to everyday life. The application of concepts has never been directly linked to chemical phenomena, only remaining theoretical. Furthermore, the teaching activity commonly implemented by lecturers is presentations. Students are assigned to prepare materials in the form of PowerPoint presentations and deliver them. Students acknowledge that during lectures, lecturers more frequently assign presentations to students and rarely provide explanations and feedback. The lecture activities experienced by students are conducted online. Learning activities utilize internet modes with the assistance of video conferencing applications such as Zoom or Google Meet. Lecturers predominantly conduct lectures using the lecture method delivered online.

Initiatives

From the questionnaire results, students proposed initiatives to address the issues they encountered during the lectures. Our analysis found that there are 3 initiatives undertaken by students: seeking help from lecturers, learning from other sources, and seeking help from peers. Among these three initiatives, seeking help from peers is the most dominant. Students admitted feeling more comfortable and understanding when asking peers who understand better. The smallest form of initiative is seeking help from lecturers. This was expressed by students because they felt hesitant and afraid to ask directly to the lecturers. Another initiative is learning from other sources, whether it be teaching materials or references from the internet such as YouTube.

The Proposed Learning Design Development Phase

The instructional design emphasizes the subjects of differential and integral calculus within the chemical mathematics curriculum. This focus is a response to challenges identified during the evaluation phase of the learning process. By addressing these specific areas, the aim is to improve student comprehension and engagement, particularly in topics that are frequently perceived as challenging. The development process takes a structured approach to ensure that the resulting educational strategies effectively meet students' needs.

The development process follows the stages outlined in the Plomp’s model, which are collecting, designing, trying, and revising the product. In the initial stage, data is gathered to identify the key issues and areas of improvement. Next, the design phase involves creating a new instructional approach or refining existing methods to better address these issues. The trying phase then implements the designed approach in a real-world educational setting to observe its effectiveness. Finally, based on feedback and observed outcomes, the product is revised and improved to better meet the learning objectives and enhance the overall educational experience.

Collecting Step

Differential and integral calculus are fundamental components of chemical mathematics courses, reflecting their crucial role in the discipline. An analysis of textbooks (Steiner, 2008 and Cunningham & Whelan, 2014) reveals that these topics constitute over 40% of the content, highlighting their importance in the curriculum. This substantial coverage is due to the wide range of applications these mathematical tools have in solving complex chemical problems. For instance, differential calculus is essential for understanding rates of reaction and changes in temperature, while integral calculus is vital for calculating quantities like total energy changes and the area under a curve representing a reaction pathway. The depth and breadth of these topics within the coursework ensure that students gain a comprehensive understanding of both theoretical and practical aspects, equipping them with the necessary skills to tackle real-world chemical phenomena.

The study of differential calculus includes the introduction to the basic concept of differentiation, rules for differentiating various types of functions such as polynomials, exponential, logarithmic, and trigonometric functions. Additionally, it covers advanced techniques like partial differentiation, which is useful for analyzing functions with multiple variables, as well as product and quotient rules used for differentiating the product or ratio of two functions. One important application of differential calculus is finding the stationary points or equilibrium points of a function, where the first derivative of the function is zero. On the other hand, integral calculus focuses on the fundamental concept of integration as the area under a curve, which is the reverse process of differentiation. The discussion includes integration notation, basic integration rules, and techniques for calculating the integrals of various types of functions, including polynomial, exponential, and trigonometric functions. This subject also encompasses numerical integration methods, such as the trapezoidal rule and Simpson's method, which are useful for numerically calculating integrals when analytic solutions are challenging to obtain. Furthermore, integral calculus covers both definite integrals with specific bounds and indefinite integrals that yield the original function plus a constant of integration. The use of variable separation techniques and integral substitution is also discussed to simplify the computation of complex integrals. By understanding these concepts, students can apply integration techniques in various contexts, including solving differential equations and finding the original function from a derivative.

Designing Step

Proposed according to Spanier (1980), Table 1 outlines the stages of learning about heating process through an in-depth mathematical approach, utilizing concepts of differential and integral calculus, along with the Maple software. Students begin by identifying problems from real-world phenomena by doing practicum, formulating mathematical equations, simplifying the equations, modeling solutions, and interpreting the results. These stages aim to sharpen students' analytical skills, critical thinking, and technical abilities in modeling and analyzing adsorption phenomena, thereby providing a deep understanding and relevant skills for scientific research.

Table 1. The Proposed Learning Design

Steps	Aims	Activities	Expected Outputs
Problems	Provide opportunities for students to identify and formulate problems based on the phenomena that occurs.	Conducting practicum related to differential and integral concepts.	Temperature vs. time curve
Equations	Draft and design mathematical approaches to solve problems based on appropriate differential and integral concepts.	Guiding students to create a flow of concepts and principles related to solving the phenomena found.	General equations
Equations'	Identify parameters related to the completion of the mathematical approach by simplifying the equations that are prepared.	Applying *Maple software* in analysing phenomena.	The function of changing temperature on time.
Solution	Formulate the most ideal approach in the form of mathematical modeling to solve problems with the help of Maple.	Applying *Maple software* in analysing phenomena.	Temperature modeling to time.
Interpretations	Analyze solutions and interpret the form of solutions obtained.	Developing ideas owned by students.	Fittings against the phenomenon of heating process

Source: Data processed (2024)

This instructional design presents the stages of learning heating process through an in-depth mathematical approach, utilizing concepts of differential and integral calculus, along with the Maple software. This approach is very appropriate for developing the analytical and technical skills of students, which are essential in the modern era where mathematical modeling and data analysis play a significant role in scientific research. The use of real-world phenomenon-based laboratories, such as heating process, not only facilitates theoretical understanding but also nurtures the students' ability to apply knowledge in real-world situations. This creates a bridge between theory and practice, which is a crucial component in science education. Additionally, the integration of Maple software in data analysis equips students with the necessary tools to face the challenges of modern research. Thus, this approach not only builds a strong foundation in scientific understanding but also prepares students for careers requiring critical thinking and complex analysis.

Trying Step

The learning stages such as problem, equations, equations', solution, and interpretation (PEE'SI) by Spanier (1980) were tested by ourselves. During the problems stage, we conducted laboratory activities as detailed in Table 1. The subsequent laboratory data were input into Maple. The data, plotting temperature (y-axis) versus time (x-axis), displayed a logistic curve pattern. Initially, the temperature changes rapidly and then slows down until it reaches a maximum point. In the equations stage, we identified that the general pattern could be modeled as a logistic function: f(x)=K/(1+e^(-ax)). Subsequently, the variables of the logistic function were modified to dT(t)/dt=a.T(t)(1-

T(t)/K). The logistic modeling obtained in the equations stage was then integrated to derive a solution for the equation, resulting in T(t)=T_b/(1+((T_b-T_0)/T_0) e^(-(0.1293+0.0543C)t)). The function T(t) models the relationship between temperature changes and time. During the interpretation stage, the T(t) function is further used to apply differential and integral concepts to solve the given case in problem form. The problems step aims to observe real-life phenomena. In the equation's steps, equations and solutions are formulated to enhance modeling skills. To apply differential and integral concepts, a case study in problem form is presented during the interpretation stage.

Revising Step

We have conducted a feasibility test on the proposed instructional design. We recommend some revisions for several components to enhance activities. This approach is intended to optimize the time spent on laboratory activities. Students will process data that combines the results from their own practical experiments with those supplied by the laboratory staff.

A program is designed with the aim of achieving specific targets. The chemistry mathematics course program is structured to assist students in learning the course material. Students are expected to have a good understanding after completing the program. In other words, a program that is implemented should facilitate students in learning course material. To determine this, the course program needs to be evaluated. According to Fitzpatrick et al. (2012), one of the program evaluations that can be conducted is the consumer approach. This evaluation prioritizes the consumer's perception as the direct user of a program.

At universities, students are consumers who directly feel the implementation of the course program. Students' perceptions can be a source of evaluation for the implementation of course activities. In the chemistry mathematics course program, the percentage of topics on differential and integral calculus is above 40% based on the analysis of the number of subtopics. This becomes one of the strong foundations for the need for program evaluation in the chemistry mathematics course, particularly on differential and integral calculus topics. Therefore, students' perceptions of the program are highly necessary as one form of evaluation.

Experiences during the course will shape students' perceptions of a course program. Based on the analysis of questionnaire results, there are 5 categories of students' perceptions found: difficulties, constraints, recommendations, learning, and initiatives. From these five categories, three topics were found to be most dominant in students' perceptions: difficulties, constraints, and recommendations. The difficulties experienced by students include mathematical operations, application of concepts, and interpretation. Furthermore, students perceive factors considered as constraints such as lecturer explanations, textbooks, learning motivation, and exam questions. Another dominating category of perception found is in the form of recommendations. Students provide recommendations as a form of learning activities they expect. Based on experiences during the course, students express their opinion that learning should be conducted offline, with additional class hours, and a combination of theory and practice.

The difficulties perceived by students are closely related to mathematical concepts in chemistry. As many as 33.3% of students still experience difficulty in understanding the notation and symbols used in differential and integral calculus materials. Students feel confused with mathematical terms applied in chemistry. In their perception, the naming or writing of mathematical terms is still relatively difficult, making chemical formulas appear almost the same and difficult to distinguish. Students also believe that mathematical operations to solve differential and integral equations are relatively complex and lengthy. This results in students being less skilled in solving mathematical operations such as derivative equations.

In addition to mathematical operations, students also experience difficulties in interpretation skills. The results of the questionnaire responses indicate that students admit they are still unable to translate data into graphical form and vice versa. They feel unskilled when representing empirical data into visual models. As many as 45.8% of participants find it difficult to interpret empirical data into visual models. Complex mathematical operations and low interpretation skills have an impact on the ability to apply concepts. As many as 58.3% of participants encounter difficulties in applying differential and integral concepts to solve chemical problems. Field findings indicate that students admit to having difficulty applying concepts to chemical phenomena Based on the findings from the questionnaire responses, students' difficulties are attributed to lecturer explanations, learning activities, textbooks, learning motivation, and exam questions. The most dominant constraint felt by students is lecturer explanations. Students feel hesitant and afraid to interact and discuss with lecturers. Students prefer to ask friends rather than directly asking lecturers if they have difficulty with the material. As many as 45.8% of participants admit to never seeking help from lecturers when facing difficulties.

The teaching style of lecturers is also acknowledged by students to be monotonous and confined to the content of the book. Explanations provided during lectures rarely offer feedback and link the material to chemical phenomena. Lectures conducted online and explanations based solely on presentations make students feel less understanding of the material. This is acknowledged by 54.2% of participants that the delivery of material provided by lecturers is unclear. Similarly, the textbooks used in lectures are difficult for students to understand. Students feel that the textbooks do not provide informative and comprehensive explanations. Formulas in the textbooks are mostly presented directly without explanations. As many as 50% of students express that the teaching materials used in lectures are relatively difficult to learn. Another factor that poses as a constraint is learning motivation and exam questions. Many students express that they are not particularly fond of the concepts of differential and integral calculus. Some of them admit to rarely reviewing the material. Likewise, the form of exam questions given by lecturers is acknowledged by students as a constraint. As many as 54.2% of participants express difficulty in answering the questions. Some exam questions are significantly different from the material reviewed by the lecturer.

The responses provided by students in the questionnaire are also found in the form of recommendations and initiatives. These recommendations can be represented as suggestions made by students for the chemical mathematics course program. Students highlight the learning activities implemented by lecturers. The most significant tendency is that in differential and integral calculus lectures, examples of concept application need to be provided. Students want lectures to connect the material with chemical phenomena. There should be a combination of theory and practice. Material explanations should also not be solely entrusted to peers but rather to lecturers who are more dominant in delivering the material. Lecturers are expected to provide more detailed explanations and not conduct lectures solely online. To address this, some students take the initiative to ask friends or seek other sources. Initiatives to seek help from lecturers are relatively few. Additionally, additional lecture hours from peer tutors and easily understandable teaching materials need to be provided in the lecture program. Overall, the recommendations provided by students are for the design of a lecture program that can link chemical phenomena with differential and integral concepts.

In chemistry, mathematics acts as an instrument that plays a role in reasoning science referring to accuracy and regularity (Cunningham & Whelan, 2014; Schandel et al., 2020; Shubin & Volodin, 2020). Patterns in every chemical process are studied and analyzed, which are then represented in the form of equations (Erduran & Kaya, 2019). At the university level, mathematical operations are increasingly used to explain chemical concepts in a more complex manner. Numerical estimates of differential and integral equations in kinetics are used to predict the rate and mechanism of chemical reactions. Mathematics plays a role in drawing conclusions by observing patterns and regularities that emerge from an empirical phenomenon. Mathematics provides models that quantify chemical phenomena (Gamsjäger & Wiessner, 2018; Hohm, 2022; Qian et al., 2018). Modeling can be done by applying differential and integral concepts (Carpena et al., 2002; Cunningham & Whelan, 2014; Steiner, 2008). With modeling, mathematical equations can be used as the basis for calculations based on empirical results or initial predictions for unobserved variables (Attary, 2018; Augner & Bothe, 2021; Buchowiecki, 2022; Gamsjäger & Wiessner, 2018; Hohm, 2022; Kim et al., 2018; Qian et al., 2018).

Based on the review of students' perceptions, there are three major areas that need to be the focus in the development of the Chemistry Mathematics course program, especially for the topics of differential and integral calculus, namely difficulties, obstacles, and recommendations. Subsequent research can be designed based on these three areas. Difficulties, obstacles, and recommendations are interrelated. In the topics of differential and integral calculus, the difficulties acknowledged by students tend to revolve around mathematical operations, application of concepts, and interpretation. Students express that the teaching style of instructors during lectures is the main obstacle affecting their difficulty in understanding the material. To address these issues, recommendations provided by students include the need for improvement in the subsequent course program. Students expect the course program to be designed by integrating theory and practice. They not only want to learn theory but also gain real-life experience connected to chemical phenomena in everyday life. Subsequent researchers can develop the Chemistry Mathematics course program, especially for differential and integral calculus topics, that integrates practice and theory. Students need to be guided to observe phenomena and then interpret them based on mathematical concepts. Learning chemistry should ideally start from observing phenomena that occur and then formulating them into mathematical modeling (Erduran & Kaya, 2019).

The learning design proposed in this study modifies the stages of mathematical modeling by Spanier (1980), which include problems, equations, equations', and interpretation. This modification aims to create a sequence of learning steps that actively engage students in connecting mathematical concepts with real-life experiences. By adapting Spanier's model, the research seeks to enhance students' understanding by framing problems in familiar, everyday contexts, allowing them to see the practical applications of equations and mathematical principles. The approach encourages students to develop their equations and interpretations based on these real-world scenarios, fostering a deeper comprehension of abstract mathematical ideas. Ultimately, this learning design strives to make the educational experience more relevant and meaningful, thereby improving student engagement and retention of the material. The real-life learning activities mentioned involve practical experiments, with a specific focus on the heating process of glucose solutions. We designed and executed a series of lab activities to provide hands-on experience with this topic. During these practical sessions, students collected data, which was subsequently simulated using Maple software. This software facilitated the visualization of the experimental data, allowing for a more comprehensive analysis through mathematical modeling. The outputs generated by Maple were instrumental in helping students interpret the results, providing a clearer understanding of the adsorption process and its underlying principles. This approach not only reinforced theoretical knowledge but also demonstrated the practical applications of mathematical models in real-world scenarios.

Subsequently, the function formulas derived from the simulation modeling were utilized as the primary equations for applying the concepts of differential and integral calculus. We developed a set of questions related to these primary equations, designed to guide students in applying differentiation and integration techniques. These questions served as practical exercises, enabling students to explore the real-world applications of these mathematical concepts. By engaging with these problems, students were encouraged to practice finding derivatives and integrals, deepening their understanding of how these operations can be used to analyze and solve complex problems. This approach not only reinforced theoretical learning but also highlighted the relevance and utility of differential and integral calculus in various scientific and engineering contexts.

The learning design, which incorporates mathematical modeling into the differential and integral calculus curriculum, is intended to facilitate real-life applications for students. By integrating these concepts into practical, everyday scenarios, the design aims to bridge the gap between abstract mathematical theories and tangible experiences. This approach encourages students to see the relevance of calculus in solving real-world problems, making the learning process more engaging and meaningful. The incorporation of real-life contexts not only helps in understanding complex concepts but also prepares students for future professional challenges where they might apply these skills. Ultimately, this teaching strategy seeks to enhance students' problem-solving abilities and critical thinking by providing them with tools to model and analyze real-life situations using mathematics.

CONCLUSION

Students identified three key areas needing improvement in the Chemistry Mathematics course for differential and integral calculus: difficulties with mathematical operations, concept application, and interpretation, largely linked to lecture teaching styles. They recommended a course design that better integrates theory with real-life practice, enabling connections between chemical phenomena and everyday experiences. Future research should focus on developing a Chemistry Mathematics curriculum that combines theoretical content with practical applications and mathematical modeling to enhance students’ problem-solving and critical thinking skills, better preparing them for professional challenges by highlighting calculus’s relevance in real-world contexts.

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