

A look at biochemistry learning difficulties in the undergraduate level



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Abstract Learning biochemistry can be a challenge for most university students. They represent a lot of difficulty in studying this module. This is evidenced by numerous failures and a lack of interest in the subject. For them, biochemistry is a dry subject requiring extensive memorization and complex language. They also find it boring. However, biochemistry is a key element in the training of biology students and future teachers of life and earth sciences. It is the basis for understanding the mechanisms of life. It helps students to understand the chemical processes that take place in living beings. The aim of our study is to identify students' difficulties in learning biochemistry, in order to deduce the main causes and factors behind the low proficiency in this subject. For this purpose, we communicated with the undergraduate students at our school using NGT and a questionnaire. Students attribute their difficulties mainly to the complexity of the subject and the large amount of information that must be assimilated in a limited time. In addition, the problem of the language of instruction as well as the lack of tutorials and practical work can represent additional factors hindering the learning process. The lack of basic knowledge and the classical teaching methods can also be considered sources of difficulty. At the end of our study, we were able to elucidate the main factors and obstacles that hinder the learning of biochemistry. The students have suggested some solutions including the adoption of new teaching methods promoting active learning, as well as by diversifying the pedagogical supports used in class and the integration of new communication and information technologies (ICT).

Keywords: biochemistry, learning difficulties, ICT, NGT

1. Introduction

Biochemistry is an elementary course that biology students must take in their training. It helps students understand the chemical processes that take place in living beings. Biochemistry is a science that describes chemical-biological and chemical-physiological processes (Hasanah & Ansyah, 2022). It is a branch of biology that explains the structure, properties, metabolism, and function of biological macromolecules. It aims to study the chemical composition of living beings, the structure of their substance and their transformation in the body (Juwita et al., 2023). Chemical methods are used to study biological processes at the cellular and molecular levels. As a basic science, biochemistry has many subbranches (bioorganic chemistry, clinical biochemistry, and immunochemistry) and widespread applications (medicine, food industry, health, agronomy, etc.). As a result, biochemistry has become the basis for understanding all disciplines related to biology (Wahyono & Susetyarini, 2021).

The teaching of this subject is an integral and essential part of the training of future science teachers and biology students. Biochemistry is the key to understanding most life processes, such as respiration, glycolysis, photosynthesis, and metabolism. The biochemistry course aims to study the structure and function of cells, carbohydrates, proteins, fats, nucleic acids, enzymes, biological oxidation, biochemical energy, and the process of anabolism and catabolism of carbohydrates, fats, proteins. Therefore, the biochemistry course can be subdivided into three parts (Lehninger, 2008 cited by Rahmatan, 2016):

- 1- Structural biochemistry studies the chemical structure of organic materials, including the structure and function of carbohydrates, amino acids and proteins, lipids, and nucleic acids.
- 2- Bioenergetics and metabolism, which includes the study of the principles of bioenergetics, the principles of metabolic regulation, enzymes, catabolism and anabolism of carbohydrates, proteins, and lipids.
- 3- Molecular genetics that includes DNA (chromosome structure and genes), DNA replication and transcription, and protein synthesis and regulation.

Generally, it is taught in the second year of the biology degree in different fields (SVI: life sciences, BCG: biology-chemistry-geology, LE-SVT: bachelor of teaching sciences of life and earth), specifically in the third semester (structural biochemistry) and the fourth semester (metabolic biochemistry & enzymology).



However, most university students regard biochemistry as a difficult subject (Elhousni et al., 2023; Munyemana et al., 2022; Usman, 2019; Spicer et al., 2019). For them, biochemistry is a dry subject that requires extensive memorization, complex language, chemical names, and many reactions (Eissa et al., 2020; Wood 1990). These students are not interested in learning this subject and express a high failure rate. They also find it boring.

As in many studies, low learning outcomes are an indication of learning difficulties (Hasanah & Ansyah, 2022; Rizki et al., 2017). Wahyuni (2019) added that low marks on final exams demonstrate students' learning difficulties. Moreover, learning difficulties can be attributed to different types of problems encountered by students at school. It includes general learning problems and poor academic performance. Cahyono (2019) defined them as learning conditions characterized by certain obstacles to achieving learning outcomes. According to Utami (2019), learning difficulties are a psychological disorder of a learner who has a perfect physique but has difficulty accepting or grasping learning well (cited by Juwita et al., 2023). Therefore, we can say that learning difficulties are a condition or process in which students experience an inability to capture lessons as expected (Hasanah & Ansyah, 2022).

These learning difficulties can be thoroughly examined by learning difficulty diagnosis. This is a positive action in didactics, which aims to explore learning difficulties to determine their origins and causes and suggest ways of overcoming them. In this context, various researchers around the world have investigated students' difficulties in learning biochemistry (Anwar et al., 2017; Halmo et al., 2018; Hasanah & Ansyah, 2022; Juwita et al., 2023; Mnguni, 2016; O'Sullivan et al., 2022; Orgill & Bodne, 2006; Rahmatan, 2016; Salame et al., 2022; Wahyono & Susetyarini, 2021; Wood, 1990). As these studies show, there are many reasons why students have difficulty learning biochemistry.

First, we can identify the abstract and interdisciplinary nature of biochemistry concepts (Harle & Towns, 2013). Biochemistry integrates various scientific fields, such as chemistry, biology and genetics. Students find it difficult to study all these concepts. For example, metabolism is a difficult subject to learn since it includes several complex pathways (D'Souza et al., 2013). Biochemistry involves numerous structures, reactions and metabolic pathways that require rote memorization. It is difficult for students to remember all this information. In addition, biochemistry contains many abstract notions that require in-depth thought. It includes abstract ideas that require students to visualize what is happening at the submicroscopic and macroscopic levels. Students may find it difficult to connect all the levels (Salame et al., 2022).

Rahmatan (2016) noted that carbohydrate metabolism is the most difficult concept for students since it involves abstract concepts and processes. However, Dianne et al. (2020) reported that students have difficulties understanding pH and enzyme kinetics. For Salame et al. (2022), metabolic pathways are one of the most challenging topics in biochemistry because they require that students combine many ideas from different disciplines. The ability to understand abstract concepts and the relationships between concepts is difficult to achieve. As a result, students tend to simply memorize reaction steps without understanding the meaning of each step, which can lead to certain misconceptions (Dobos et al., 1999; Verkade et al., 2017).

Second, we have teaching methods and techniques. These factors may also affect students' learning in biochemistry. If students are not satisfied with the way biochemistry is taught, they may show disinterest in and negative attitudes toward biochemistry and its teaching (Sachyani & Ronen, 2022). The transmissive model is the most dominant model at universities. Prolonged periods of lecturing set up students for passive learning, which focuses students on information (Harlen & James, 1997 Cited by Arthurs & Kreager, 2017). Indeed, the absence of interaction in class prevents good assimilation of knowledge. The majority of undergraduate biochemistry students take a surface approach to learning, associated with rote memorization of material (Kulak & Newton, 2014). In addition, a lack of understanding or misconceptions of other subjects, such as biology (Çimer, 2012; Tracy et al., 2022, Etobro & Fabinu, 2017), chemistry (Tekane et al., 2020; Timilsena, 2022) and mathematics (Dianne et al 2020), can lead to difficulties in learning biochemistry. A low level in these subjects can make it difficult to understand biochemistry (Harle & Towns, 2013).

In general, the difficulties experienced by students studying biochemistry are caused by several factors, including the abstractness and complexity of biochemistry concepts, teaching practices, misconceptions of topics, low education levels in other subjects (biology, chemistry and mathematics), and a lack of practical classes.

We observed a high rate of biochemical failure at our school. Students find it very difficult to study this subject. Over 50% of the students failed this module. The imbalance between student learning processes and student learning outcomes in biochemistry courses encourages the need to resolve this problem. By clarifying the source of the difficulties, we can suggest solutions and methods of remediation to help students learn biochemistry. From this perspective, there is a need for a deeper and better understanding of the factors that may be at the root of learning difficulties and poor results in biochemistry. For this reason, in this study, we attempted to identify and explain the various causes of the difficulties encountered by students at ENS Tetouan in learning biochemistry. To this end, we have formulated the following questions:

What difficulties are encountered by ENS students when they learn biochemistry? What are the remedial methods used to overcome these problems?

2. Materials and Methods

To answer our question, we conducted an exploratory study with students majoring in a bachelor's degree in teaching sciences of life and earth (LE-SVT) at the Higher Teacher Training School (ENS) of Tetouan. The aim of our study was to identify the difficulties that students encounter during their learning of biochemistry. We adopted the Nominal Group Technique (NGT) and used a questionnaire. It should be noted that our study was preceded by a preinvestigation (interview and questionnaire) as well as an analysis of the biochemistry grades of students from the same school.

2.1. Sampling

The selected sample for the NGT included 24 LE-SVT students who agreed to participate voluntarily in this study. The sample chosen for the questionnaire included 76 students in two consecutive years (2022 and 2023). All students who attended the last session of the biochemistry course at the end of the second semester were invited to participate in this study. Absent students were excluded. The participants in this study were trained by the same teacher in the same learning environment and were exposed to the same course.

The target population for our study consisted of 100 students from LE-SVT who were distributed according to Table 1:

Table 1 Student distributions.

	NGT	Questionnaire	
		2021-2022	2022-2023
Women	23	37	29
Man	1	3	7

2.2. Data collection technique

2.2.1. Survey by the NGT

First, we used the nominal group technique (NGT) to identify challenges and difficulties encountered by students when they learned biochemistry. This method was chosen because it encourages the active participation of all group members to generate ideas on a common topic.

Indeed, the NGT is a group technique developed by Delbecq and Van in 1971. It is used to generate and prioritize responses to a specific question called "the nominal question". It is an organized process that gives participants an equal opportunity to contribute their personal views and eventually leads them to a collective idea on a specific topic. It is a more structured form of brainstorming. It is frequently used to identify problems, suggest solutions or make decisions. Because of its efficacy, it has been applied in many fields (industry, medicine, marketing, management, education, etc.).

2.2.2. Steps of NGT

Referring to the literature (Grenier & Lagarde, 2000; Harris et al., 2019; Maguire et al., 2022; Olsen, 2019; Potter et al., 2004; Rankin et al., 2016; Søndergaard et al., 2018), we followed a classical NGT, which includes the following steps (Table 2):

Table 2 Steps of NGT.

Step 1: Silent idea generation	Invite each participant to respond individually to the question presented.
Step 2: Sharing ideas in turn	Each participant presents one idea in turn. All answers are written on a support to be visible by everyone. This process can be repeated until all ideas have been exhausted.
Step 3: Clarification	Encourage discussion to explain and clarify the ideas collected.
Step 4: Categories	Answers with similar ideas or suggestions are grouped together in the same category.
Step 5: Voting and classification	Each participant votes privately and ranks the different categories by degree of importance.

2.2.3. Process

1. First, we assembled our sample of students who agreed to participate in this session. Then, we present a brief description of the NGT process, the purpose of the study, and the different steps to follow. Next, we gave each participant a piece of paper with a question to discuss and asked them to write down all the ideas that came to their mind while thinking about this question: "What are the difficulties and the problems that you have while you are studying biochemistry?" During this step, participants work silently and independently. This step took approximately 10 minutes.
2. Each participant provided a single idea and wrote it on the board. This process continued until all ideas were collected. No discussion was allowed at this point.
3. In the next step, participants discussed each idea on the list so that all ideas were clear to everyone.

4. Afterwards, we arranged the responses that had the same ideas or similar suggestions into one category. Responses that were considered duplicate or not related to the problem were eliminated.
5. During this phase, each participant was asked to rank the difficulties by giving a score from one to nine to each category. The highest score (9) was given to the difficulty ranked first (most important).

Finally, we ranked the results in decreasing order based on the total score accorded ($\sum Si$) to each statement, producing a weighted list of difficulties (Table 5).

2.2.4. Questionnaire survey

Using the results of the nominal group technique and the previous investigations, we developed a questionnaire with three sections. This questionnaire was validated by members of the research team in pedagogical engineering and science didactics (ERIPDS). Based on their remarks, the questionnaire was revised and modified. Then, the questionnaire was distributed in paper format to 2nd-year LE-SVT students at the end of the second semesters of 2022 and 2023.

The first section presents general information about the students (gender, age, institution, Bacculaureate series, etc.); the second section focuses on the difficulties encountered during the learning of biochemistry (teaching method, level of prerequisites, hourly volume, complexity, etc.); and the third section tries to elucidate some solutions and suggestions.

2.3. Data processing

The questionnaire was anonymous to optimize the number of returns. The students' answers were registered and processed with Excel and SPSS software. The percentages that appear in the different tables and graphs are expressed in terms of the number of participants.

3. Results

3.1. Analysis of the scores

Initially, we analyzed the grades of biochemistry exams over three years to determine the student's performance on this subject (table 3).

Table 3 Descriptive statistics (structural biochemistry).

Promotion	Student numbers	Minimum	Maximum	Standard deviation	Variance
2019-2020	45	1,53	18,25	4,76437	22,699
2020-2021	53	0,25	16,38	4,68392	21,939
2021-2022	36	4,50	18,00	3,22841	10,423

The results show that biochemistry grades have varied in recent years between [0,25; 18,25], with a large dispersion around the average [3,22; 4,76]. The grades are not homogeneously distributed; there is a large gap between students' marks.

Thus, we noted that the general average of the students is very low and varies between [5; 12]. Ultimately, after the statistical calculations, more than 40% of the students had grades lower than 5, and approximately 25% of them repeated this study with a grade that varied between [5; 10]. However, only 7% of the students had very satisfactory grades [15; 20]. Globally, more than half of students have failed this subject (Table 4).

Table 4 Cumulative average (2019-2022).

Score intervals	center Ci	E1 (2019-2020)	E2 (2020-2021)	E3 (2021-2022)	Percentage
[0 ; 5]	2,5	21	33	1	41%
[5 ; 10]	7,5	13	11	6	22%
[10 ; 15]	12,5	7	8	25	30%
[15 ; 20]	17,5	4	1	4	7%
Total (\sum)		45	53	36	100%
X pondered		6,83333	5,3301	11,9444	

The results obtained show a significant variation in the average over three years. The considerable increase in the average (11,94) for the promotion of 2021-2022 may be explained by the reinforcement of the tutorials and practical sessions during this year. Those in the 2020-2021 class took distance learning courses during the COVID-19 period. This may explain



their rather low average (5,33) compared to the other classes, and the absence of practical sessions may significantly affect their learning.

This observation led us to make a series of hypotheses and questions about the student's performance. To answer this question, we opted for the NGT and the questionnaire to try to explain this situation.

3.2. Survey by the NGT

The analysis of the NGT results helped us draw a list of difficulties encountered by the students during their learning of biochemistry (| Table 5).

Table 5 List of difficulties.

Order	Statements	Σ of scores	Percentage	Percentage cumulate
1	Large and detailed program	188	17%	17%
2	Explanation difficult	147	14%	31%
3	Classical teaching method	142	13%	44%
4	Insufficient hourly volume	137	13%	57%
5	Complexity of some concepts	133	12%	69%
6	Absence of links between different chapters	115	11%	80%
7	Lack of prerequisites	103	10%	89%
8	Problem of language	68	6%	96%
9	The long duration of the courses and practical work	47	4%	100%

Analysis of this table shows that students associate their difficulties in biochemistry mainly with the complexity of some concepts and the absence of links between different chapters. Therefore, they think that courses are too long compared to the time allocated to teaching this discipline. They also added that the traditional teaching methods and learning strategies used did not encourage interaction in class. Other students suggested that the problem of language, the lack of knowledge in chemistry and biology and the long duration of the courses may hinder their learning.

In summary, we can deduce that the main causes of students' difficulties are as follows:

- Large and detailed programs also lack time (31%);
- Classical teaching method and explanation difficulty (27%);
- Difficulty and complexity of some parts (12%);
- Lack of links between different chapters (11%).

3.3. Survey by questionnaire

3.3.1. Promotion 2021-2022

The ages of our respondents were very close, between 18 and 22 years, with a predominance of girls compared to boys. Concerning the type of baccalaureate, we found a high percentage of students in physical sciences (PC) (72.5%) and a low percentage in life and earth sciences (SVT) (25%) (Table 6).

Table 6 General information (2021-2022).

Promotion	2021-2022		
Baccalaureate series	[SVT] 25%	[PC] 72.5%	[MATHS] 2.5%
Gender	[Man] 7.5%	[Woman] 92.5%	
Age range	[between 18 and 22 years old] 100%		

As shown in Figure 1, most of our respondents said they often encounter difficulties when studying biochemistry (70% yes, 30% a little). However, none of the students found this subject difficult. To clarify this point, we asked them questions about the nature and causes of their difficulties.

As shown in Figure 2, the majority of the students thought that the content of the course was very loaded (82.5%: 33 responses of 40) and that the time dedicated to teaching this subject was insufficient (45%: 18 responses of 40), especially given the complex nature of several concepts in biochemistry, which requires considerable time for their assimilation (62.5%: 25 responses of 40).

In addition, the classical teaching method (40%: 16 responses of 40), which does not promote interaction in class, can be considered one of the possible causes. They also claim that the lack of prerequisites, the language of instruction, and the absence of review sessions may be additional factors preventing the correct learning of this module.

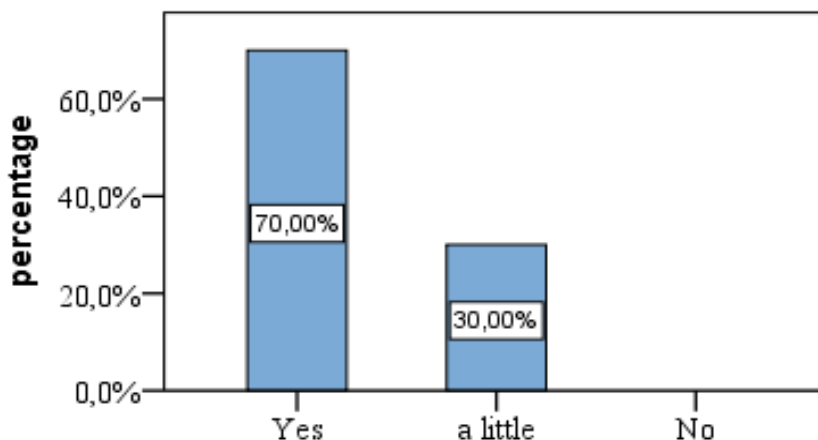


Figure 1 Percentages of students who encounter difficulties in biochemistry.

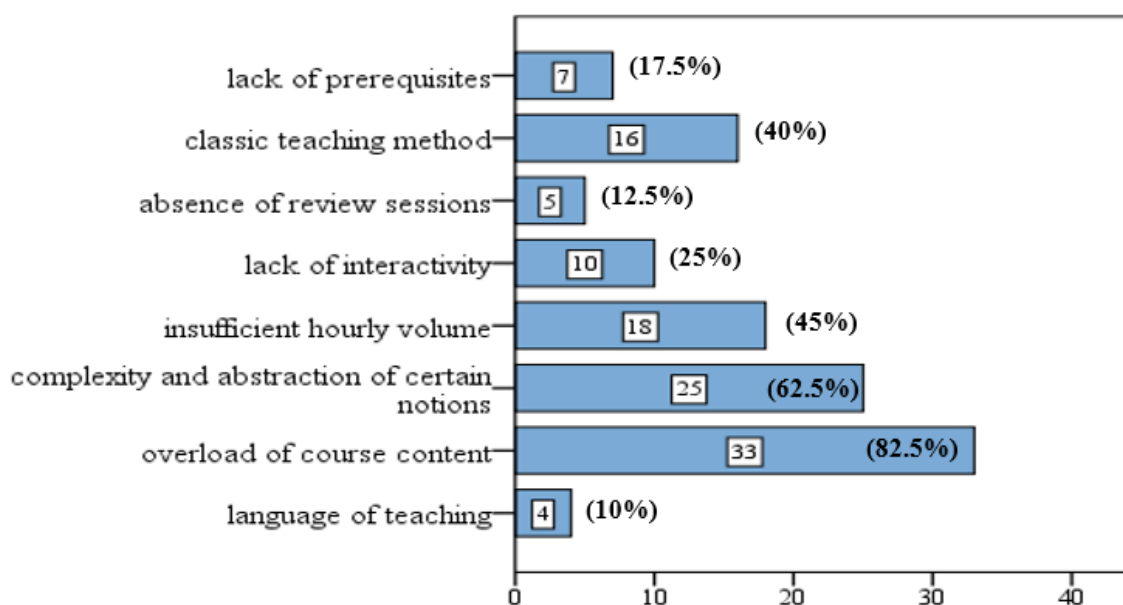


Figure 2 Causes of difficulties encountered in biochemistry.

As illustrated in Figure 3, many students feel that the amount of time dedicated to lectures, tutorials and practical work is not sufficient. Moreover, it does not promote adequate learning.

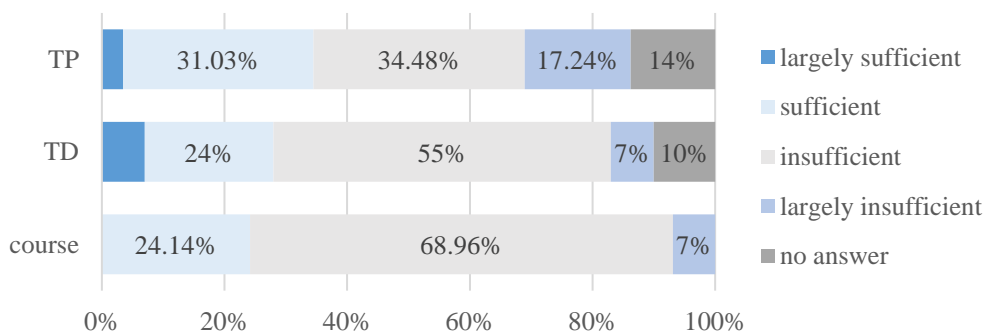


Figure 3 Time allocated for teaching biochemistry.

As presented in Figure 4, most students consider the biochemistry module to be an interesting subject (85% interesting and very interesting) and are aware of its importance in their training course. However, a small portion (15%) did not know why they were studying this subject. In addition, the students thought that the course was complicated (85%) and needed to be reorganized and simplified.

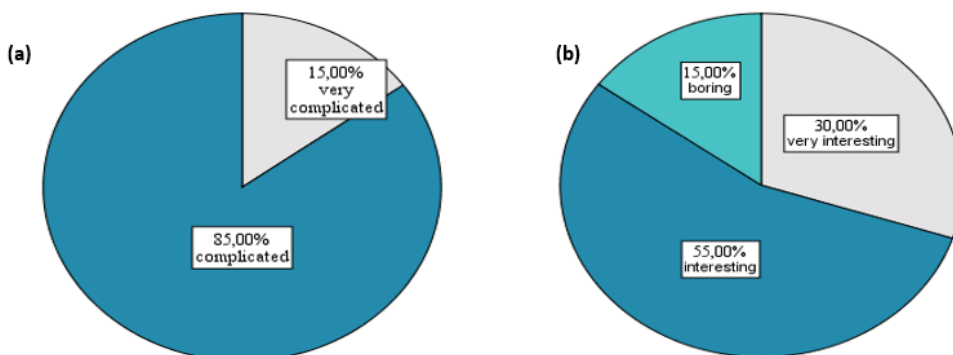


Figure 4 (a) Impression of the biochemistry course (b) Personal opinion of the biochemistry subject.

The students proposed some solutions to improve the teaching of this subject as shown in Figure 5. A large proportion of students suggested reducing the content of the course (77.5%: 31 responses of 40) and planning review sessions (55%: 22 responses of 40). Others suggested changing the teaching method and adopting new pedagogies that promote interaction in class (50%: 20 responses of 40). They also expressed their interest in new communication and information technologies (ICTs), particularly by using animations (45%: 18 responses of 40), videos, and summary diagrams (37.5%: 15 responses of 40).

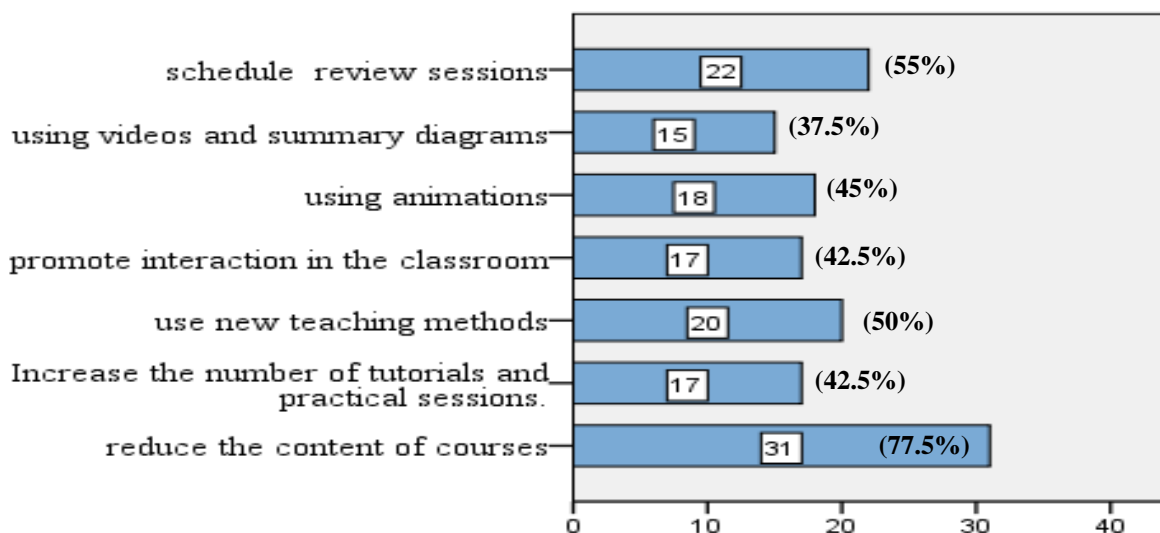


Figure 5 Suggestions for solutions and remediation.

3.3.2. Promotion 2022-2023

We also interviewed another group of students (2022-2023) to determine their opinions on this topic and obtain an overview. In general, the ages of the interviewees were very close to each other, between 18 and 22, with a predominance of girls over boys. Regarding the type of baccalaureate, there is still a high percentage of students in physical sciences (63.9%) and a low percentage in life and earth sciences (36.1%) (table 7).

Table 7 General information (2022-2023).

Promotion	2022-2023		
Baccalaureate series	[SVT] 36.1%	[PC] 63.9%	[MATHS] 0%
Gender	[Man] 19.4%	[Woman] 80.6%	
Age range	[between 18 and 22 years old] 100%		



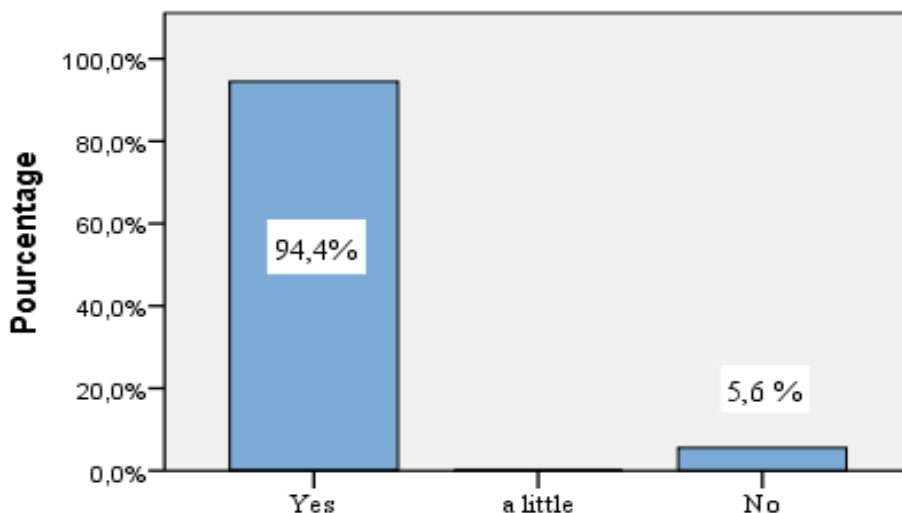


Figure 6 Percentages of students who encounter difficulties.

Figure 6 shows that, more than 90% of the students had difficulties in biochemistry, while only 5% did not have any problems. To clarify this point, we also asked them about the origins and nature of their difficulties.

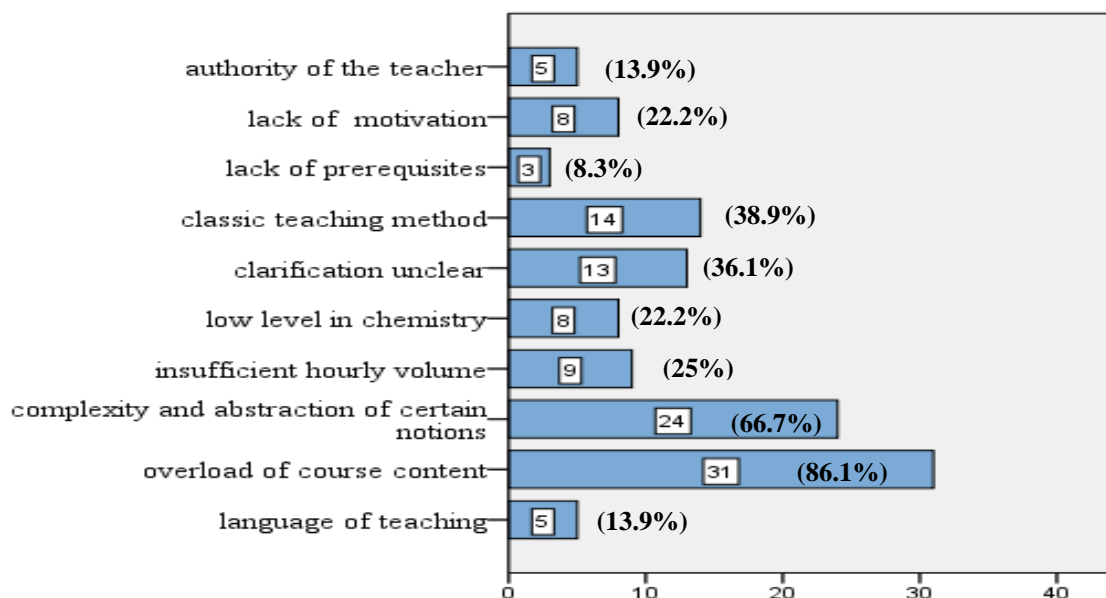


Figure 7 Causes of difficulties encountered in biochemistry.

As shown in Figure 7, these students share the same opinion as the last promotion; they also think that the course is overloaded (86.1%: 31 responses of 36) with an insufficient hourly volume (25%: 9 responses of 36) and that it contains many complex and abstract notions (66.7%: 24 responses of 36). However, they add other factors, such as the teacher's authority (13.9%: 5 responses of 36), a low level in chemistry (22.2%: 8 responses of 36), and lack of motivation (22.2%: 8 responses of 36). In addition, traditional teaching methods, explanations, and the language of instruction can also hinder the learning process.

The classical pedagogy may not be efficient for the new generation. They need new teaching tools that can encourage their learning.

On the other hand, these students have suggested solutions that could help them overcome these problems. These include simplifying the course (83.3%: 30 responses of 36), increasing interaction in the classroom (33.3%: 12 responses of 36) by using some active pedagogy (36.1%: 13 responses of 36), using animations (38.9%: 14 responses of 36), and using videos and schematic diagrams (58.3%: 21 responses of 36). Additionally, they proposed creating a review platform (30.6%: 11 responses of 36) that included exercises with correction, videos, Mind Maps and various supports.

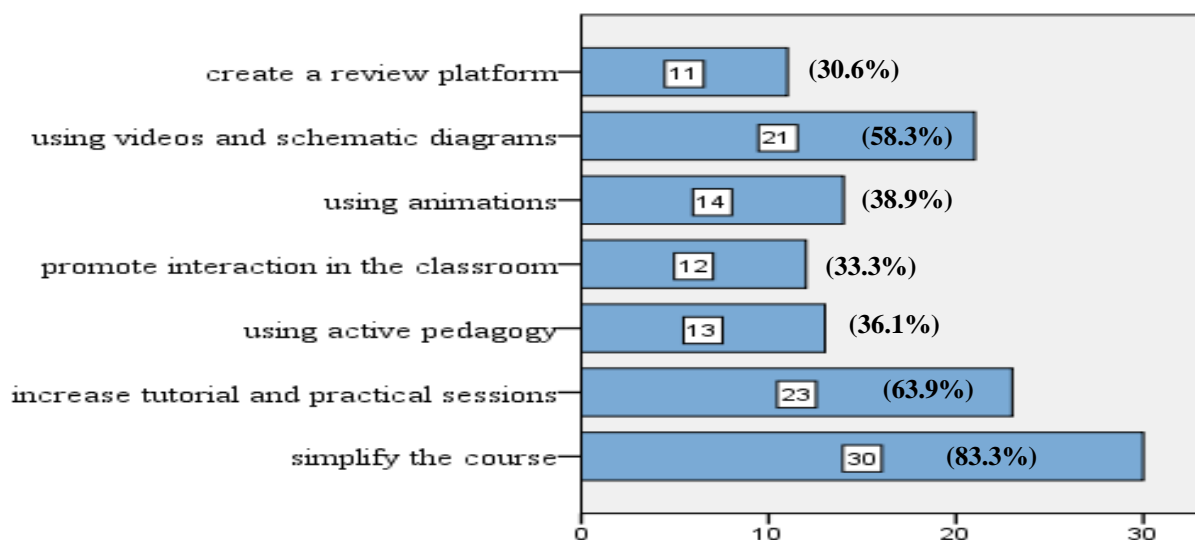


Figure 8 Some suggestions and solutions.

4. Discussion

After intense reflection, we can deduce that several factors might explain this failure. One of the main obstacles faced by students learning biochemistry is the large quantity of information that must be learned in a limited amount of time. Students frequently resort to the memorization of concepts without truly understanding what they mean. Consequently, teaching in a fragmented way can lead to difficulties in making connections and relationships between different chapters (Rowland et al., 2011, Rahmatan, 2016).

However, biochemistry is one of the basic courses that is a fundamental and mandatory subject for biology students. This course is designed to help students understand the chemical processes that occur in living organisms. Biochemistry is the science of structure, organization and function of molecular processes in living things. It contains several branches, including enzymology, bioenergetics, metabolism, molecular biology, immunology, and structural biochemistry. Each of these disciplines involves a different component of biochemistry (Wahyono & Susetyarini, 2021). Biochemistry covers a wide discipline field requiring a strong foundation in chemistry and biology. Therefore, it has become the basis for understanding all biology-related disciplines (Yoho, 2019).

Nevertheless, learning this subject requires a great effort of concentration, which can lead to fatigue and frustration for students, making the assimilation and understanding of new concepts more difficult. In addition, students may encounter other difficulties related mainly to the complexity of biochemical concepts and their abstract character. First, they need to assimilate the basic concepts before understanding the more complex concepts (Mnguni, et al., 2016). On the other hand, the ability to understand abstract notions and the connections between concepts is difficult to achieve. This is a major challenge that most often leads to misrepresentations (Erman et al., 2020; Tian et al., 2018, Wahyono & Susetyarini, 2021).

Furthermore, the lack of tutorials and practical sessions can also cause learning difficulties. Practical work and tutorials are times when the learner becomes familiar with the knowledge. They are very important in the learning process. They allow students to structure and mobilize all of their notions in various situations. Indeed, practical sessions allow students to have a more concrete understanding of the phenomena studied and to develop their experimental skills (Shana & Abulibdeh, 2020).

In fact, practical sessions provide students with a more concrete understanding of the studied phenomena and help them develop their experimental skills. They take a primordial place in teaching biochemistry. It is an opportunity for students to conduct syntheses, analyze compounds and confront both theory and experiments (Canac et al; 2021). The tutorials allow them to practice and to better understand the taught concepts. They are used to measure their level of assimilation, allowing them to evaluate themselves and become more autonomous and creative. In addition, tutorials often allow professors and students to get closer and establish a relationship of trust between them (Kounou, 2021). The reinforcement of tutorials, practical sessions and programming review sessions can greatly improve student performance.

Other students said that the lack of prerequisites and the problem of the language of instruction can create additional difficulties preventing good assimilation of this subject. Many studies have concluded that the language of teaching can be an obstacle to learning. The lack of fluency in French can even lead to a situation of failure. Therefore, French has become a cause of student failure (Bessonnat, 1998; Bouhafs, 2022; Chakib et al., 2013; Jarmouni et al., 2021; Ziane Cherif, 2020).

We can also highlight the teaching practices of teachers. The transmissive model still dominates in the classroom. This generally limits interactions within a class. The teacher is the only person who holds the knowledge, while the student is just a

receptor. The student is seen as a blank slate or an empty pail. His job is simply to assimilate new knowledge, whereas the purpose of teaching is to transmit knowledge from the teacher to the student (Duguet et al., 2021; Paivandi & Younès, 2019).

These methods have demonstrated their effectiveness in the past. However, the student population is changing, and methods must evolve. Today's students are no longer focused or motivated, and a high rate of distraction surrounds them on all sides (Blanquet et al., 2018). As a result, the question of how to make biochemical knowledge and principles more interesting to study, easier to understand, and more useful has become a major concern for teachers (Wahyudi et al, 2019).

Some studies have shown that learning difficulties are related not only to the knowledge itself and student and teacher representations of science but also to teaching practices (Rahmatan, 2016; Duguet & Berthaud, 2021; Hasanah & Ansyah., 2022). It remains necessary to examine how teachers teach and how students learn biochemistry. Both aspects are closely related to the learning methods used in the classroom (Guillemette, 2020).

Thus, it should be noted that students do not learn in the same way; each one learns differently in his own way. Some prefer audio-visual support (pictures, videos, animations, etc.), while others prefer diagrams and mind maps. This makes classical teaching methods somewhat limited and does not explain this difference (Desmarais et al., 2020; François & Lise, 2021).

Consequently, the students proposed solutions that can alleviate their difficulties, notably by adopting new pedagogies that promote interaction in class, as well as by diversifying the pedagogical support used in class (PPT, animations, videos, diagrams, etc.). They also suggested scheduling review sessions, increasing the number of tutorials and practical sessions as well as simplifying the content.

In this context, several studies on pedagogical innovation have recommended the use of new information and communication technologies in teaching (ICT) as well as the introduction of various teaching tools that consider the individual differences of learners and promote active learning (Andrews et al., 2024; Anwar,2020; Coan et al., 2020; De Oliveira Silva et al, 2016; Espinosa et al., 2020; Nowak et al., 2023; O'Sullivan et al., 2022; Wang et al, 2021; Rowland et al., 2011, St-Jean & Dupuis Brouillette, 2021).

These studies have shown a positive impact and significant improvement in the process of teaching and learning biochemistry. To this end, the integration of ICT (videos, animations, 3D pictures, etc.), educational games, simulations, online tutorials and the renovation of teaching practices can be effective and can help to overcome these difficulties.

In future studies, we will try to test some remedial methods on LE-SVT students from the same school and evaluate their impact on their academic performance.

5. Conclusions

At the end of our study, we were able to identify the main factors and barriers to learning biochemistry. They can be grouped as follows:

- ✓ Disciplinary: Biochemistry involves difficult and abstract concepts. Additionally, it takes a large disciplinary field (several notions to be learned, needs prerequisites);
- ✓ Methodologic: Classical teaching methods and different learning strategies do not promote the integration of learners in the educational process;
- ✓ Curricular: The nature of the training characterized by a loaded program and an insufficient time volume;
- ✓ Linguistic: A low level of students in French, making expression and communication difficult;
- ✓ Other problems include a lack of basic knowledge (biology, chemistry and mathematics) and a lack of student motivation for learning.

Overall, learning biochemistry can be considered a worrying and arduous process for most university students. Students often claim that biochemistry is a difficult and complicated subject. It is even considered by some to be a "problem subject". This situation can lead to the development of negative attitudes toward the module. For example, feelings of boredom, dissatisfaction, difficulty studying, or increased disinterest, as if studying this subject is not important (Wahyudi et al., 2019). These prejudices can distort learners' representations and give a rather wrong image of this interesting subject.

On the other hand, by understanding the causes of difficulties associated with learning biochemistry, as well as different possible pedagogical and technological solutions, we can improve the teaching and learning of this module.

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Ethical considerations

To protect the anonymity of the respondents, all the collected data were encrypted and stored anonymously. Additionally, we provided participants with comprehensive information about the research purpose and the voluntary nature of their participation.



Conflict of interest

The authors declare that no conflicts of interest are associated with this research.

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