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Learning Difficulties in Biochemistry: Student Perspectives and Emerging Trends

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Abstract

This study analyzes students' learning difficulties in understanding biochemistry concepts, materials, and processes through a survey, and examines bibliometric patterns of biochemistry learning models and methods to identify potential alternative solutions. A descriptive research design was employed, combining survey methods and bibliometric analysis. The survey was conducted with 82 fourth-semester students of the Chemistry Study Program, including Class B (48 students) and Class E (34 students). Data were collected using an open-ended questionnaire and analyzed descriptively and qualitatively. In parallel, a bibliometric analysis of scientific articles on biochemistry learning difficulties was performed using VOSviewer software, identifying dominant sub-themes such as learning models, learning methods, and biochemistry education. The survey results indicate that students experience the greatest difficulties in protein biosynthesis (82%), lipid metabolism (55%), enzymes (53%), protein metabolism (50%), and carbohydrate metabolism (45%). These findings highlight challenges with metabolic pathways and molecular structures, emphasizing the need for visualization-based learning media. Additionally, the bibliometric analysis suggests that flipped classroom and blended learning approaches have strong potential as innovative strategies to address these difficulties. The study concludes with recommendations for future research focused on the development and evaluation of such approaches in biochemistry education.

Keywords: bibliometrics, biochemistry learning difficulties, blended learning, flipped classroom, surveys

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1. Introduction

Biochemistry is one of the core courses in the chemistry education curriculum at the higher education level (Barbosa & Galembeck, 2022). This course serves as a bridge between basic chemical principles and complex biological processes, including metabolic pathways, biomolecular structure and function, and enzymatic reactions. However, several studies have shown that students often experience difficulties in learning biochemistry due to its high cognitive demands, extensive technical terminology, and the requirement for advanced abstract and visual thinking skills (Salame et al., 2022; Mnguni, 2024). In the Chemistry Study Program, Faculty of Mathematics and Natural Sciences (FMIPA), Universitas Negeri Yogyakarta (UNY), Biochemistry is a 3-credit course (3 SKS). The learning process is implemented through discussions, case-based lectures, and project or assignment-based activities, with case studies and projects contributing 50% of the overall course assessment. College students generally experience difficulties in memorizing the sequence of metabolic reactions, understanding the three-dimensional structure of molecules, and integrating concepts across different topics (Juwita et al., 2023). Moreover, biochemistry instruction in the classroom still tends to rely heavily on rote learning and lecture-based approaches, whereas students require a more in-depth, interactive, and contextual understanding of concepts (Erman et al., 2022). This mismatch creates a gap between the teaching strategies employed and both the nature of the subject matter and students' learning needs.

One approach to mapping scientific knowledge is bibliometric analysis. Bibliometrics is a widely used method for examining and understanding large bodies of scientific literature through statistical and quantitative techniques to identify patterns in academic publications, thereby helping researchers observe trends, developments, and key contributions within a field of study (Donthu et al., 2021; Kumar, 2025; Arianingrum et al., 2023). In essence, bibliometric analysis evaluates and categorizes bibliographic data in a given scientific domain. This computer-assisted approach processes metadata from electronic databases, extracts indicators such as the h-index, and produces scientific maps using specialized software (Lazarides et al., 2023).

Several studies have proposed innovative approaches to overcoming learning difficulties in biochemistry. The use of 3D visual models, for example, has been reported to be effective, with 83% of students agreeing that 3D animation helps them better visualize biochemical molecular conformations (Abdinejad et al., 2021). Scaffolding has also been shown to enhance students' investigative awareness, positively influencing 19 out of 30 learners (Al Mamun & Lawrie, 2023), and was found to be effective in helping 88 students (21 high-achieving and 67 lower-achieving) explain biochemistry-related socio-scientific issues scientifically (Erman et al., 2022). In addition, the integration of green chemistry into biochemistry learning has been reported to play an important role in building biochemical ethics, as evidenced by 77% of students achieving a "fairly good" category (Mamluaturrahmatika et al., 2024). However, most of these studies are either conceptual in nature or conducted outside the Indonesian context. To date, there has been a limited number of studies that systematically map Indonesian students' learning difficulties in biochemistry while concurrently linking these difficulties to global research trends through bibliometric analysis.

Building on this background, this study aims to analyze students' learning difficulties in understanding biochemistry learning materials and processes through a survey, and to examine bibliometric patterns of biochemistry learning models and methods in order to propose alternative solutions and recommend relevant instructional approaches. By integrating survey data with bibliometric analysis, this research is expected to make a substantive contribution to the design of biochemistry instruction that is more effective, contextual, and aligned with both students' learning needs and current trends in the scientific literature.

2. Research Method

This study employed a descriptive research design, combining survey methods with bibliometric analysis. The population consisted of students in the Chemistry Study Program, FMIPA UNY, who were enrolled in the Biochemistry course. The participants were fourth-semester students from two classes, Class B and Class E with 44 and 38 students, respectively. The study was conducted in May 2025 at FMIPA UNY.

Data were collected using a questionnaire, as presented in Table 1. The instrument was adapted from Dewi (2021) and consisted of open-ended questions addressing indicators related to difficulties in biochemistry content and the biochemistry learning process. The questionnaire was validated through expert judgment to ensure content relevance and clarity. The responses obtained were then analyzed qualitatively using percentage techniques. Furthermore, a bibliometric analysis was conducted to identify appropriate learning models and methods that could provide solutions to students' difficulties in learning biochemistry. The . Questionnaire Instrument for Students' Learning Difficulties in Biochemistry Material can be seen in Table 1.

Table 1. Questionnaire Instrument for Students' Learning Difficulties in Biochemistry Material

No	Question
1	At the beginning of the lecture, do the lecturers give the Biochemistry Semester Learning Plan (RPS) to students?
2	Do students have difficulty understanding biochemistry courses on: 1. Carbohydrates 2. Protein 3. Lipids 4. Carbohydrate metabolism 5. Lipid metabolism 6. Protein metabolism 7. Protein Biosynthesis 8. Enzyme 9. Vitamins, Minerals and hormones 10. Transport of substances If Yes, write down the difficulty section of the selected material in the description field!
3	Do students feel happy with the lecturer's learning method used?
4	Is the interaction between students and lecturers well formed in biochemistry courses?
5	Does the assessment of this course take into account individual work and group work in biochemistry courses?
6	Does the cooperative learning model (group-based) help students actively understand biochemistry courses?
7	Do lecturers inspire and motivate students in the learning process in biochemistry courses?
8	Do students understand the material better if the lecturer uses the discussion method in the biochemistry learning process?
9	Does the lecturer provide good guidance to students who have difficulty understanding biochemistry courses?
10	Do the lecturers explain and facilitate the learning activities of the Biochemistry course on all materials well?
11	Do students need additional teaching materials that are more visual such as pictures, videos, and animations?
12	Do students feel that the teaching materials are helpful enough in understanding the learning process in the biochemistry course?

3. Result and Discussion

3.1. Results and Analysis of the Difficulties of Learning Biochemistry

The results of the questionnaire on students' difficulties in the biochemistry learning process in Class B and Class E of the Chemistry Study Program, FMIPA UNY, are presented in Figure 1. The data indicate that the lecturer responsible for the biochemistry course provides a RPS at the beginning of the semester and also offers motivation and encouragement during lectures. Nevertheless, 61 students (74.4%) reported experiencing difficulties in understanding the biochemistry course, whereas 21 students (25.6%) indicated that they did not experience such difficulties, as shown in Figure 1.

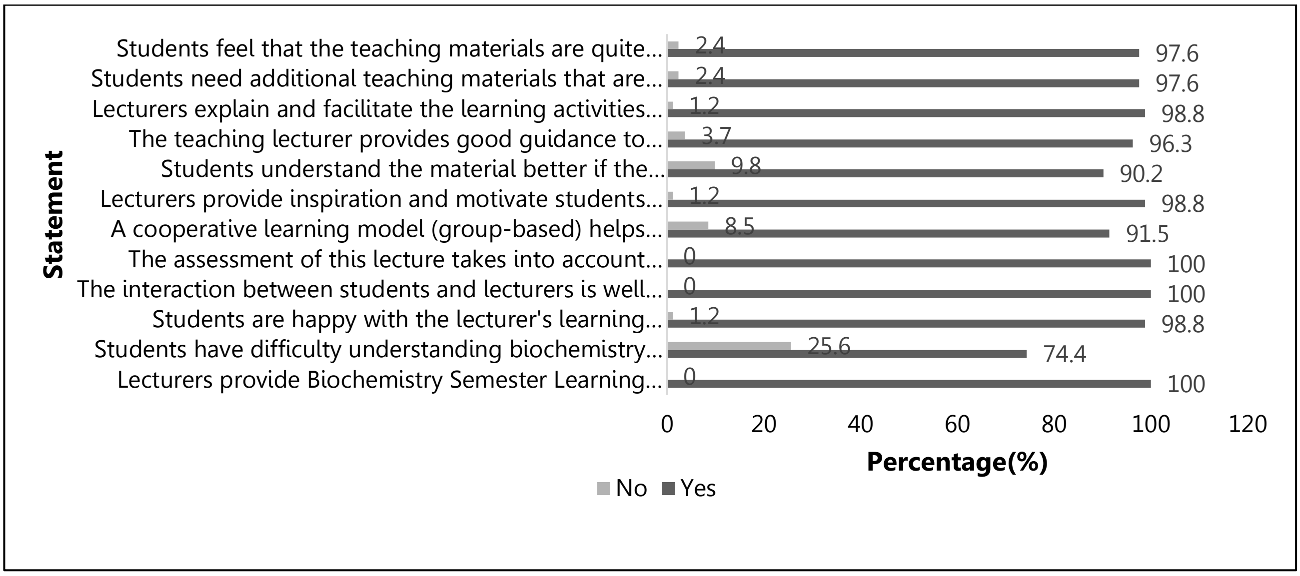

Figure 1. The Importance of Studying Biochemistry for Students

The red bars in the figure represent "yes" responses, while the blue bars represent "no" responses. The results show that 81 students (98.8%) reported feeling satisfied with the learning methods used by the lecturer, whereas only one student (1.2%) reported dissatisfaction; students indicated that they understood the material better when it was explained and discussed directly with the lecturer. Furthermore, 75 students (91.5%) stated that cooperative (group-based) learning helped them actively engage with and understand the biochemistry course, and 74 students (90.2%) reported that they understood the material more effectively when the lecturer employed discussion-based methods. However, the student responses also suggest that not all topics can be easily understood through cooperative or discussion-based learning alone, particularly complex and conceptually dense topics such as protein biosynthesis, carbohydrate metabolism, protein metabolism, lipid metabolism, and enzymes. For these topics, students expressed a need for more in-depth reinforcement and support.

Based on the course contract and RPS provided by the lecturers, biochemistry learning at UNY is organized such that 50% of the activities are case study-, project-, or assignment-based, and the course carries a weight of three credits, excluding practicum sessions. The main teaching methods used in class are lectures and discussions. The lecture method is primarily applied to topics such as carbohydrates and lipids, whereas the discussion method is employed for topics that require deeper conceptual understanding, including protein metabolism, lipid metabolism, and protein biosynthesis, with lecturers assigning different projects for each of these themes. This teaching strategy is intended to encourage students to first explore and understand the biochemistry material independently, after which the lecturer provides reinforcement at the end of the lesson. Furthermore, 80 students (97.6%) reported that they needed additional teaching materials with stronger visual components, such as images, videos, and animations, and 71 students (86.6%) stated that such materials were quite helpful in supporting their understanding of biochemistry. Students also indicated that visualization and the integration of socio-scientific issue (SSI)–based content can facilitate a better understanding of biochemical concepts.

The survey findings related to the learning process are consistent with several previous studies, which indicate that learning difficulties are not only linked to students' and teachers' scientific knowledge and representations but also to the teaching practices implemented in the classroom

(Haatainen & Aksela, 2021; Pichardo et al., 2021). According to Mnguni (2024), the learning process should also include activities that support students' visualization skills in order to minimize misconceptions and difficulties with abstract concepts. Research by Erman et al. (2022) further demonstrates that the use of scaffolding sets plays an important role in helping students understand and explain biochemical concepts as well as SSI related to science. In today's digital era, where information is often presented broadly and generally; therefore, scaffolding is needed to help students connect such information with deeper scientific and technological knowledge.

3.2. Results and Analysis of Difficult Biochemical Materials According to Students

Figure 2 presents the questionnaire results on students' difficulties with biochemistry content in Classes B and E, based on their self-reported experiences while taking the course. Figure 2 show that students experience the greatest difficulties in understanding biochemical topics related to protein biosynthesis (82%), lipid metabolism (55%), enzymes (53%), protein metabolism (50%), and carbohydrate metabolism (45%). In absolute numbers, 31 students reported difficulty with protein biosynthesis, 21 with lipid metabolism, 20 with enzymes, 19 with protein metabolism, and 17 with carbohydrate metabolism. Research by Kurniawati and Jailani (2020) and Salame et al. (2022) indicate that the large number of technical terms, as well as the need to memorize stages, enzymes, intermediates, and reaction sequences, contributes substantially to these learning difficulties. Students generally do not agree that rote memorization is the best way to understand and master biochemical content; instead, they emphasize the importance of deep conceptual understanding. In line with this, Demirci and Oktay (2021) report that concept mapping can help students grasp micro-level concepts such as protein synthesis and facilitate the formation of meaningful connections between related ideas, making concept maps a promising alternative strategy to strengthen biochemistry learning.

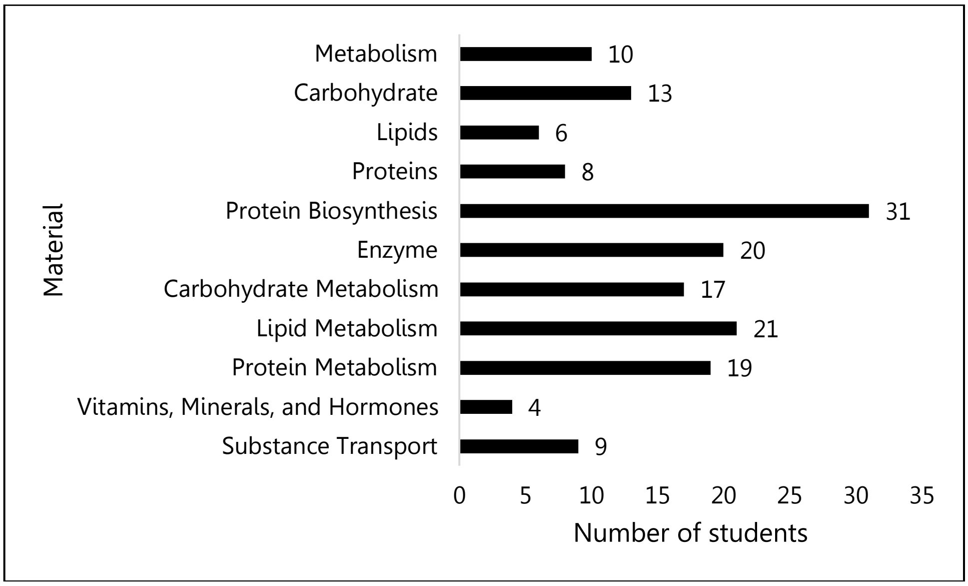

Figure 2. Material that is Difficult to Learn From The Student's Point of View

Kurniawati and Jailani (2020) note that metabolic content in learning resources is generally presented in the form of flow charts accompanied by molecular structures, chemical formulas, molecular names, arrows indicating reaction direction, and the enzymes that catalyze each step. The complexity and level of detail in this material require students to understand or memorize numerous sequential processes, which in turn worsen their learning difficulties in biochemistry. To address this, self-paced learning tools such as *Metro Metabolism* developed by Lee et al. (2024) and *iMtool* developed by de França and Campos (2021) have been shown to help students study metabolic pathways in a more interactive and accessible manner, significantly improving their understanding and knowledge.

Similarly, Ferreira et al. (2023) reported that the use of *Enzigame*, an instructional game developed to explore key concepts of metabolism and enzymatic activity, provides substantial benefits for students. *Enzigame* simulates enzymatic processes in the body and is accompanied by explanatory texts, enabling learners to significantly enhance their understanding through play-based activities.

3.3. The Next Innovation of Biochemistry Learning According to the Student's Point of View

Findings related to student suggestions for biochemistry learning are presented in Table 2.

Table 2. Answers for Students in Grades B and E for Biochemistry Learning Innovations in the Future

Category	Student Answers	Frequency of Similarities
Teaching Materials	Need additional teaching materials that are more visual such as videos, animations, and images to be clearer in visualizing the material, learning summaries, especially complex materials, additional references	14
Individual and group assessments	Presentations, individual assignments and group projects, giving additional points to students who give feedback	6
Learning Model	Requires further discussion with lecturers after group assignments because they are constrained to understand other confusing material and better understand the material itself	8
Material	Requires a more detailed explanation, especially protein biosynthesis,	31
Learning Methods	It is necessary to add quizzes/games that include learning materials so that they are not full of material only, materials that look complex require further explanation by lecturers, explanation of concepts in case studies, linking biochemistry material with SSi	5
Motivation	How to memorize quickly	3

Findings from students' suggestions in Table 2 indicate that innovations involving additional teaching materials in the form of videos, animations, and images can help students visualize biochemistry content, thereby addressing one of the key factors contributing to their learning difficulties. Similar results have been reported by Long et al. (2021), who found that the use of animation increases student engagement and confidence in understanding the connectivity between metabolic pathways and metabolic regulation. The use of electronic learning media that incorporate animations, videos, and images has also been shown to improve conceptual understanding and learner autonomy (Sa'adah & Ikhsan, 2023; Fitri et al., 2023). Furthermore, combining a flipped learning approach with animated videos and images facilitates students' understanding of electron transport and molecular biochemistry (Wikandari et al., 2021; Jefferies & Jefferies, 2022; Stadlinger et al., 2021). Teaching materials developed using the ADDIE model.

Another innovation suggested by students is the provision of systematic feedback from lecturers following student presentations, in order to clarify and align their understanding of the biochemical concepts taught, particularly complex topics such as carbohydrate, lipid, and protein metabolism, as well as protein biosynthesis. Feedback given on each learning activity is essential for enhancing student learning (Irons & Elkington, 2021), as it provides opportunities for students to develop their metacognitive skills and monitor their learning progress (Nowak et al., 2023), and it ultimately supports the achievement of more effective learning outcomes (Grønlien et al., 2021).

Students also expressed the need for innovation in learning methods through the combination of *quizzes*, games or *liveworksheets*, case studies, and the integration of biochemistry into real-life contexts, including SSI. Such approaches can help create a more immersive learning experience (Vossoughi et al., 2023), focusing not only on content mastery but also on fostering a sense of meaning in learning (Jia & Ren, 2025). The use of electronic worksheets (LKPD) supported by *liveworksheets* has been shown to improve higher-order thinking skills (Marpaung et al., 2023). Abdelazim et al. (2023) reported that quiz-based learning via smartphones was positively received by students, with 50% stating that the application was easy to use and 100% agreeing that the breadth of knowledge presented was comprehensive. In addition, the use of case studies in learning has the potential to inform future research and provide practical insights for both practitioners and researchers (Casino et al., 2021)

3.4. Bibliometric Analysis for Problem-Solving Solutions in Learning Difficulties

To obtain the initial data, the researchers used the keywords "learning model," "learning method," and "biochemistry" with the assistance of the Publish or Perish software, targeting publications from the last 10 years (2014–2024) and limiting the search to 200 articles. After further screening and analysis based on the specified keywords, a total of 19 relevant articles were identified: two from Semantic Scholar, five from Crossref, one from OpenAlex, and 11 from Google Scholar (Table 3). These results indicate that research on learning models and methods in biochemistry is still relatively limited.

Table 3. Number of Articles Obtained by Keyword

Source	Number of Articles		
	Beginning	Middle	End
Scopus	200	19	0
Semantic Scholar	200	4	2
Crossref	200	5	5
OpenAlex	200	2	1
Google Scholar	200	11	11
Total			**19**

The analysis identified dominant sub-themes including learning models, learning methods, and biochemistry, resulting in 19 selected articles that met the inclusion criteria: nine from national journals indexed in SINTA 1–4 and 10 from international journals indexed in Scopus Q1–Q4. The increase in the number of published research articles on biochemistry learning models and methods in higher education from 2014 to 2024 is shown in Figure 3.

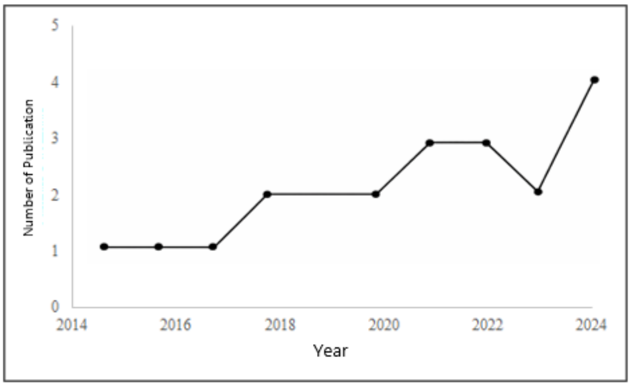

Figure 3. Number of Publications of Chemistry Learning Models and Methods in 2014-2024

Figure 3 shows that the number of articles published annually between 2014 and 2024 varies. The highest number of publications occurred in 2024, while the fewest were recorded between 2014 and 2017. Overall, the data indicate that the number of studies on biochemistry learning models and methods in higher education fluctuated between 2017 and 2024. All article data obtained were stored in ".ris" format for subsequent analysis.

In this study, VOSviewer software (version 1.6.20) was used as the main analytical tool to visualize and analyze key elements in the form of knowledge graphs, which are presented in three views: network visualization, overlay visualization, and density visualization, generated from metadata (Eck & Waltman, 2023). Through the co-occurrence network view, the researchers were able to identify which terms are most closely related and interconnected within the VOSviewer network (Xie & Waltman, 2025).

The VOSviewer analysis of the title and abstract fields identified 661 terms across 19 articles that met the inclusion threshold. These terms were visualized into distinct clusters, with each cluster represented by a different color. Following further analysis, the data were grouped into five clusters containing interrelated keywords. The keywords representing each cluster derived from the VOSviewer analysis are presented in Table 4.

Table 4. Keywords that Represent Each Cluster

Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
Biochemistry course	Cooperative learning	Flipped classroom	Blended learning method	Active learning
Biochemistry student	Technical jigsaw	Higher education	Pbl	
Cooperative flipped learning method				

Each cluster in Table 4 groups together related terms or topics, highlighting the most prominent keywords that appear across the analyzed articles. The network visualization generated in VOSviewer illustrates the relationships between these keywords and the corresponding publications, with different colors indicating distinct clusters (McAllister et al., 2022). The resulting network visualization from VOSviewer is presented in Figure 4.

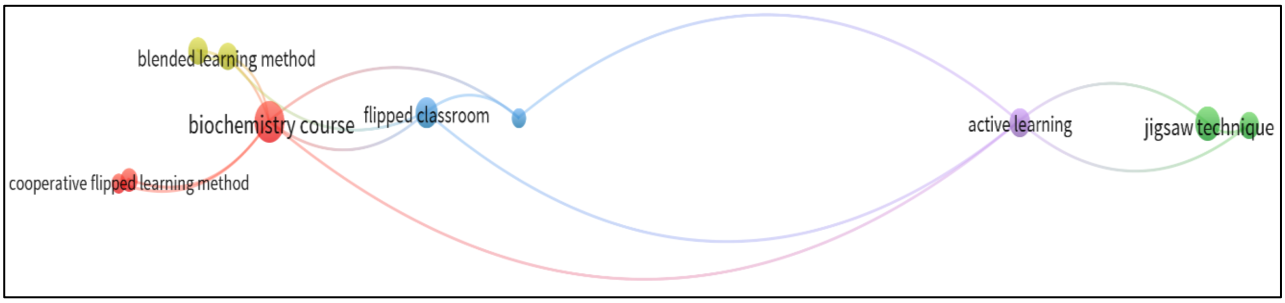

Figure 4. Network Visualization Model and Biochemistry Learning Methods

Figure 4 illustrates a strong relationship between biochemistry learning and the use of various learning models and methods. Cluster one is represented by red nodes, Cluster two by green nodes, Cluster three by blue nodes, Cluster four by yellow nodes, and Cluster five by purple nodes. The visualization highlights the item "biochemistry learning" as a central node that is connected to multiple other terms, indicating its high level of association with related concepts. To further examine these relationships and derive evidence-based recommendations regarding emerging trends, as well as learning models and methods relevant to future biochemistry education, the overlay visualization from the VOSviewer analysis is presented in Figure 5.

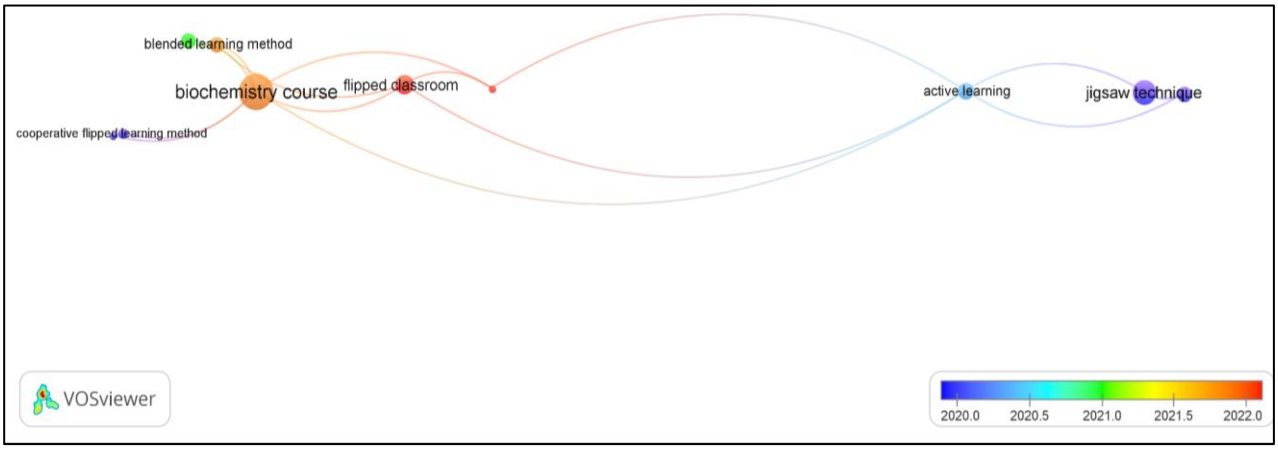

Figure 5. Overlay Display Visualization of Biochemistry Models and Learning Methods

Analysis of the overlay visualization in Figure 5 shows that current research trends in biochemistry education are still centered on the relationship between the flipped classroom model and biochemistry learning, as well as on blended learning methods. The red shading on the "flipped classroom" keyword indicates that research on this topic is relatively recent, suggesting substantial potential for novelty in addressing students' learning difficulties in biochemistry. This pattern is further supported by the density visualization generated by VOSviewer, as presented in Figure 6.

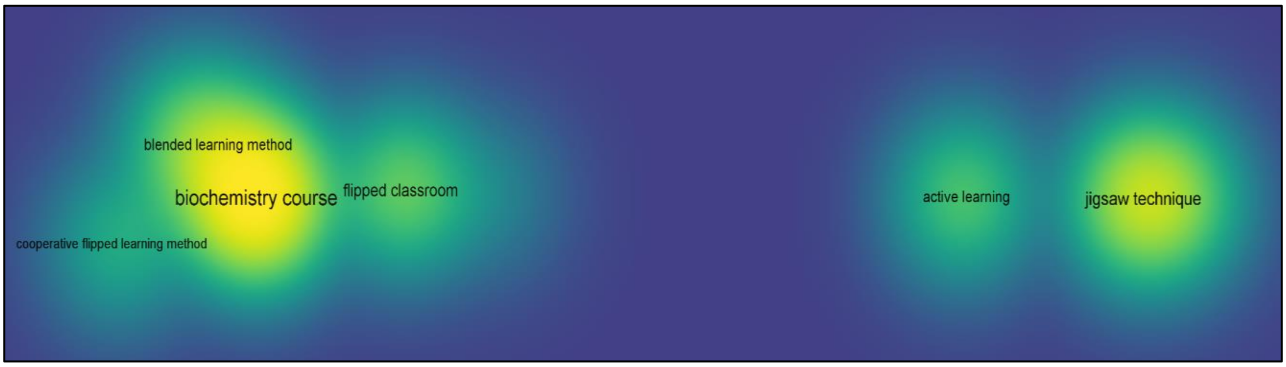

Figure 6. Overlay Display Visualization of Biochemistry Models and Learning Methods

Figure 6 presents the density visualization of research developments on models and methods in biochemistry learning. In this type of visualization, each item is represented by a dot whose color reflects its density (Mulyawati & Ramadhan, 2021). Areas appearing more yellow indicate stronger and more frequent associations among items, while greener areas indicate weaker or less frequent associations. This pattern suggests that there remains substantial room for researchers, educators, and librarians to further explore and expand research linking the flipped classroom model and blended learning methods as innovative approaches to addressing students' difficulties in learning biochemistry, and it highlights promising directions for future studies.

The flipped classroom model was first introduced by Bergmann and Sams (2012) to provide flexibility for high school students who were unable to attend all class sessions, with learning activities completed by students prior to face-to-face meetings. Research by Ajmal and Hafeez (2021) shows that the flipped classroom model is an effective strategy for enhancing students' self-efficacy compared with traditional lecture-based instruction. In addition, flipped classrooms have been found to promote a student-centered learning environment and increase student attendance (Talbert & Bergmann, 2023). A meta-analysis by Doğan et al. (2023) reported that the implementation of flipped classrooms has a moderately positive effect on academic achievement in science courses (g = 0.727), with the strongest impact observed in small class settings (Z = 8.608). Eichler (2022) further recommends that researchers and practitioners in chemistry education focus on optimizing skill-based flipped classroom practices and fostering a deeper conceptual understanding of chemical thinking.

The blended learning method is an approach that combines face-to-face instruction with electronic technologies, providing flexibility in education and enabling students to engage in learning anytime and anywhere (Ayob et al., 2023). The advantages of blended learning include increased effectiveness and knowledge retention, greater active engagement of learners in online sessions, and the meaningful integration of technological advancements into the learning process (Sharma et al., 2022). Research by Sánchez-Ruiz et al. (2023) indicates that the successful use of ChatGPT within blended learning requires a balanced approach in which teachers and educational institutions carefully monitor its use to ensure that it supports, rather than hinders, the learning process. Furthermore, the integration of ChatGPT has been shown to facilitate more effective learning experiences in blended environments and to promote higher levels of student engagement (Lee et al., 2024).

4. Conclusion

Based on the survey data, students experience the greatest difficulties in understanding biochemical content, particularly in protein biosynthesis (82%), lipid metabolism (55%), enzymes (53%), protein metabolism (50%), and carbohydrate metabolism (45%). The bibliometric analysis supports these findings, indicating that global research increasingly emphasizes flipped classroom models and blended learning approaches integrated with technology to enhance students' understanding of biochemistry. These approaches are therefore identified as promising directions for future research. Accordingly, the integration of active learning models and technology-enhanced methods should be strongly considered in the design of biochemistry curricula. This study contributes to mapping learning needs in biochemistry based on empirical student data and prevailing trends in the scientific literature. Future research should examine the effectiveness of flipped classroom and blended learning interventions, particularly those incorporating 3D visualization, in authentic classroom settings.

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