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Using concept maps for teaching Physics-Chemistry: the case of concept forces in physical science students at the qualifying secondary school in Morocco

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Abstract

The research work examines the effectiveness of concept maps in teaching the concept of force in the mechanics section qualifying secondary school students in Morocco. The main aim is to assess the extent to which the use of concept maps can clarify physical concepts, in particular force, and facilitate their integration with mathematical concepts such as vectors. The research proposes the use of concept maps as an innovative pedagogical tool to overcome potential learning challenges. Objectives include assessing the usefulness of concept maps in student problem-solving, analyzing the intersection between physical and mathematical concepts, evaluating the effectiveness of graphical representation, verifying the impact on student understanding and formulating recommendations for teaching. In summary, this research offers an in-depth perspective on the use of concept maps in teaching physics in Morocco, highlighting innovative solutions for improving student understanding without specifically mentioning learning barriers.

Keywords: Science didactics, Pedagogical innovation, Concept map, mechanical concept.

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1. Introduction

Science education, and physics teaching in particular, stands at the intersection of a stimulating challenge and an opportunity for pedagogical innovation. The use of concept maps is emerging as a promising strategy for addressing the diverse educational needs in this field. This article explores the potential of concept maps as a multifunctional tool in science education, while examining the difficulties encountered by physics teachers in solving complex problems [1]. In today's era of education focused on deep conceptual understanding, physics teachers face the challenge of making lessons more accessible and concepts more tangible for students. The use of concept maps is emerging as a relevant response to these challenges, offering a clear visualization of the relationships between complex ideas. As a communication strategy, concept maps facilitate the effective transmission of complex information while promoting holistic understanding. As a learning aid, they provide a visual framework for structuring knowledge, promoting retention and application of concepts. The ability of concept maps to support pedagogical planning also offers a structured way of organizing content, improving coherence and progression in teaching [2]. However, despite these potential advantages, physics teachers face particular difficulties in solving complex problems, such as those encountered in the exercise we address in this study. This research aims to examine how the use of concept maps can offer innovative solutions to overcome these specific obstacles.

1.1 Research objectives

1. Explore the multiple uses of concept maps in science education, focusing on their role as a communication

strategy, learning aid, planning support, and assessment support.
2. Identify the specific difficulties faced by physics teachers in solving complex problems, based on the example of an exercise dealt with in this research.
3. To examine how the strategic integration of concept maps can help to alleviate these difficulties, improving conceptual clarity and student understanding.

Through this exploration, our aim is to enrich the dialogue on innovative pedagogical practices in science, while offering practical insights for teachers seeking to optimize their approach in similar educational contexts.

1.2 Concept map

1.2.1 Definition of the concept map

A concept map is a formal, organized structure and method of organizing and representing knowledge. It consists of concepts labeled by boxes or circles that are linked by relationships between them indicated by arrows. The words, verbs or connectors on these arrows specify the types of connections between different concepts. According to Novak [3]. The use of concept mapping in teaching has long been recognized as a valuable tool for teachers, with a proven track record of improving students' abilities. Concept mapping enables the structure of knowledge to be represented visually, and students' achievements to be organized and assessed on the basis of interconnected concepts. This approach offers a multitude of benefits, such as assessing students' fundamental skills, helping them make connections between new information and existing knowledge, honing critical thinking skills and developing creative thinking. In addition, it helps students meet the challenges of understanding concepts and their interrelationships, while enhancing their metacognitive capacity and serving as a valuable assessment tool for identifying misconceptions [3-5]. Teachers have been using concept maps in the classroom for a very long time. This has been proven by numerous studies that have reported the effectiveness of concept maps in improving students' skills. Another promising piece of evidence many textbooks include concept maps right at the beginning or end of the book section. Concept mapping is a method of visualizing the structure of knowledge [3,6].

1.2.2 Characteristics of a concept map

A concept map was first proposed by Novac and Gowen [7]. It is a visual tool that graphically represents the links between different ideas, concepts or information. It is used to organize and structure knowledge in a clear and concise way. A concept map is generally made up of nodes, which represent concepts or ideas, and links, which indicate the relationships between these concepts. Here are some key features of a concept map.

1.2.2.1. Nodes

Main concepts are represented by nodes, often in the form of words or short phrases. Each node represents a key idea.

1.2.2.2 Links

Links establish connections between nodes and indicate the nature of relationships between concepts. Links can be directed to indicate hierarchical or unidirectional relationships.

1.2.2.3 Hierarchy

Concept maps can often be organized hierarchically, with more general concepts at the top and more specific concepts at the bottom.

1.2.2.4 Visual consistency

Concept maps often use colors, shapes, and sizes to help organize information in a visually consistent way. This can facilitate comprehension and recall.

1.2.2.5 Keywords

Keywords are used to summarize concepts and help keep the concept map concise.

1.2.2. 6 Flexibility

Concept maps are flexible and can be adapted as required. Nodes and links can be added, deleted or modified to reflect new information or perspectives [7, 8]. Concept maps are widely used in education, knowledge management, planning, and other fields to help visualize and organize ideas in a meaningful way. They are a powerful tool for thinking, decision-making and communicating complex information in a simple, structured way.

1.2.2 Difficulties in learning the concept of force

It is important to note that access to specific research on difficulties in learning the concept of strength among qualifying secondary school students in Morocco may be limited [9]. However, here are some general points that may be related to difficulties in learning this concept, based on common educational trends and general observations. Traditional methods of teaching physics can often focus on memorization rather than deep understanding. Students may find it difficult to apply force concepts to real-life situations. As in Morocco, teaching may be in Arabic, and some students may find it difficult to understand complex scientific concepts, such as force, in a language other than their mother tongue. What's more, many schools may face limitations in terms of educational resources, such as well-equipped laboratories for practical experiments that could help in understanding the concept of force. And it will always be attractive to use methods based on graphic illustrations, whether pictures, maps or videos, in the teaching-learning of scientific subjects, as they are one of the most widespread didactic means [10]. It is also the experience of many teachers that assessment methods that focus on memorization rather than comprehension and application can negatively influence the way students' approach and understand the concept of force.

In the work of *Boumghar* et al. [11] they mention that the definition of force is crucial to understanding this concept. Defining force through its four characteristics, namely point of action, direction, its sense and magnitude of force, does not guarantee understanding of this concept. The transition between the definition of a force and the application of a force (or forces) in context is often lacking [12]. According to *Maarouf* et colleagues [13] understanding a system of forces is not very intuitive for the learner, which leads to difficulties in determining the forces acting on different bodies. Furthermore, the simplification of problematic situations and the examples used when teaching the concept of force can lead to contexts that seem aberrant from the point of view of physics [11], [12].

1.3 Equilibrium of a force

The notion of force equilibrium is also subject to simplifications that create undesirable epistemological shortcuts [11]. Teaching-learning the concept of "force" and the persistence of difficulties What mathematical influence in reality, a common notion is to assert that in a given situation, forces balance, when in fact it is the "body [...] that balances under the effect of the forces applied to it" [11]. In addition, it is essential not to omit to represent any combination of forces in a situation. If two forces exert opposite effects and their vector sum is zero, it is not physically correct to neglect the representation of these forces [11,12]. According to *Maarouf* [13], understanding a system of forces poses challenges for the learner, as the definition of this concept is not instinctive. Consequently, the learner finds it difficult to discern which force acts on which body [12,13]. In addition, the simplification of problematic situations and the examples used in teaching the concept of force can lead to contexts that appear aberrant from the point of view of physics [11]. Static situations frequently involve the use of ropes, masses, pulleys and springs. In many cases, the mass of ropes, pulleys and springs is neglected, and forces are assumed to be transmitted from one solid to another. When the learner is faced with solving a problem situation independently, this raises the crucial question of which forces can be considered negligible [14].

1.4 Problems linked to obstacles encountered in acquiring scientific knowledge

Numerous studies [15,16] have highlighted the considerable obstacles students face when it comes to understanding seemingly elementary concepts. In disciplines such as physics or chemistry, even students who perform well on school tests and exercises do not necessarily demonstrate a thorough understanding of the principles being taught. They struggle to interpret problems and assess the relevance of procedures or solutions. In terms of cognitive psychology, we could say that they have not developed the conditional knowledge needed to determine when, how and why to use a specific piece of knowledge. Thus, the mere acquisition of principles or operations does not automatically guarantee their proper application. Students' difficulties in learning scientific concepts, principles and methods stem from a variety of factors [17].

1.5 The problem

The teaching of the physical sciences, and more specifically the concepts of physics, involves the transmission of scientific knowledge based on natural or artificially induced physical phenomena. In the act of teaching [18], particularly those related to force and vectors, we are often faced with challenges linked to the intrinsic complexity of these ideas and the need to link them to mathematical concepts such as vectors. The central question of our research lies in finding effective ways of clarifying these complex concepts and facilitating their understanding by students.

1.6 Research objectives

1.6.1 Assessing the usefulness of Concept Maps:

Measure the extent to which the use of concept maps can help to clarify physical concepts, focusing on notions such as force and vectors.

1.6.2 Analyze the Intersection between Physical and Mathematical Concepts

Explore how concept maps can serve as a bridge between physical and mathematical concepts, focusing on the graphical representation of vectors and their integration into physics teaching.

1.6.3 Evaluate the Effectiveness of Graphical Representation

Examine how the use of graphical representations, in this case concept maps, can improve the effectiveness of teaching physical concepts, bearing in mind that teacher professionalization is an ongoing process of professional development for teachers, aimed at improving their skills, knowledge and pedagogical practices [9], [19]. particularly in relation to force and vectors.

1.6.4 Verify Impact on Student Comprehension

Assess the impact of using concept maps on students' understanding, by analyzing their responses to complex exercises integrating physical and mathematical concepts.

1.6.5 Propose Recommendations for Teaching

To formulate practical recommendations based on the results obtained, aimed at guiding teachers in the successful integration of concept maps into their physics teaching, particularly when dealing with complex concepts such as force and vectors. Through these aims, our work aspires to provide valuable insights into the strategic use of concept maps in physics teaching, with a focus on clarifying complex concepts and the intersection between the physical and mathematical domains. The research aims to contribute to the improvement of pedagogical practices in the specific context of science education.

1.7 Research question

To what extent can the use of concept maps serve as an effective means of clarifying physics concepts, such as force, and facilitating their integration with mathematical concepts, particularly vectors, in physics teaching, and what impact does this approach have on student understanding?

2 Methodology

2.1 Working design

The aim of this study is to examine the effectiveness of using a concept map as a pedagogical tool in the teaching of mechanics. The latter, which is a fundamental branch of physics taught in Moroccan secondary schools, includes complex concepts such as force, motion, and energy, which require in-depth understanding. Our approach is to create a detailed concept map that prioritizes the main concepts of the course section on forces in mechanics and establishes links between them. This concept map will be used interactively during teaching sessions, guiding students in two classes of the "Physical Sciences and Chemistry" stream at qualifying secondary level through the key concepts, their interconnections and their practical applications. We plan to evaluate the impact of this method by analyzing students' performance in solving the proposed exercise based on the concepts of the concept map. In addition, we will examine knowledge retention over time by integrating the concept map into regular course reviews.

2.2 Search type

Our study adopts a quantitative approach to examine the impact of physical science teachers' use of a concept map to help learners find solutions to an exercise in mechanics, specifically on the forces applied to a body. The approach is based on the main objective of evaluating students' responses to the proposed exercise, taking into account the prior use of a concept map, Perceived causes of error, Emerging causes of error and the impact of error.

2.3 Population

The target population in the study are 68 students in the physical sciences class of the secondary cycle - first year Moroccan baccalaureate, with the participation of the teacher of both classes.

2.4 Instrument

As agreed, the instruments used in our work are applied in both stages of research. In the first stage, the teacher aims to use a disruptive tool to explain the course of a part of the mechanics' chapter. So, we proposed using a concept map (Figure 6) to explain the course, which can be a powerful way of visualizing and structuring key concepts. The second part is to propose to the students a course application exercise, the choice of which is crucial to the framework of our research, as we agreed with the teacher that the exercise must be aligned with the concepts taught in the course and allow a meaningful assessment of the students' understanding.

2.5 suggested activity

- Determine the system under study.
- Name the external forces acting on the plate (S), then determine the force whose intensity can be neglected in relation to the intensities of the others.
- Give the characteristics of the actions exerted on the plate.
- Extend in pencil, on the experimental document, the lines of action of these three forces towards the inside of the plate.
- Are the lines of action coplanar?
- represent the vector sum of these three forces, what do you find?
- Conclude on the equilibrium conditions of a solid subjected to three non-parallel forces.

The link created between what is taught using the concept map and what the exercise contains as a question was very important in our preparation of the work tool, below are some of the steps we followed in choosing the exercise.

2.5.1 Identify Key Concepts

Identify the key concepts that are important for understanding force vectors. These concepts have been presented in the course and through the concept map.

2.5.2 Assessment of difficulty

Selection of an exercise that presents an appropriate challenge for the students, but is still achievable with the knowledge acquired. It should require the application of key concepts.

2.5.3 Alignment with the Concept Map

The exercise is aligned with the elements present in the concept map. Students have been able to apply the concepts in the map to solve the exercise.

2.5.4 Variety of skills

Choose an exercise that assesses different skills, such as force vector manipulation, conceptual understanding, problem solving, etc.

2.5.5 Pedagogical Validation

Validation of the exercise choice was with colleagues in the same subject to ensure that it is appropriate for assessing understanding of the concepts being taught.

2.5.6 Consistency with Research Objectives

We also took into account whether the chosen exercise contributed to meeting the specific objectives of our research into the use of concept maps.

3. Results

The results analysis stage offers an in-depth perspective on the impact of using the concept map as a pedagogical tool. In this section, we undertake a direct exploration of the percentages derived from the responses of students who successfully built their knowledge by putting into practice the concepts taught through this innovative method. We will also dive into an in-depth discussion of the evolution of learners' knowledge [1] highlighting the results arising from the specific approach adopted within our research. This analytical approach will enable us to identify significant trends and evaluate the effectiveness of our methodology, offering enlightening perspectives for the ongoing understanding and improvement of the teaching process [1].

3.1 Figure 1

This question asks students to determine the system to be studied in the application exercise. More than half the students managed to give correct answers to the first question, while 18% gave no answer at all. One of the key questions in our application exercise was aimed at assessing students' ability to identify the system under study. The results reveal an encouraging trend, with more than half the students managing to provide correct answers from the very first question. This initial success suggests a solid understanding on the part of the learners regarding the determination of the system under examination. However, it is important to note that a significant percentage, 18%, did not provide any answers to this question. This may reflect a variety of factors, such as conceptual gaps, interpretation difficulties, or lack of familiarity with the subject. This observation raises interesting questions as to the underlying reasons for this non-response, and further investigations may be required to better understand these specific aspects. Considering these findings, it becomes imperative to implement targeted pedagogical strategies to address the identified gaps. This could include differentiated didactic approaches, additional review sessions, or interactive activities aimed at reinforcing understanding of the system concept in the context of our study. This first question serves as a basis for the remainder of our analysis, highlighting both initial successes and areas requiring further attention. By examining these results, we are better positioned to adapt our pedagogical approach and maximize student learning in the specific area of system determination studied.

3.2 Table 1

In our survey of 68 students concerning the identification of external forces acting on the study plate, we observed significant variations in learners' performance. The results break down as follows.

3.2.1 35 Students Citing the Three Forces

Among the group surveyed, a cohort of 35 students distinguished themselves by exhaustively identifying the three external forces. This success demonstrates a thorough understanding of the concepts covered, highlighting their ability to apply this knowledge to concrete situations.

3.2.2 11 students identifying two out of three forces

A second group of 11 students managed to identify two out of three external forces. This performance, while indicating a partial understanding, suggests a certain mastery of external influences on the system studied.

3.2.3 7 Students who identified only one of the three forces

A third group of 7 students managed to identify only one of the three forces. This initial achievement, though modest by comparison, shows some ability to recognize at least one external force.

3.3 Table 2

The next stage of our investigation involved asking students to provide the specific characteristics of each force identified, including point of application, line of action, direction and intensity. The results reveal some interesting trends in student understanding.

3.3.1 Correct answers from 25 students

A group of 25 students demonstrated an adequate understanding of the characteristics of the forces, providing correct answers regarding point of application, line of action, direction and intensity. This performance indicates a notable mastery of the concepts covered, reflecting a successful assimilation of the lessons given.

3.3.2 Incorrect answers from 29 students

However, an average of 29 students provided incorrect answers, suggesting gaps in understanding of force characteristics. Identifying the recurring patterns in these incorrect responses may be essential in targeting specific areas requiring clarification or revision in our teaching.

3.3.3 Correct Intensity Value by 19 Students

Among the participants, only 19 students managed to assign the correct intensity value for each force identified. This result underlines the complexity of accurate force characterization and highlights the need to deepen our understanding of this specific parameter in future teaching sessions.

3.4 Figure 2

An important step in our investigation was to ask the students to extend the lines of action of the three forces identified towards the interior of the experimental plate. The results reveal significant trends in learners' spatial understanding.

3.4.1 Correct answers from 17 students

Seventeen students succeeded in correctly extending the lines of action of the forces towards the inside of the experimental plate. This skill demonstrates an advanced understanding of spatial relationships and shows a successful application of theoretical knowledge to a concrete situation.

3.4.2 Incorrect answers from 32 students

In contrast, a majority of thirty-two students provided incorrect answers when it came to extending the lines of action of the forces. These errors could result from a variety of factors, such as difficulties with spatial visualization or conceptual misunderstandings. Analysis of the incorrect answers could reveal common patterns requiring attention in our teaching.

3.5 Figure 3

A crucial question concerned the coplanarity of the lines of action of the forces identified. The answers obtained provide essential indications of students' understanding of the spatial arrangement of the forces involved.

3.5.1 Correct answers from 28 students

Twenty-eight students correctly identified that the lines of action of the forces are coplanar. This response demonstrates a solid understanding of the concepts of coplanarity and highlights a successful integration of spatial principles in the context of our study.

3.5.2 Incorrect answers from 20 students

However, twenty students provided answers indicating an erroneous or incomplete understanding of the coplanarity of lines of action. These errors may be the result of various interpretations or conceptual misunderstandings. Analysis of these responses may reveal specific reasons for clarification in our teaching. Assessing the coplanarity of action lines is of particular importance in the context of our study, as it directly influences the modeling of the physical system in question. This stage of the investigation provides crucial information on students' ability to conceptualize the spatial relationships between the forces identified.

Table 1: Name the external forces acting on the plate (S), then determine the force whose intensity can be neglected in relation to the intensities of the other forces.

	Students	Percentage%
quote 3 forces	35	51,47
quote 2 forces	11	16,17
Quote A single Force	7	10,29
No answer	15	22,05
Determining the force that can be neglected	31	45,58
Total	68	

Table 2: Fill in the table showing the characteristics of the actions exerted on the plate

	Application point	Action line	Sens	Intensity
Correct answer	29	28	23	19
Wrong answer	24	25	30	34
No answer	15	15	15	15
Total	68			

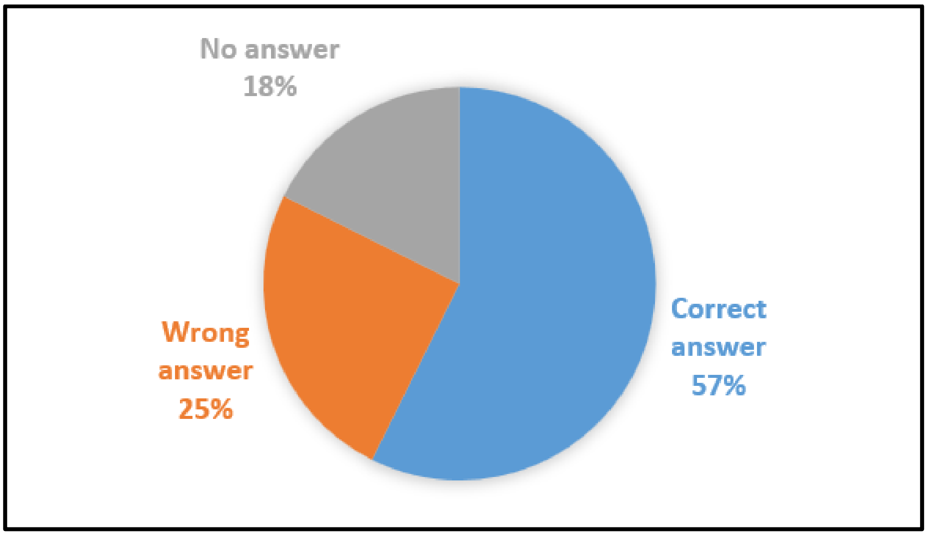

Figure 1: Identifying the system under study.

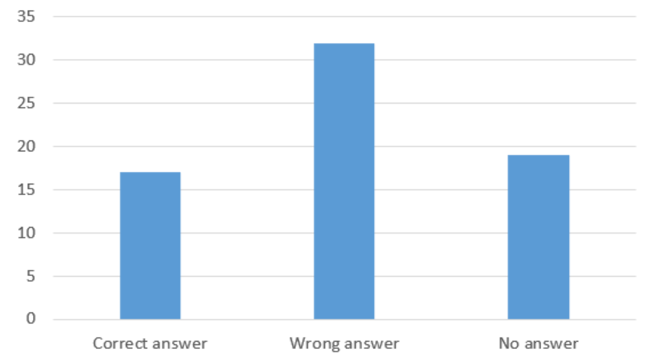

Figure 2: Extend the lines of action of these three forces in pencil, the lines of action of these three forces towards the inside of the plate.

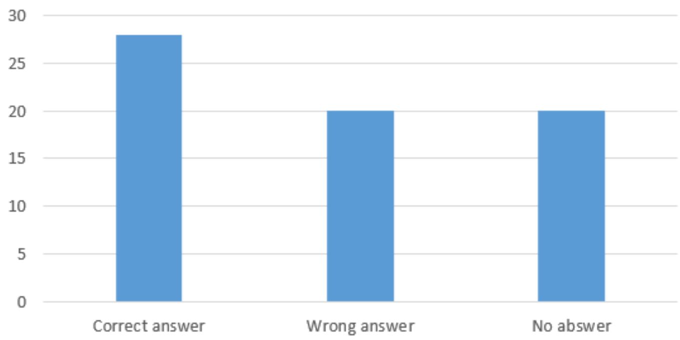

Figure 3: Are action.

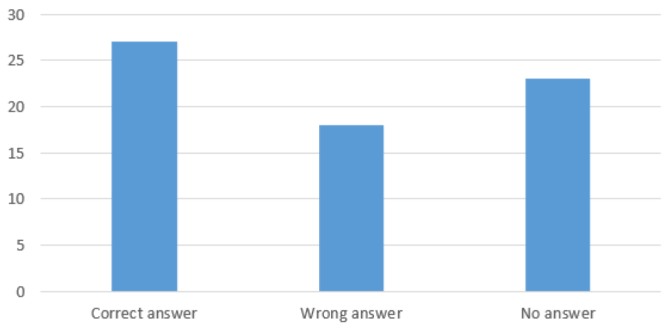

Figure 4: Show the vector sum of these three forces.

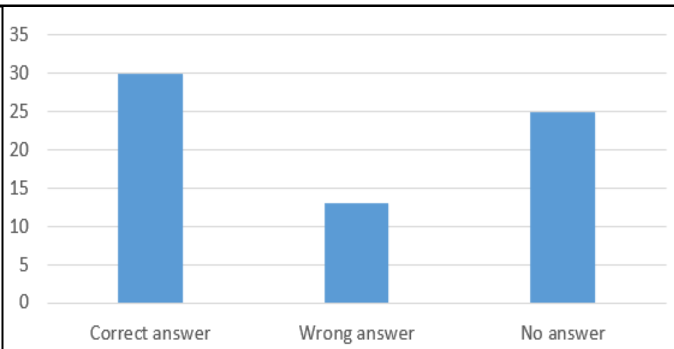

Figure 5: Conclude the equilibrium conditions of a solid subjected to three nominally parallel forces.

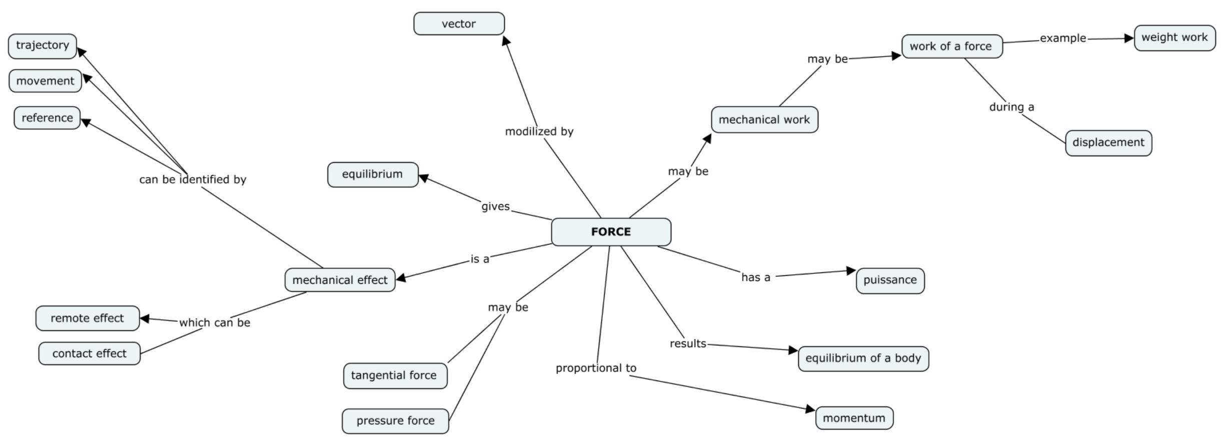

Figure 6: Conceptual map of the force concept used by the teacher.

3.5 Figure 4

A crucial step in our investigation was to assess students' ability to represent the vector sum of the three forces identified. The results obtained offer an insight into learners' competence in the practical application of vector sum concepts.

3.5.1 Correct answers from 27 students

Twenty-seven students succeeded in correctly representing the vector sum of the three forces. This skill demonstrates an adequate understanding of vector sum principles and indicates an ability to apply these concepts concretely in the context of our study.

3.5.2 Incorrect answers from 17 students

In contrast, seventeen students provided incorrect answers, indicating difficulties in accurately representing the vector sum. These errors could result from conceptual misunderstandings or vector visualization challenges. Analysis of these responses can help identify specific obstacles and guide our teaching to remedy these difficulties.

3.5 Figure 5

The final question in our survey assessed students' understanding of the conditions of equilibrium of a solid subject to three non-parallel forces. The results show a positive development compared with the previous questions.

3.5.1 Correct answers from 30 students

Thirty students provided correct answers, demonstrating a marked improvement in understanding the equilibrium conditions of a solid subjected to three non-parallel forces. This success suggests an effective assimilation of the fundamental principles of force and moment equilibrium.

3.5.2 Incorrect answers from 13 students

Despite this improvement, thirteen students gave incorrect answers, pointing to areas where further clarification may be required. Analysis of incorrect responses can help identify specific concepts that challenged students, making it easier to adjust our teaching to reinforce these areas.

4. Discussion

Concept maps are based on the theory of "meaningful" learning. According to Pour [1], these maps contribute to the development of learners' metacognitive skills. They also help to give meaning to their learning, by promoting meaningful learning, which is the in contrast to conventional or routine learning. They can pursue different pedagogical purposes. Before a lesson, for example, they are an excellent tool for the emergence of prior conceptions. Langlois's work [20] has shown that concept maps also concept maps can also be used to identify certain conceptions held by students, and to pinpoint concepts not assimilated by them, by comparing the maps produced before and after the teaching sequence [14]. The pedagogical approach centered on the use of concept maps to explain mechanical concepts revealed instructive results through our investigation. This methodology, aimed at visualizing relationships between concepts, was a key element in the teaching process.

4.1 The Identification of Forces

The use of concept maps has probably contributed to students' overall understanding in identifying external forces. In-depth discussions and visual demonstrations can further improve students' ability to determine which forces to overlook.

4.2 Force characteristics

Concept maps have probably served as useful visual tools in explaining force characteristics, although challenges persist in accurately determining intensity. Visual reinforcement and practical exercises could be considered to consolidate these concepts.

4.3 Extending the Lines of Action

Concept maps were able to facilitate students' understanding in extending action lines, although improvements are needed. Interactive graphic representations could reinforce students' competence in this area.

4.4 Coplanarity of Lines of Action

The use of concept maps probably fostered a solid understanding of the coplanarity of action lines. Further discussion to clarify incorrect answers may help reinforce this concept.

4.5 Vector Sum representation

The concept maps probably played a role in the understanding of vector sum representation. Interactive exercises to apply these concepts could be incorporated to reinforce this skill.

4.6 Equilibrium conditions under three forces

The use of concept maps may have facilitated students' progress in understanding equilibrium conditions under three non-parallel forces. In-depth discussions and practical applications to consolidate this knowledge can be envisaged. All in all, the concept-map approach was an asset in explaining mechanical concepts. The positive results reflect students' overall understanding, while also pointing to specific areas requiring attention. The ongoing evolution of this method, incorporating student feedback and iterative adjustments, will help refine our pedagogical approach. By maintaining a balance between concept visualization and practical application, we are well positioned to stimulate a deep and lasting understanding of mechanical principles.

4 Conclusion

This research work explored in depth students' understanding of specific mechanical concepts, implementing an innovative pedagogical approach based on the use of concept maps. The results provide rich insights into students' strengths, as well as areas requiring particular attention. The analysis of students' responses throughout the survey revealed significant progress in understanding forces, force characteristics, coplanarity of action lines, vector sum representation, and equilibrium conditions under three non-parallel forces. The integration of concept maps into the teaching process has probably played a key role in these advances, offering a clear visualization of the relationships between concepts. However, challenges remain, such as determining which forces to neglect, accurately characterizing force intensity, extending lines of action, and point errors in vector sum representation. These areas for improvement suggest the need for further development of targeted teaching strategies. The major conclusion of this study is the confirmation that the use of concept maps in the teaching of mechanical concepts can be an effective approach to fostering student understanding. The visualization of conceptual relationships appears to have stimulated the assimilation of knowledge and contributed to positive performance in several areas. To further enhance the effectiveness of this approach, specific adjustments may be considered. Hands-on activities, interactive exercises, and in-depth discussions to address identified errors can reinforce students' understanding and ensure a thorough mastery of mechanical concepts. In conclusion, this research work provides a solid basis for adapting and refining our pedagogical approach, thus contributing to the continuous improvement of the teaching of mechanical concepts in an educational context. The results offer valuable leads for the development of future pedagogical strategies, fostering robust and sustainable understanding among students.

6. Prospects for the research work

Integration of student feedback: Future prospects for this work could include the integration of student feedback. Gathering feedback directly from students on the usefulness of concept maps and on which aspects were most beneficial could provide valuable information for refining and improving the pedagogical approach. Longitudinal studies: To assess the long-term impact of using concept maps, longitudinal studies could be considered. Tracking students' progression in their understanding of physical concepts over time would provide a better understanding of the durability of the effect of this method. Comparisons with other methods: An interesting prospect would be to compare the effectiveness of concept maps with other teaching methods. Such a comparison could provide insights into the specific advantages of concept maps over other approaches. Teacher training: Exploring how teacher training could be adapted to optimally integrate the use of concept maps in physics teaching would be an interesting avenue. The way in which teachers are prepared to use this approach can significantly influence its effectiveness.

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