Diversitas Journal
ISSN 2525-5215
Volume 9, Issue 3 (Jul./Sep. 2024) p. 1459 – 1469
https://diversitasjournal.com.br/diversitas_journal

Teaching Stability in Physics: Problem Solving with Neuroeducation

BRANDÃO, Daniel Nicolau[1]

[1] 0000-0002-0291-8638; State University of Alagoas (*Universidade Estadual de Alagoas*). Arapiraca, AL, Brazil. daniel.brandao@uneal.edu.br.

ABSTRACT

The concept of stability in physics is often taught in a traditional way, focusing on theoretical explanations and formula-based problem solving. However, this approach may not pique student's interest or help them truly understand the topic. In this article, we present a proposal for a didactic sequence, which seeks to make the teaching of stability more engaging and meaningful. Using problem solving and integrating principles of neuroeducation, the proposal is divided into five stages: introduction to the concept of stability, identification of problems that challenge students, development of strategies to solve them, application of these strategies and, finally, an assessment that considers learning holistically. We believe that this methodology not only facilitates a deeper understanding of the concept of stability, but also encourages engagement and lasting retention of knowledge. This proposal was developed from a careful review of the literature and the analysis of existing didactic approaches, with the aim of addressing the specific challenges of teaching stability in undergraduate courses in Physics.

RESUMO

O conceito de estabilidade em física é, muitas vezes, ensinado de forma tradicional, com foco em explicações teóricas e resolução de problemas com base em fórmulas. No entanto, essa abordagem pode não despertar o interesse dos alunos ou ajudá-los a compreender verdadeiramente o tema. Neste artigo, apresentamos uma proposta de sequência didática, que busca tornar o ensino de estabilidade mais envolvente e significativo. Utilizando a resolução de problemas e integrando princípios da neuroeducação, a proposta é dividida em cinco etapas: introdução ao conceito de estabilidade, identificação de problemas que desafiem os alunos, desenvolvimento de estratégias para solucioná-los, aplicação dessas estratégias e, por fim, uma avaliação que considera o aprendizado de forma holística. Acreditamos que essa metodologia não apenas facilita uma compreensão mais profunda do conceito de estabilidade, mas também estimula o engajamento e a retenção duradoura do conhecimento. Esta proposta foi desenvolvida a partir de uma revisão cuidadosa da literatura e da análise de abordagens didáticas existentes, com o objetivo de enfrentar os desafios específicos do ensino de estabilidade em cursos de licenciatura em Física.

ARTICLE INFORMATIOS

Article Process:
Submetido: 06/25/2024
Aprovado: 08/26/2024
Publicação: 08/30/2024

Keywords*:*
Didactic Sequence. Stability. Problem-Solving. Neuroeducation. Physics Education.

Palavras-Chave:
Sequência Didática. Estabilidade. Resolução de Problemas. Neuroeducação. Ensino de Física.

DOI: 10.48017/dj.v9i3.3067

Introduction

Teaching the concept of stability is a fundamental piece in Physics degree courses, as understanding stability is crucial to understanding a wide range of physical phenomena. In the context of physics, the concept of stability can be defined as the ability of a physical system to return to a state of equilibrium after suffering a disturbance. According to Halliday *et al.* (2016), a physical system is in stable equilibrium when it returns to its original equilibrium position after undergoing a minor disturbance. In an unstable equilibrium, the disturbance results in an even greater distancing of the system from its original position, while in an indifferent equilibrium, the disturbance has no effect on the system. The concept of stability is widely used in several areas of physics, including mechanics, thermodynamics, and electricity and magnetism.

In order to assist teachers in teaching stability, this article proposes a didactic sequence based on the problem-solving strategy, using a neuroeducation approach. This approach is based on studies on the functioning of the brain and its relationship with the learning process.

Neuroeducation is an interdisciplinary field of research that seeks to apply knowledge from neuroscience to enhance education. In this way, by using teaching strategies that take into account the ways in which the brain learns, we can increase the possibility of effective learning and contribute to the retention of knowledge.

According to Guillén (2017), learning has its neurobiological basis in the complex communications between neurons, which occur through electrical signals in the neuron and chemical substances released between them, known as neurotransmitters. Some well-known neurotransmitters have major repercussions in the classroom, such as high levels of dopamine associated with students motivation to play, high levels of serotonin associated with laughter, low amounts of norepinephrine that can cause distraction, and low amounts of acetylcholine that can lead to sleep in an explanation that the student may find tedious.

For Herculano-Houzel (2019), neuroeducation is a promising approach to teaching Physics, as it allows teaching strategies to be adapted according to the individual needs of students, taking into account cognitive and emotional differences.

The problem-solving method is a teaching strategy that encourages the active participation of students in the search for solutions to practical problems, and is widely used in the teaching of Physics. This approach allows students to apply theoretical concepts in real-world situations and develop analysis, synthesis, and evaluation skills (Bonjolo, 2015).

Therefore, problem solving is proposed as a useful method to lead the student to a better understanding of concepts because, through problem solving, students are encouraged to develop critical and creative thinking skills, in addition to improving their ability to apply theoretical concepts in practical situations.

In this context, our didactic sequence emphasizes problem-solving as a teaching strategy that promotes the activation of brain areas related to memory and comprehension.

The sequence includes the presentation of problems that involve real and everyday situations, in order to make the content more relevant and meaningful for students. In addition, activities that stimulate metacognition and self-regulation of learning processes are used, such as individual and group reflections on the strategies used to solve problems.

Throughout this article, some of the main theoretical foundations of the neuroeducation approach and how they can be applied in stability teaching will be presented. Practical examples of problems that can be used in the proposed didactic sequence will also be presented, as well as pedagogical strategies that take into account the individual differences of the students.

This research intends only to propose the sequence, without effectively applying it in the classroom, exploring how the concept of stability can be worked using the problem-solving strategy, based on assumptions of neuroeducation. The aim is to expand knowledge about the teaching of Physics and identify possibilities for future research.

Theoretical framework

Teaching Physics can be quite challenging, especially when it comes to abstract concepts like stability. In this sense, it is important to seek pedagogical strategies that facilitate student learning, promoting a more meaningful understanding of the concepts involved. One possibility is to use problem solving as a teaching strategy in a neuroeducation bias, aiming to take advantage of neuroscience knowledge to improve processes in education. In this theoretical framework, some concepts and bibliographic references that support this proposal will be presented.

The first important concept for the teaching of Physics, in view of its interdisciplinarity, is that of significant learning, which Ausubel (2003) defined as that in which the new content is integrated with the student's previous knowledge in a non-arbitrary and non-mechanical way. In other words, learning is meaningful when there is a non-arbitrary and relevant relationship between the new content and the student's previous knowledge. Therefore, for learning to be meaningful, there needs to be a relationship between the new knowledge and the student's previous knowledge, so that the new knowledge can be incorporated into their cognitive structure in a meaningful and lasting way.

In this approach, the teacher plays an important role in helping students make connections between new knowledge and their previous knowledge, providing examples and real-world situations to illustrate abstract concepts, as well as creating activities that promote reflection and practical application of the acquired knowledge.

Neuroeducation is considered an educational paradigm, which seeks to integrate neuroscience knowledge with educational practice, and has shown ways for the student to achieve meaningful learning. Rotta *et al.* (2018) state that the development of new knowledge and behaviors is the main purpose of education, and this occurs through the learning process.

To acquire skills that allow us to perform tasks or solve problems, it is necessary to go through the teaching and learning process. This learning is possible thanks to brain activity, which encompasses sensations, perceptions, motor actions, emotions, thoughts, ideas, and decisions, all associated with brain functioning.

Mora (2017) tells us that neuroeducation uses neuroscience to find ways to apply knowledge about brain processes related to emotions, curiosity and attention in the classroom, and how these processes can stimulate learning and memory.

Among the methods that can be used for the student to achieve meaningful learning, problem solving is an important learning strategy that can be applied in different areas of knowledge, including physics. According to Polya (1945), problem solving consists of a process that involves understanding the problem, preparing an action plan, executing this plan and evaluating the results obtained. For Schoenfeld (1992), problem solving can be seen as a complex cognitive process, which involves not only mathematical skills, but also the use of metacognitive strategies and the construction of a meaning for the problem in question.

In Physics teaching, the use of problem solving has been widely discussed in the literature, especially in the context of teaching by inquiry. According to McDermott and Redish (1999), research in Physics teaching has focused on identifying students difficulties in relation to physical concepts and on the elaboration of teaching strategies that can contribute to the construction of more meaningful knowledge.

The research carried out by Costa *et al.* (2016), Problem solving as a strategy for teaching electric field in high school, which used problem solving in Physics teaching and obtained positive results. The authors applied a didactic sequence with problem solving to teach the concept of electric field to high school students. A significant increase in student performance in problem solving was observed, as well as an improvement in understanding the concept in question. The authors concluded that problem solving is an effective methodology for teaching Physics, which can contribute to the improvement of students learning and understanding of concepts.

Another research that used problem solving in the teaching of Physics associated with teaching by investigation was carried out by Carvalho *et al.* (2015). In this research, the authors applied a didactic sequence with problem solving to teach the concept of Ohm's law to high school students. It was observed that the students showed a better performance in problem solving and a greater understanding of the concept of Ohm's law after the application of the didactic sequence.

Sousa *et al.* (2020) applied a didactic sequence using problem-solving and the mind mapping technique in teaching kinematics to high school students. For this, questionnaires were used to assess the students' previous knowledge about the content, as well as engagement in the activities and understanding of the content after the application of the didactic sequence. The results showed that there was a significant increase in student engagement in the activities, as well as an improvement in the understanding of the content after the application of the didactic sequence. In addition, it was observed that the use of the mind mapping technique helped in the organization of the students knowledge, enabling an effective learning process. These results reinforce the importance of using methodologies in which students are protagonists of their own learning in the teaching of Physics, such as problem solving and the use of neuroeducation techniques, which can contribute to the use of neuroeducation techniques, that can contribute to a more meaningful learning of the contents.

Thus, the proposition of a didactic sequence for the teaching of stability in a Physics degree course, using the strategy of problem solving and assumptions of neuroeducation, can be an alternative to improve the teaching-learning process in this area of knowledge.

Methodology

Exploratory research aims to explore and learn more about a given topic, identifying its main characteristics, gaps, and research possibilities. According to Gil (2008), exploratory research is indicated when the topic addressed is little known or little studied, or when one wants to obtain a broader and more comprehensive view of the subject.

According to Marconi and Lakatos (2017), exploratory research is a type of research that seeks to discover new aspects of a little-known reality, identify new problems, and understand complex phenomena. For these authors, the main objective of exploratory research is to formulate questions and hypotheses for further research.

Thus, the proposition of a didactic sequence for the teaching of stability in physics, using problem solving associated with neuroeducation, can be considered an exploratory research, since it seeks to explore the possibilities of these approaches for the teaching of a specific concept and identify new aspects that can be the object of study in future research.

To compose the didactic sequence, it was necessary to collect bibliographic data through a literature review on the subject. To this end, a systematic search was carried out in the SciELO and Google Scholar databases, in order to obtain access to books and articles related to the theme of neuroeducation, problem solving and teaching stability in physics. From this literature review, it was possible to build the theoretical framework to support the proposal of didactic sequence.

Proposal for a didactic sequence

The section that deals with the didactic sequence is one of the most important parts of this article, as it presents the proposal of teaching stability in a Physics degree course, using the combination of the problem-solving strategy with a neuroeducational approach. In this section, the objectives, steps and activities proposed for the didactic sequence will be presented, aiming to assist the teacher in the organization of the teaching and learning process. The following will describe the activities in detail, indicating the specific objectives and the resources needed to carry them out. In addition, theoretical justifications for the use of problem solving and neuroeducation in stability teaching will be presented, as well as the main results of research that used this approach in Physics teaching.

Specific Objectives:

1. Understand the concept of stability and its relationship with the laws of physics;
2. Identify the variables involved in the stability of a physical system;
3. Apply troubleshooting to stable and unstable systems analysis;
4. Develop cognitive skills, such as selective attention, working memory, and decision-making, through neuroeducation-based practices;
5. Use technological tools, such as simulation and modeling software, for the visualization and analysis of stable and unstable systems.

Resources needed to apply the didactic sequence:

- Whiteboard and markers;
- Computers with internet access and simulation and modeling software (e.g., PhET Simulations, Tracker, etc.);
- Problems proposed for resolution in the classroom.

Steps:

1. Introduction to the concept of stability: In this step, the teacher will present the concept of stability, its types and examples of application in different contexts. Examples of objects in equilibrium and the factors that influence their stability can be explored.
2. Problem-solving activities: in this stage, students will be asked problems related to the theme of stability. The problems should be designed in such a way that students need to use the concepts of stability to solve them. It is important that students work in groups so that they can discuss solutions and exchange knowledge. Let us cite two examples that can be used by the teacher to introduce the concepts:

Problem 1: Stability of a Suspension Bridge

Context: Imagine that you are on a suspension bridge, which crosses a river, on a windy day. Suddenly, the bridge starts swaying from side to side, and you wonder what's causing it.

Problem: How would you explain the behavior of the bridge when swinging? What factors could be affecting the stability of the bridge during high winds? Use the concepts of force, moment of inertia, and center of mass to understand what is happening. What could be done to make the bridge more stable under these conditions?

Question 2: Stability of an Object on an Inclined Surface

Context: Think of an everyday situation, such as when you place a book or box on a sloping surface. As you tilt the surface, you notice that the object may start to slide or even tip over.

Question: At what point does the object lose stability and begin to slide or tip over? What factors influence this behavior, such as gravity, friction, and the position of the center of mass? Use these concepts to explain how the tilt angle affects the stability of the object and calculate the critical angle where stability is lost.

3. Neuroeducation activities: In this stage, neuroeducation techniques will be used to assist students in learning the contents. One of the techniques that can be used is the elaboration of mind maps, which helps to organize knowledge and relate concepts. In addition, other techniques can be used, such as gamification, which consists of transforming the learning process into a game, or storytelling, which, according to Lôbo *et al.* (2024), is an effective strategy to enrich the teaching-learning process, promoting a more dynamic and meaningful learning environment. This methodology helps engage students by connecting academic content with narratives that pique interest and facilitate understanding, resulting in better knowledge retention and the development of critical and analytical skills.
4. Group discussion: In this stage, students will meet in groups to discuss the solutions to the proposed problems, as well as to present and discuss their mind maps. It is important that the teacher encourages participation and the exchange of ideas among students, so that everyone can contribute to the discussion.
5. Evaluation: In this stage, evaluations will be applied to verify the student's level of understanding on the topic of stability. It is important that the assessments are designed in such a way that students need to apply the concepts of stability to solve them.

This didactic sequence seeks to provide significant learning of stability content, using problem solving and neuroeducation as methodologies in which students are protagonists in the teaching and learning process. For the application of the sequence in the classroom, the teacher must consider the following points during the elaboration of the steps:

1. Awareness: At this stage, the teacher should arouse the interest of students in the topic of stability, using examples from everyday life, experiments and explanatory videos.
2. Establishment of basic concepts: In this step, the teacher must present basic concepts such as force, torque, moment of inertia, center of mass, static and dynamic balance, among others.
3. Application of concepts: In this stage, the teacher must propose practical problems involving situations of balance, rotation and oscillations, so that students can apply the concepts learned in the previous stag.
4. Case studies: At this stage, the teacher should present real cases that exemplify the importance of stability concepts in everyday life, such as in the construction of bridges, buildings, vehicles, safety equipment, etc.

5. Complex problem solving: In this step, the teacher should propose more complex problems that require the integration of several concepts learned in the previous steps, using problem solving as a methodology. The teacher can introduce scenarios where students must consider variables such as external forces, temperature changes, or changes in the initial conditions of a system. Such problems require students to apply what they have learned in new and creative ways, often necessitating detailed analysis, use of simulations, or mathematical modeling.
6. Reflection and metacognition: At this stage, the teacher should encourage students' reflection on the learning process, stimulating metacognition, so that students can identify their difficulties and their learning strategies.
7. Evaluation: In this stage, the teacher must evaluate the performance of the students using different instruments, such as tests, assignments, reports, among others. Additionally, it is important to incorporate formative assessment throughout the learning process, allowing students to identify and correct their difficulties on an ongoing basis. To enrich this stage, the teacher can also integrate neuroeducational activities, which aim to feed back into the learning process. For example, the teacher can use **mind maps** for students to visualize and organize their knowledge about the concepts studied, facilitating the identification of gaps and promoting the integration of new information. Another strategy is the use of **reflective dialogues** in which students discuss in groups how they approached a specific problem, what they learned and how they could improve their future approaches. **Self-regulation exercises**, such as keeping a learning diary where students record their difficulties and successes over time, can also be utilized to encourage metacognition and help students adjust their study strategies.

It is important to remember that problem-solving must be present at all stages, as it is an efficient methodology to develop **cognitive and metacognitive skills** in students. For example, the cognitive skill of critical analysis will be developed as students evaluate and interpret different aspects of the problems presented. The **metacognitive ability of self-regulation** will be strengthened by encouraging students to monitor and adjust their problem-solving strategies, reflecting on what worked and what can be improved.

In addition, neuroeducation should be used as a pedagogical approach that takes into account neuroscience findings on the functioning of the brain during the learning process. In this didactic sequence, neuroeducation is present in different stages, such as the choice of problems to be solved, the use of metaphors and analogies to facilitate the understanding of concepts, the use of immediate feedback to strengthen neuronal connections and the promotion of activities that stimulate students' curiosity and motivation.

Conclusion

The proposal of a didactic sequence for the teaching of stability, in a Physics degree course, which uses problem solving and principles of neuroeducation, is a promising strategy for the improvement of student learning. Approaching this theme in a more dynamic and challenging way can contribute to a deeper understanding of concepts related to stability in physics, which can reflect in a more satisfactory learning.

The use of neuroeducation in the teaching and learning process has been shown to be an effective approach to stimulate students motivation and attention. In this sense, the application of problem-solving methodology associated with neuroeducation strategies can be an innovative way to teach more abstract concepts of physics and to make them more attractive and interesting.

Therefore, the present proposal can contribute to the development of more dynamic and effective didactic strategies in the teaching of stability in physics, allowing students to be able to understand and apply these concepts in a more meaningful and autonomous way. It is important to note that this proposal can be adapted and improved according to the needs and particularities of each group of students, enabling a personalized teaching and learning process.

REFERENCES

Ausubel, D. P. (2003). *Aquisição e retenção de conhecimentos: Uma perspectiva cognitiva*. São Paulo: Plátano Edições Técnicas.

Bonjolo, É. L. (2015). A resolução de problemas no ensino de física. *Revista Prática Docente*, 1(1), 1-14.

Carvalho, A. M. P., Falcão, T. P., & Gomes, R. M. (2015). Resolução de problemas como estratégia de ensino em física: uma revisão bibliográfica. *Revista Brasileira de Ensino de Física*, 37(2), 1-12.

Costa, V. B., Silva, M. A., Oliveira, J. P., Santos, A. L., & Gomes, R. F. (2016). Resolução de problemas em física: Uma proposta baseada em estratégias de resolução. *Revista Brasileira de Ensino de Física*, 38(3), 1-10. https://doi.org/10.1590/S1806-11173812002

Costa, V. M. R., Sousa, A. L. S., Ribeiro, S. M., & Fernandes, P. C. (2016). Resolução de problemas como estratégia para o ensino de campo elétrico no ensino médio. *Revista Brasileira de Ensino de Física*, 38(1), e1301. https://doi.org/10.1590/S1806-11173812002

Gil, A. C. (2018). *Métodos e técnicas de pesquisa social* (7ª ed.). Atlas.

Guillén, J. C. (2017). *Neuroeducación en el aula: De la teoría a la prática*. Barcelona: Createspace Independent Publishing Platform.

Halliday, D., Resnick, R., & Walker, J. (2016). *Fundamentos de Física*. Volume 2. 10. ed. Rio de Janeiro: LTC.

Herculano-Houzel, S. (2019). Neuroeducación y aprendizaje de la física. *Enseñanza de las Ciencias*, 37(1), 81-89.

Lôbo, I. M., Assis, A. H. S., Gonthier, H. A., Pereira, S. M. J., & Vicente, R. D. (2024). O papel do storytelling na melhoria da qualidade educacional em escolas públicas de ensino fundamental. *Revista Ibero-Americana de Humanidades, Ciências e Educação*, 10(04), 1454-1461. https://doi.org/10.51891/rease.v10i4.13719

Marconi, M. de A., & Lakatos, E. M. (2017). *Fundamentos de metodologia científica* (8ª ed.). Atlas.

Mcdermott, L. C., & Redish, E. F. (1999). Resource letter: PER-1: Physics education research. *American Journal of Physics,* 67(9), 755-767.

Mora, F. (2017). *Neuroeducación: Solo se puede aprender aquello que se ama*. Madrid: Alianza Editorial.

Polya, G. (1945). *How to solve it: A new aspect of mathematical method.* Princeton: Princeton University Press.

Rotta, N. T., Bridi Filho, C. A., & Bridi, F. R. (2018). *Plasticidade cerebral e aprendizagem: abordagem multidisciplinar*. Porto Alegre: Penso.

Schoenfeld, A. H. (1992). Learning to think mathematically: Problem solving, metacognition, and sense-making in mathematics. In D. A. Grouws (Ed.), *Handbook of research on mathematics teaching and learning* (pp. 334-370). Macmillan.

Sousa, A. S., Ribeiro, S. B., Santos, A. S., Candido, R. B., & Cruz, A. C. (2020). A utilização da neuroeducação e a resolução de problemas na aprendizagem da cinemática no Ensino Médio. *Research, Society and Development*, 9(4), e199432040. https://doi.org/10.33448/rsd-v9i4