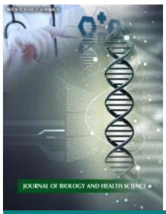

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Research Article

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Problem-Based Learning in the Disciplines of Applied Genetics, General Chemistry and Inorganic Chemistry

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Abstract

The research analyzed the application of the problem-based learning method in the disciplines of Applied genetics, general chemistry and inorganic chemistry at two higher education institutions in Benguela, Angola, over four consecutive academic years, highlighting how this methodology can contribute to improving learning and developing integrative skills. The study followed a mixed methods research format and used document analysis, participant observation and a questionnaire. The results revealed that the problem-based learning method contributes to developing students' ability to analyze and interpret concrete situations, encourages teamwork, integrates theory, research, practice and real-world aspects and requires the mobilization of diverse basic knowledge and skills and the integration of competencies. The results also demonstrated that this methodology effectively contributes to the training profile defined for the courses studied. This study is part of a program that has been developed within the scope of the challenges facing higher education in Angola, regarding the current perspectives of science teaching that prioritize problem-based learning with a view to building knowledge and developing integrative skills.

Keywords: Problem-based learning; Applied genetics; General chemistry; Inorganic chemistry; Integrative competencies

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Introduction

One of the objectives of higher education in Angola is to ensure training in close connection with scientific research aimed at solving societal problems and integrated into the framework of scientific, technical and technological progress, as per Article 5 of Presidential Decree 310/20, of December 7 [1]. In this context, the relevance and timeliness of reflections on the application of problem-based learning emerge from the general provisions of curriculum organization, which consider, among other aspects, the principle of comprehensiveness of training and the principle of applying contemporary pedagogical trends, as per Article 4 of Presidential Decree 193/18, of August 10 [2]. The principle of comprehensiveness of training stipulates that instruction should translate into a set of scientific, technical and social competencies to solve common and regular problems within the respective area of knowledge. The comprehensiveness of training must adapt to the four pillars of education for the 21st century, according to Article 5 of the last cited Decree. The application of contemporary pedagogical trends is, therefore, imperative.

One possibility for the realization of this fundamental principle of higher education is the use of pedagogical methods that allow students to play a more active role, ensuring greater autonomy in the learning process [3]. Among the methodologies that make the teaching-learning process more dynamic and meaningful, problem-based learning stands out. This strategy places the student at the center of the educational process, promoting learning through investigation and the resolution of real problems, based on stimulating their capacity for analysis, problem-solving and decision-making, favoring a more contextualized and interdisciplinary education [4]. Thus, problem-based learning contributes to the development of competencies, which are associated with different levels of understanding at the person level (individual competence) organizations (core competencies) and countries (educational systems and competence training) [5]. As it is not the objective of this research to join the theoretical debate on the concept of competence, the reference to it focuses on the need to highlight the approach to individual and social competencies that the school is supposed to offer. In this sense, this Article seeks to focus on the relationship between problem-based learning processes and the development of integrative competencies.

In formal educational contexts, different learning processes are associated with distinct aspects that can be included in the KSC logic (Knowledge, Skills and Competences). According to these authors, if intellectual capacities are necessary to develop knowledge and similarly, operationalizing knowledge is part of the skill development process, all these elements are prerequisites for developing competencies, also considering other social and attitudinal factors [6].

For the context of higher education in Angola, the application of the problem-based learning methodology in disciplines that have a practical laboratory component and require the mobilization of various competencies still lacks studies on its effective contribution to improving learning and developing integrative competencies.

Thus, the guiding question that guided this study was: how can the problem-based learning methodology contribute to improving the learning and development of integrative competencies of students in the disciplines of applied genetics, general chemistry and inorganic chemistry, in two higher education institutions in Benguela-Angola?

The research therefore aimed to describe the results of using the problem-based learning methodology in the progression of learning and the development of integrative competencies of students in the disciplines of applied genetics, general chemistry and inorganic chemistry, in two higher education institutions in Benguela-Angola.

The research considered the guidelines and ethical principles of research in the social sciences as described in detail in the Methodology section of this article [7-9]. At the beginning of each academic year and throughout the four years in which the research was carried out, the following elements were presented to the students: the purpose, objective and nature of the research, as well as their form of participation in the research; guarantee of anonymity and confidentiality of data; non-compulsory participation in the study; availability of a copy of the final work after publication. This Article does not contain photographic images of the students and the institutions where the research was carried out.

This study is thus part of a program that has been developed within the scope of the challenges facing higher education in Angola, regarding current perspectives on science teaching that prioritize problem-based learning in a vision of knowledge construction and the development of integrative competencies.

Active methodologies and problem-based learning

In the field of neuroscience, learning has been one of the most studied brain phenomena, at least in the last three decades, fundamentally from the point of view of the neuronal transformations that occur in the different brain areas involved. Particular attention has also been given to the mechanisms of behavior modification induced by learning in the individual, with discussions on how to increase the brain's potential for learning [10]. Although the different neurophysiological processes involved in learning are not the object of analysis of the present research, we consider it pertinent to present a brief framework of the brain's focus on learning, as it constitutes an important subsidy for the aspects discussed in this article.

Present learning as a process by which different neuronal groups from different brain areas establish connections to create a temporary network, until exercise and repetition convert it into a permanently stable network [10,11]. This stable neuronal network will allow new information to be integrated, translating into new learning, that is: new learning is the product of the interaction between new and already assimilated information. For these authors, good learning is that which allows more and more connections to develop between different brain areas, which facilitates the integration of these connections within a neuronal network and that this network participates in previously consolidated networks.

Thus, effective learning is superior to the mere accumulation of information in the brain; it should also translate into the ability to retrieve information that is useful for a specific situation, which represents a greater degree of difficulty [12].

The search for methodologies that not only modernize education but also make it more effective and inclusive results from the need to adapt the teaching-learning process to new technological, social and cultural realities. Active methodologies have stood out as one of the most effective approaches within the context of pedagogical innovation, bringing a fundamental change in the way the teaching-learning process is conducted [13]. In this methodology, the student takes on a more participatory stance, in which they solve problems, develop projects and thereby create opportunities for the construction of knowledge, which presupposes involving them in learning through discovery, investigation or problem-solving. Thus, active methodologies seek to create learning situations in

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which students can do things, think and conceptualize what they do, build knowledge about the content involved in the activities they carry out, as well as develop critical capacity, reflect on the practices performed, provide and receive feedback, learn to interact with colleagues and the teacher and explore personal attitudes and values [14].

Among the active methodologies, problem-based learning is one of the main ones and on which this Article focuses.

In the field of neuroscience, the ability to solve problems has been identified as the cognitive capacity necessary to modulate or control the different new stimuli that reach the brain, providing meaning to achieve a unitary response to the problem and that this is adjusted to the context, training in problem-solving could occur by exposing the individual to many social situations in which they have to give an adequate response to each situation and through stimulation by means of verbal, spatial, social and verbal comprehension problems, in which they have to elaborate a mental process before giving the answer [11].

Problem-based learning is characterized by the following essential principles: centrality of the problem, student autonomy in the learning process, collaboration among students, flexibility and interdisciplinarity and experience-based learning. By encouraging an active and investigative posture, problem-based learning enables deeper and more meaningful learning, preparing students for solving real problems and for a more complete civic and professional education [4].

The problem-based learning methodology relies on the tutorial group; its application can be summarized in the following steps [15]:

- Students are presented with the pre-prepared problem at this stage; students seek to clarify unknown terms and identify the proposed problem;
- Next, students, in groups, formulate hypotheses about the stated problem;
- Still together, students formulate study objectives, by clarifying what needs to be studied to deepen the hypotheses;
- Students then proceed to individual study of the issues raised in the previous stage and return to the group to discuss the proposed problem in light of the new knowledge obtained.

One can agree with the author cited above and thus it is important to understand that the problem must be clear and unequivocal, that is, it should bring situations close to everyday life, generating stimulus for individual research and group debate, focusing on a situation that is compatible with the students' reality. At the same time, the problem structure must be consistent with the curriculum, which is responsible for guiding the conception of the problems to be presented.

Regarding the student's action in this problem-based learning methodology, there is a multi-stage strategy called "seven steps" with the aim of helping students solve a given problem, starting from identifying causes, seeking to analyze the underlying processes or principles of the described phenomena [16]:

- Clarify confusing phrases and concepts in the problem formulation;
- Define the problem: describe exactly which phenomena should be explained and understood;
- Brainstorm: use prior knowledge and common sense, trying to provide as many explanations as possible;
- Detail the proposed explanations: try to build a personal, coherent and detailed "theory" of the processes underlying the phenomena;
- Propose topics for self-directed learning;
- Seek to fill knowledge gaps through individual study;
- Share conclusions with the group and integrate acquired knowledge into an adequate explanation of the phenomena. Check if enough is known. Evaluate the knowledge acquisition process.

Problem-based learning therefore implies proposing a problem situation, as a didactic situation in which a task is proposed to the subject that they cannot perform without precise learning. This learning, which constitutes the true objective of the problem situation, occurs by overcoming the obstacle in performing the task, emphasizing that we should not learn to give right or wrong answers, but rather learn to solve problems [17].

Problem-solving skills, depending on the intellectual and mental model adopted, can be acquired and developed through continuous practice [6]. In this sense, it is not a question of only teaching how to solve problems, but also of teaching how to propose problems to oneself, to transform reality into a problem worth questioning [17]. Along this same line of thought, it should be highlighted that solving problems is a fundamental activity in the teaching-learning process that aims to develop the student's critical capacity.

Problem-based learning is one of the active methodologies that presents several advantages [15]:

- Contributes to giving more meaning, relevance and applicability to learned concepts;
- Significantly promotes knowledge retention;
- Favors the transfer of knowledge and skills learned in the classroom to the world of work, as problems are presented in a real context;
- Increases students' competence in seeking information,

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as teachers are seen not as sources of answers, but as guides for problem-solving;

- Enhances interpersonal skills and teamwork and;
- Stimulates a lifelong learning perspective.

Problem-based learning also has a positive impact on student motivation for learning [4]. This is also understood regarding neuroscience discoveries, according to which a brain is happy analyzing and comparing new situations, so learning in which the brain is confronted with new and varied alternatives will be much better than one in which the brain always has to produce the same type of response, even if it is always correct [11].

In summary, problem-based learning not only promotes the development of cognitive skills but also consolidates socioemotional competencies, preparing students for the challenges of the contemporary world [4].

The implementation of problem-based methodology, however, requires significant changes in the school environment and faces limitations related to the reduction of time allocated to teaching subject fundamentals and the requirement of much more time than traditional procedures, resistance to changes in teacher and student roles, the teacher's expertise in formulating appropriate problems and the complexity of evaluating student achievement [15].

Revisiting the concepts of competence

The topic of the concept of competence still seems to be strongly marked by diversity, divergence and debates, which makes it impossible to identify or attribute a coherent theory or even arrive at a definition capable of accommodating and reconciling all the different perspectives in which this term has been used [6]. However, although the concept of competence is still much discussed, oscillating between a behaviorist conception and a constructivist-inspired conception, that there is always a need to pay attention to its meanings, conceptually and within a theoretical framework of analysis that allows for deepening its meaning [18].

From an organizational management perspective, competence implies knowing how to mobilize, integrate and transfer knowledge, resources and skills in a specific professional context. Thus, the notion of competence associates' aspects such as: knowing how to act, mobilizing resources, integrating multiple and complex knowledge, knowing how to learn, knowing how to engage, taking responsibility and having a strategic vision. Competence is therefore not merely the set of theoretical and empirical knowledge that an individual possesses, nor is it encapsulated in the task [5].

Specifically, regarding action competencies, it must consider the cognitive, motivational and social prerequisites for successful learning. This approach to action competencies generally includes general problem-solving competence, critical thinking skills, domain-specific and non-specific knowledge, realistic and positive self-confidence and social competencies. In addition to cognitive and motivational components, action competencies should also include specific and non-specific vocational competencies [6].

Competence also may be defined as a global trait inherent in the action of the individual or professional group, about which it is possible to make a value judgment. So, this concept can also refer to the interpretation of characteristics evident in the individual's action, thus being observable and describable [19].

When considering that competencies refer to the set of deliverables that the individual makes based on their qualification, that is, their stock of knowledge, skills and attitudes, provided that it is recognized in the context in which it is presented [20].

Regarding the classification of competencies, also a much-debated topic, we present a summary:

- Basic competencies literacy, numeracy, methodological competencies such as problem-solving, communication skills, critical thinking and judgment.
- Meta-competencies planning, initiation, monitoring and evaluation competencies that the individual applies to their own cognitive process (learning to learn); experience and knowledge of the different types of difficulty associated with each task; knowledge about learning and problem-solving; skills in the effective use of cognitive support and other tools.

Specifically, regarding intellectual capacities and skills, these authors consider six main categories: Knowledge (mobilization of data), comprehension (understanding meanings, interpretation), application (using a concept in a new situation), analysis (separating material into its components), synthesis (building a structure or pattern) and evaluation (making a judgment) [6].

This article intends to highlight this notion as being intimately associated, but not exclusively, with the results of the school curriculum. Competencies constitute the goal to be achieved by the school curriculum [18]. Thus, the construction of competencies is based on knowledge, understanding and the development of higher-order cognitive dispositions, analysis, synthesis, evaluation, critique and divergent thinking that school education curricula stimulate and develop. Competence does not refer exclusively to cognitive resources, but also to a series of other resources of diverse origin, such as innate dispositions. It is subsumed in a contextualized action, not being a disposition of the subject prior to the action [19]. The mobilization of resources by the subject is done according to operative networks and not by simple addition or in a linear sequence logic, resulting in the distinction between competence and performance.

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Therefore, competencies refer to knowledge that translates into the effective capacity for use and management – intellectual, verbal or practical – and not to accumulated content with which we do not know how to act concretely, perform any mental operation, solve any situation or think with them [18].

Methodology

From the survey conducted based on the bibliographic collection of higher education institutions in Benguela, no empirical research was identified that specifically focused on the application of problem-based learning methodology in the context of applied genetics, general chemistry and inorganic chemistry disciplines. Nor was research identified on the use of this method in other disciplines or courses in the two institutions under analysis.

The study followed a mixed methods research format [8,9,21,22]. This format has been frequently referred to as one that condenses, in the same study, data collection, analysis and combination/integration procedures from quantitative and qualitative approaches or strands. For its realization, literature review, documentary analysis, participant observation and questionnaires were used. The research was conducted over four consecutive academic years.

Two groups of students from two higher education institutions in Benguela province participated in the study: one group of students from the Applied Genetics discipline and another group of students from the general chemistry and inorganic chemistry disciplines. Although the collected data were presented and analyzed separately, this configuration was not intended for comparative purposes between the two institutions regarding the application of the problem-based learning methodology. This was due solely to the fact that these were distinct disciplines and courses, consequently with different curricular programs and training profiles. This had an impact on the design of the activities, depending on the specific content and nature of each discipline, as well as the character and degree of complexity of the problems presented to the two groups.

For the application of the Google forms questionnaires, the selection of both groups of participants resulted from a non-random "snowball" sampling from a total of 146 students in applied genetics and 117 students in general chemistry and inorganic chemistry. Two distinct questionnaires were applied. 31 students answered the questionnaire for applied genetics and 53 students answered the questionnaire for general chemistry and inorganic chemistry.

The questionnaires aimed to assess various elements about the disciplines under analysis and a specific matrix was prepared to ensure the best organization of the questions in each questionnaire, according to the defined objectives. Both questionnaires had the following generic organization:

- **Block I:** Assessment of the relevance of the discipline's content considering the course's training profile;
- **Block II:** Assessment of the methodology for organizing the teaching-learning process;
- **Block III:** Development of skills and relationship between conceptual and methodological knowledge;
- **Block IV:** Perception of the discipline's learning levels and;
- **Block V:** Perception of the development of general and specific competencies.

Considering the specificities of each of the three disciplines, as described previously, the questionnaires had a different number of questions. Likewise, the typology of these questions varied depending on the aspects they focused on. For the purposes of this research, only the data that allowed assessing the results on learning and the development of general and specific competencies as a result of the application of the problem-based learning methodology are presented.

Participant observation was used throughout the applied genetics classes and the general chemistry and inorganic chemistry classes over the academic years under analysis. The notes focused on the development of the capacity to apply and interpret knowledge, *i.e.,* the evolution of student learning. They also focused on the main difficulties, expectations, fears of failure, aspects of student-student and student-teacher relationships. During the application of this problem-based learning methodology, records were made in the researchers' logbook. It should be noted here that one of the researchers is the teacher of the three disciplines.

Regarding data collection, this process included two fundamental phases in the case of General Chemistry and Inorganic Chemistry disciplines, considering the nature of the activities carried out. The first phase consisted of observations made by the researchers during the practical laboratory activities based on problem-based learning. In this first phase, students were confronted with specific problems, on which they carried out previous theoretical research and then presented proposals for laboratory procedures to solve these problems. Field notes were recorded in the researchers' logbook and referred not only to the methodological and procedural aspects of the practical laboratory activities and the progress of learning and development of students' laboratory skills, but also to how students dealt with the degree of complexity and the challenge of the problems they faced and what the students themselves inquired about each situation. The notes also reflected the students' evolution in aspects such as communication skills, teamwork and cooperative learning.

The second phase of data collection consisted of applying a questionnaire, as described previously, which, among various aspects, sought to identify students'

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perceptions regarding the use of the problem-based learning methodology in General Chemistry and Inorganic Chemistry disciplines and the perceived advantages and gains in terms of developed socio-professional competencies.

For the Applied Genetics discipline, the data collection process also included two stages. The first consisted of observations made by the researchers during the sessions in which the problem-based learning methodology was employed. As the curriculum of this discipline did not include laboratory activities, the problem situations presented to the students were more theoretical in nature, although many of the topics included probabilistic mathematical calculations, as in the content on Mendelian inheritance. These problems proposed to the students focused mainly on various anomalies or hereditary diseases, their pattern of generational transmission and the role of mutations, as well as their sociocultural implications in the Angolan context. However, the problem-based learning methodology in this discipline followed the standard sequence. In this discipline, notes were also recorded in the researchers' logbook, referring to how students executed the methodological procedures in interpreting and solving problems and exercises involving Mendelian inheritance cases. Likewise, the notes reflected the students' evolution in aspects such as communication skills, teamwork and cooperative learning.

The second phase of data collection consisted of applying a questionnaire, as described above, which, among various aspects, sought to identify students' perceptions regarding the use of the problem-based learning methodology in the Applied Genetics discipline and the perceived advantages and gains in terms of developed socio-professional competencies.

In the data collection process, documentary analysis was also used on the curricular plans of the courses that include these disciplines, with the objective of identifying the defined training profile for each course, its curricular grid and the nature of the disciplines (core, complementary and general). The analytical programs of the disciplines were also analyzed, aiming to familiarize with the methodological suggestions contained therein. Furthermore, the legislation in force in Angola regarding the higher education subsystem was analyzed.

Given that the research did not aim to compare the institutions where the investigation was conducted regarding the use of problem-based learning, descriptive statistics, through the distribution of simple frequencies, were chosen for the analysis of data from the questionnaires. Their presentation was made in figures.

Data collection, through participant observation during the classes of the disciplines targeted by this research and the questionnaire, sought to comply with the ethical principles of social sciences research through the following measures:

- Provision of information to students, at the beginning of each academic year, regarding the objective and nature of the investigation, forms of their participation, access to and use of the obtained data;
- Non-compulsory participation of students in the research and the right to withdraw, throughout the didactic activities involving problem-based learning and also in answering the questionnaires;
- Anonymity of the questionnaires;
- Confidentiality of personal information and descriptions contained in the researchers' logbook, ensuring the use of this data only for the declared purposes in the investigation and under anonymity, with access to it being restricted to elements outside the research team;
- No capture of photographic images and videos of students and institutions where the research was carried out that contain identification elements;
- Sharing of research results with students and the management of the higher education institutions where the research was carried out, by providing a copy of the work after the Article's publication.

Systematization of Results

As mentioned previously, two distinct questionnaires were administered. The data collected from these questionnaires are presented separately. This is not intended to be a comparison between the two higher education institutions targeted in this research, but rather to highlight student perceptions regarding the application of problem-based learning methodology.

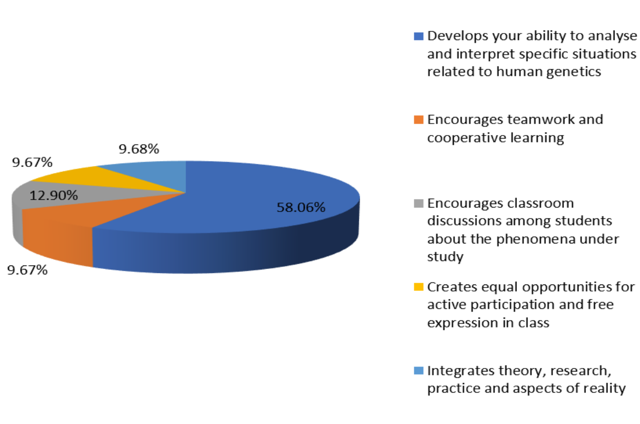

Figure 1: Applied genetics students' perception of problem-based learning methodology.

To support their answers to this question, students provided some examples, which are transcribed below:

- As a future psychologist, I will know how to deal with people whose psychological disorders are hereditary.

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- Regarding genotype, two individuals with the same genotype may exhibit morphological and physiological differences due to the influence of the environment in which they develop.
- I can now calculate the probability of a couple having a child with a certain dominant or recessive characteristic.
- By applying the rules of probability, I can calculate when one event might occur in relation to another and/or when they might occur simultaneously.
- As for albinism, we used to give empirical answers, but with this methodology and after understanding its autosomal recessive nature, it allowed us to give clearer answers through statistical probability calculations.
- I learned how to calculate genetic diseases.
- I further developed my argumentative skills.

These examples mentioned by the students coincide with the findings made by the researchers regarding the benefits of this methodology for learning specific aspects of applied genetics content.

Regarding the content areas in which students felt they significantly developed their research skills, the indications given by the participants follow **(Figure 2)**.

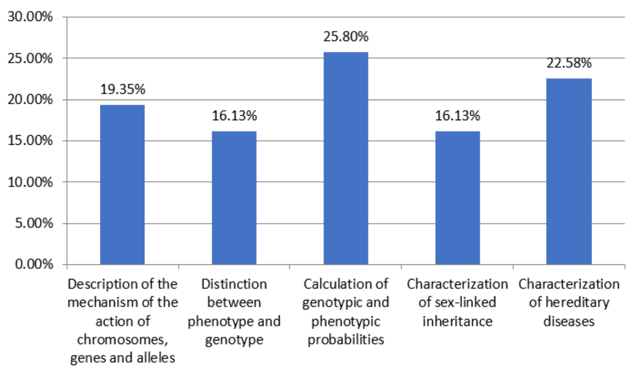

Figure 2: Applied genetics students' opinion regarding the content areas in which they significantly developed their research skills.

It is understood that students need to develop the ability to discover and use information, build their own problem-solving skills and learn the necessary content. The curriculum that best prepares future citizens and market professionals is not solely based on theory, but one that, in addition to theoretical knowledge, shows how to learn independently and how to use acquired information.

Regarding the type of assessment within the problem-based learning sequence, students indicated that it requires the mobilization and integration of various knowledge and skills, such as interpreting and formulating hypotheses for problem/exercise resolution and mathematical calculations. This can be seen in **figure 3**:

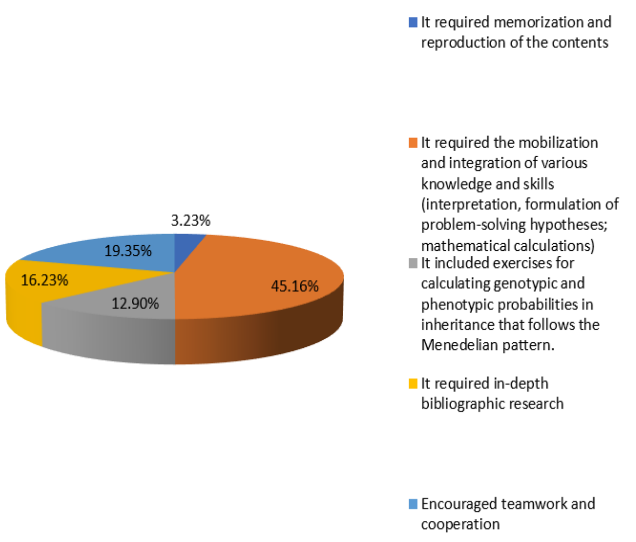

Figure 3: Applied genetics students' perception of the assessment's demands in the problem-based learning methodology.

These results corroborate the need to adjust assessment strategies to the problem-based learning methodology, considering its specificities. This is also confirmed by the researchers' notes, detailing the strategies by which student learning is assessed in a problem-based learning context.

The curriculum of these two disciplines includes a vast practical laboratory component, so the approach to content, within the problem-based learning methodology, demonstrated a predominance of inquiry-based teaching. The problem-solving teaching strategy was thus emphasized by the results in **Figure 4**.

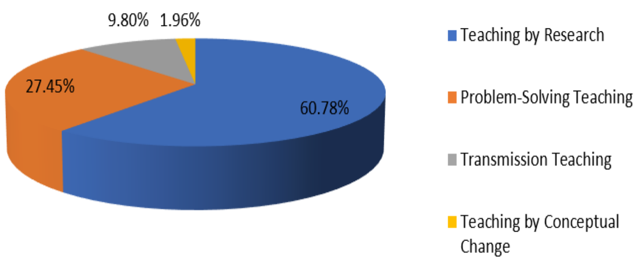

Figure 4: Opinion of general chemistry and inorganic chemistry students, characterizing the type of teaching in these disciplines.

The general perception of students about the practical laboratory activities carried out in these two disciplines points to teamwork and cooperative learning, with these activities based on problem situations, as illustrated in **Figure 5**.

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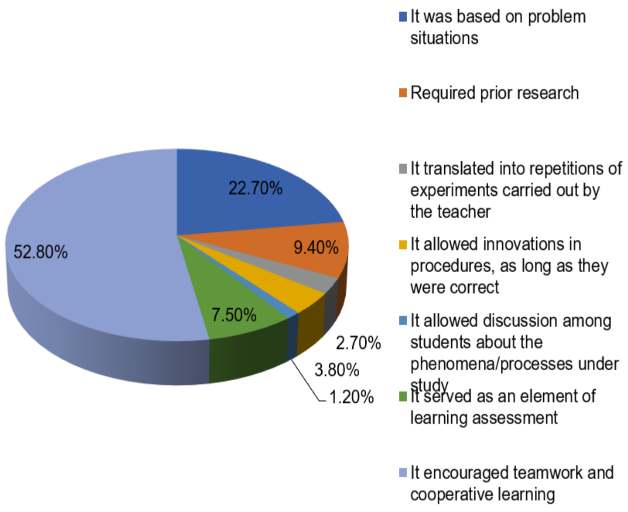

Figure 5: Opinion of general chemistry and inorganic chemistry students on the methodology of the laboratory activities performed.

For this question, some examples that students provided to support their answers were:

- With each laboratory experiment, we worked as a team and had significant learning.
- The teacher guided a topic for each group and the students researched and presented with practical lab experience, which helped cooperative learning.
- The teaching of Organic Chemistry and Inorganic Chemistry disciplines was based on research because we carried out many investigative tasks and applied the principle of the relationship between theory and practice, which consists of presenting practically everything learned in theory.
- Laboratory activities required investigative and teamwork from students, with laboratory experiments carried out by the student collective.
- During practical laboratory classes, we as students solved problems through experiments related to the topic we were discussing, all under the guidance/supervision of the teacher. In addition, we organized ourselves into groups to address the topics.
- Yes! They allowed me to develop this ability because we solved the problem situations presented.
- For example, before, I had problems analyzing a problem situation. After these Chemistry classes, I can now say that I have a greater ability to analyze certain research problems presented by the teacher.

Regarding the specific competencies developed in these two disciplines, it was found that the ability to formulate a specific problem and the steps for its formulation was a highly emphasized aspect, both in the researchers' logbook notes, as shown in **Figure 6.**

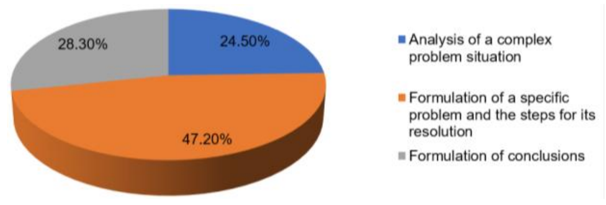

Figure 6: Perception of general chemistry and inorganic chemistry students about the specific competencies developed in these disciplines.

These results obtained through questionnaires are consistent with the observations made throughout the classes of the disciplines targeted by this research, as described in the researchers' logbook. Furthermore, they highlight the theoretical arguments presented in the first part of this Article regarding the benefits of problem-based learning in the progression of learning and the development of integrative competencies.

Final Considerations

Regarding the Applied Genetics discipline, the main results show that problem-based learning contributes to developing students' ability to analyze and interpret concrete situations related to human genetics. It encourages teamwork and cooperative learning and allows for the integration of theory, research, practice and real-world aspects. On the other hand, it demands the mobilization of basic knowledge and skills in probability and statistical calculation. These results also highlight the relationship between this methodology and the defined training profile for this course. In the General Chemistry and Inorganic Chemistry disciplines, the use of problem-based learning showed positive results in increasing students' interest and motivation across all programmatic content, greater dynamism of study groups and cooperative learning, greater autonomy of students in constructing their own knowledge in Chemistry, development of observation, manipulation and data interpretation skills and more contextualized and meaningful learning.

Declaration on Data Availability

The underlying content of the research text is contained within the manuscript. The complete set of anonymized data supporting the results of this study, program codes and other materials underlying the manuscript text have been made available on SciELO Data and can be accessed at "Replication data for: Problem-based learning in applied genetics, general chemistry and inorganic chemistry disciplines".

Authorship Declaration

Henriqueta Mutaleno Camenhe Pereira: Project coordinator. Responsible for the design and development

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of the research methodology. Responsible for formulating research objectives and goals, planning and executing research activities, conducting the research, specifically the data collection process. Active participation in data analysis and final writing review. Preparation and initial writing of the manuscript and final writing review.

Benedito Cangeno: Co-responsible for planning and executing research activities, designing and developing the research methodology. Active participation in data analysis and co-responsible for the preparation of the initial manuscript and final writing review.

Modesto Vilembo Jorge: Execution of research activities, specifically active participation in data analysis and data collection.

Conflict of Interest Declaration

The authors declare that there is no conflict of interest with the present article.

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