Ciencia y Tecnología, 37(2): 30-36, 2021
ISSN: 2215-5708

TOOLS TO HELP STUDENTS MAXIMIZE THEIR LEARNING

Mariela A. Porras-Chaverri‡.

[1]School of Physics, University of Costa Rica, San José, Costa Rica.

Received May 2021; accepted November 2021

Abstract

Physics instructors, especially those who are new to teaching, often have a strong background in their field but limited knowledge of educational theory. This work aims to address this issue by providing a summary of learning strategies utilized by students, along with their key advantages and disadvantages, in a clear and concise manner. The focus is on techniques that promote efficient time utilization and active thinking among students. In addition to summarizing various learning strategies, this work also offers recommendations and practical examples of how these strategies can be implemented in the classroom. The intention is to provide instructors with actionable insights that can enhance their teaching methods and improve student engagement and understanding. It is worth noting that while this work specifically focuses on physics education, the knowledge and strategies presented can be applied by instructors in other STEM (Science, Technology, Engineering, and Mathematics) fields as well. By incorporating these effective learning strategies into their teaching practices, instructors in various STEM disciplines can create a more engaging and productive learning environment for their students.

Resumen

Las personas docentes de Física, especialmente aquellas que son principiantes, suelen tener una sólida formación en su campo pero un conocimiento limitado en teoría de la educación. Este trabajo tiene como objetivo abordar esta situación al proporcionar un resumen de estrategias de aprendizaje utilizadas por los estudiantes, junto con sus principales ventajas y desventajas, en un lenguaje claro y conciso. Se enfoca en técnicas que promueven el uso eficiente del tiempo y el pensamiento activo entre estudiantes. Además de resumir diversas estrategias de aprendizaje, este trabajo también ofrece recomendaciones y ejemplos prácticos de cómo implementar estas estrategias en el aula. La intención es brindar ideas concretas que puedan mejorar los métodos de enseñanza del personal docente y aumentar la participación y comprensión de las personas estudiantes. Es importante destacar que si bien este trabajo se centra específicamente en la educación en Física, el conocimiento y las estrategias presentadas también pueden ser aplicados por instructores en otros campos de STEM (Ciencia, Tecnología, Ingeniería y Matemáticas). Al incorporar estas estrategias efectivas de aprendizaje en las prácticas de enseñanza, se puede crear un ambiente de aprendizaje más interesante y productivo.

Keywords: STEM education, Physics education, active learning, learning strategies

Palabras clave: Educación STEM, educación de la Física, aprendizaje activo, estrategias de aprendizaje

I. INTRODUCTION

The following document is intended as a brief guide for basic science instructors. It aims to bridge the gap between didactic research and classroom implementation for beginner instructors with basic instructional knowledge. As such, it presents the concepts in language familiar to recent Physics graduates with no prior training in Education and is not intended to be an exhaustive review of didactic theory.

The main motivation is to provide Physics instructors, particularly beginner instructors, with a summary of successful learning strategies that can be used to plan their lessons and guide students in the learning process, as well as guidance on how to apply them in their lesson design. The knowledge

[1*]Corresponding Author: mariela.porras@ucr.ac.cr

summarized in this document can also be extended to instructors of other STEM (Science, Technology, Engineering and Mathematics) fields.

The contents of this document are based on the author's previous experiences as a Physics instructor using active learning techniques. These experiences were shared in presentations at the XIII Latin American Symposium on Nuclear Physics and Applications, as well as in a workshop presented at the American Association of Physicists in Medicine Annual Meeting in 2017. It is important to note that there are no previous written publications specifically related to the contents of these presentations.

Physics graduates undergo several years of training in their respective fields. One possible career path for these professionals is teaching at both high school and university levels. However, it is important to note that training in Education is not typically included as part of a Physics undergraduate or graduate curriculum (Oficina de Orientación, 2021). As a result, while Physics graduates may have the necessary knowledge and expertise to teach the technical content of a syllabus, they may lack the necessary tools to effectively impart this knowledge to their students and foster the development of other skills in the classroom. This limitation becomes particularly significant because STEM courses are frequently taken by students at the onset of their university education, making them ideal opportunities for the development of critical thinking and professional communication skills (Mäntylä, 2011). Moreover, instructors have the responsibility to prepare students for a rapidly changing world, where knowledge in all fields is constantly being renewed and updated (Patel, 2012).

Instructors may also encounter the limitation of insufficient time to cover all topics in depth during their classes. Therefore, it becomes crucial to optimize both the instructor's time and the students' individual study time, aiming for an efficient learning experience. (Suciu, 2011).

The term "efficient" in the context of learning refers to the effective use of time and resources, while also promoting long-term retention and recall of knowledge. It involves ensuring that students not only acquire knowledge during their learning experience but also retain it in their long-term memory, allowing them to apply that knowledge creatively in real-world situations. Without this long-term retention and recall of concepts, students may struggle to effectively solve future problems in their professional field (Westover, 2009).

II. REVIEW OF LEARNING STRATEGIES USED BY STUDENTS

As instructors, it is crucial to understand the techniques that students commonly use and evaluate their effectiveness in promoting long-term retention. It should be noted that different learning strategies may be more suitable for different types of content, and it is the responsibility of the instructor to guide students based on the specificities of the course materials.

Some of the commonly used techniques include rereading, highlighting, and summarizing. Rereading is a straightforward approach, but its effects on long-term retention may be limited compared to more active strategies. Highlighting, when used in conjunction with reading or rereading, can give students a sense of progress, but it may not facilitate the connection of ideas across the text. While highlighting can serve as a starting point, it is unlikely to lead to enduring knowledge on its own.

It is important for instructors to explore and implement more effective learning strategies that promote active engagement and deeper processing of the material. Such strategies may include concept mapping, practice testing, elaborative interrogation, and spaced repetition, among others. These techniques encourage students to actively interact with the content, make connections, and apply their knowledge, which can enhance long-term retention and the ability to apply that knowledge in real-world scenarios (Dunlosky et al., 2013).

Indeed, summarization is a more active learning strategy that encourages students to carefully analyze and connect concepts. However, it is important to note that effective summarization requires proper training and practice (Özdemir, 2018). Additionally, creating comprehensive summaries can be time-consuming for students.

While summaries or concept maps provided by the instructor can be valuable resources to highlight important concepts and ideas, it is the act of summarizing performed by the students themselves that truly enhances their understanding and knowledge retention. This personal engagement with the material promotes deeper processing and critical thinking skills.

However, it is also essential to consider the efficiency of the learning process. Given the time constraints that instructors and students often face, it may not be feasible for students to spend excessive time on summarization, especially for extensive or complex subjects. In such cases, a balance should be struck between the benefits of summarization and the time investment required.

Instructors can support students by providing guidelines and examples for effective summarization, as well as offering opportunities for collaborative summarization activities. This way, students can practice summarization skills while also benefiting from peer learning and feedback. By incorporating a combination of active learning strategies, instructors can optimize the use of instructional time and facilitate meaningful learning outcomes.

Another set of techniques utilized by students to aid memorization is the use of mental imagery (Dunlosky, 2013). One specific technique is the use of keyword mnemonics, where keywords are associated with vivid mental images. This approach can be particularly effective for learning vocabulary or technical terms. However, it is important to note that the effects of this technique on long-term memory may be limited.

Similarly, the technique of using imagery for text involves creating mental images to represent the concepts being studied. While this technique can be enjoyable and engaging, its benefits may be more short-term in nature. Furthermore, it requires a significant investment of time and effort to generate the imagery.

Instructors should consider the trade-off between the potential benefits of mental imagery techniques and the time and effort required to implement them. While these techniques can be helpful in certain contexts, they may not always result in long-lasting memory retention. Therefore, it is important to supplement these techniques with other strategies that promote deeper understanding and retention of the material.

A set of more efficient learning strategies falls under the category of active reading techniques (Dunlosky, 2013). These techniques encompass elaborative interrogation and self-explanation. Elaborative interrogation involves posing questions about the text, specifically using the prompt "why?". It is important to note that the emphasis is not solely on providing correct answers to these questions. The value of this technique lies in encouraging students to actively revisit and review the material, which enhances their retention of the information (Roediger, 2012).

By engaging in elaborative interrogation, students actively interact with the text, critically analyzing and seeking explanations for the content. This process fosters deeper understanding and improves the ability to recall and apply the knowledge in the future. The act of questioning prompts active thinking and promotes a more meaningful connection with the material being studied.

It is worth mentioning that incorporating active reading techniques like elaborative interrogation requires guidance and practice. Instructors can support students by providing examples of effective questioning strategies and encouraging them to apply this technique consistently. By engaging in active reading, students can enhance their comprehension, retention, and application of the subject matter, resulting in a more efficient learning experience.

In the self-explanation strategy, students not only explain concepts and ideas in their own words as they read the text, but they also make connections to their prior knowledge. By doing so, students actively engage with the material, processing the ideas and constructing their own mental maps of knowledge (Roediger, 2012).

Self-explanation involves articulating and elaborating on the content, either verbally or in writing, to make sense of the information and integrate it with existing knowledge. By actively explaining the material, students reinforce their understanding and identify any gaps or misconceptions in their comprehension. This process encourages critical thinking and deepens the learning experience. Moreover, self-explanation helps students become more aware of their own learning processes and monitor their understanding. By reflecting on their explanations, students can identify areas of confusion or uncertainty and take appropriate steps to address them, such as seeking clarification or further study.

By incorporating self-explanation as a learning strategy, instructors empower students to take ownership of their learning and foster meaningful connections between new information and their existing knowledge frameworks. This active engagement enhances comprehension, retention, and application of the material, facilitating a more effective and efficient learning experience.

Finally, we come to the mindful practice techniques (Dunlosky, 2013). These strategies include practice testing, distributed practice, and interleaved practice.

Practice testing involves using tests as a learning tool, including both instructor-designed tests as part of course activities and tests created by students during their own study. This technique complements other more passive learning techniques discussed earlier (Roediger, 2012). By actively engaging with test questions, students enhance their understanding and retention of the material.

Distributed practice is a variation of the traditional massed practice, where students study a single subject for an extended period of time. In distributed practice, students spread their study activities for a subject in a non-linear fashion. This approach encourages the linking of material across different topics and improves long-term retention, even when the same amount of time is dedicated to studying (Roediger, 2012).

Interleaved practice is another variation of practice that involves mixing topics and subjects during study sessions (Rohrer, 2015). While initially counterintuitive, this approach helps overcome the illusion of competence that can arise from focusing on a single topic or subject. Interleaved practice promotes the recall of information and the making of connections across disciplines, leading to longer-term retention of the content (Koriat, 2005; Moreira, 2019). This approach is particularly valuable for the comprehensive and efficient learning necessary for the training of future professionals.

By incorporating these mindful practice techniques into their study routines, students can enhance their learning efficiency, improve long-term retention, and develop a more integrated understanding of the material. These techniques go beyond passive reading or massed practice, offering effective strategies for meaningful learning and application of knowledge.

III. RECOMMENDATIONS FOR INSTRUCTORS

The learning strategies summarized above can serve as valuable tools for instructors in designing course activities and guiding students in their approach to class materials. To facilitate easy reference, a summary of these techniques and recommendations for instructors are provided in Table 1 below.

Table 1. Summary of learning techniques and recommendations for instructors.

Type of strategy	Learning strategy	Advantages	Disadvantages	Recommendations
Common	Rereading	Easy to implement	Passive Results may not be long-lasting	Use along more active strategies
	Highlighting or underlining	Gives sense of progress in covering material	Passive May hinder connection of ideas	Use as a starting point for more active strategies
	Summarization	Active processing of the reading material	Requires guidance and more time than other techniques	Recommended when theory is evaluated directly (for example, definitions)

Type of strategy	Learning strategy	Advantages	Disadvantages	Recommendations
Mental imagery	Keyword mnemonic	Active Useful to learn vocabulary	Benefits may be short-term	Use along other techniques
	Imagery for text	Enjoyable	Benefits may be short-term Requires mor time than other techniques	Instructors may use storytelling as part of their lesson
Active reading	Elaborative interrogation	Improves understanding and retention	It may take time to adjust to make stops when reading material.	Encourage students to as 'why?' and answer, even if the answer is not correct at first.
	Self-explanation	Active processing of material Links to previous material	It may take time to adjust to make stops when reading material Students may not be confident of their own explanations.	Emphasize that this is different from paraphrasing the material, it must be linked to previous knowledge.
Mindful practice	Practice testing	May be implemented in notetaking Helps assign priority to contents	Students may not be used to ask questions while taking notes If tests are graded, the level of stress in class may be increased	Include questions as part of the lesson, emphasized the learning experience over grading (redoing tests, group tests, etc.)
	Distributed practice	Students use same amount of time as in massed practice Longer term retention of material Encourages link to previous knowledge and other course contents	Counterintutive	Include as part of the lesson design and when recommending practice problems or giving out homework.
	Interleaved practice	Students use same amount of time as in massed practice Longer term retention of material Encourages link across disciplines	Counterintutive	Include as part of the lesson design, particularly for practice problems, homework and course projects.

It is highly recommended that instructors provide guidance to students on how to study for different topics, as the most appropriate learning strategies may vary. This guidance is crucial for students who may not be familiar with the strategies mentioned or who have been using less effective approaches in the past. Additionally, such guidance can help students manage the stress associated with the course, which can negatively impact their learning experience (Vogel, 2016).

In a typical Physics course that involves both theory learning and problem-solving, students may need to employ different sets of strategies. However, students may not be aware of the need to use different approaches or which approach is most suitable. Therefore, the instructor's guidance on how to study each topic becomes an essential part of the learning process.

For example, the instructor can inform students that relying solely on rereading and highlighting may not be sufficient when it comes to solving practice or exam problems. Instead, the instructor may introduce mental imagery techniques to help students understand and recall topics or concepts. Storytelling can also play a helpful role in sharing mental imagery with students (Hadzigeourgiou, 2006).

The instructor can also encourage students to use practice testing by incorporating questions into their notes and later recalling the answers from memory during review. These questions can be included as part of the lesson design, prompting students to write them in a way that the answers are not immediately visible. Additionally, the instructor can advise students to engage in practice problems as part of their individual study, encouraging them to approach these problems in a distributed or interleaved manner. This approach helps students recognize their own limitations and avoid the illusion of competence when solving problems that are only introductory or not the focus of evaluation.

In the classroom, the instructor can mix topics from the textbook and introduce brief mentions of other subjects, creating a distributed or interleaved practice approach to the material. This can be especially useful when presenting example problems or engaging students in activities like group discussions or problem-solving. By doing so, students are actively processing the theory materials and becoming active creators of their own knowledge.

Furthermore, instructors can incorporate discussion questions or utilize approaches like Peer Instruction (Mazur, 1997) to encourage active engagement with the theory materials during class. This ensures that students are not passive recipients of information but actively involved in constructing their understanding.

It is important for instructors to recognize that students bring their prior knowledge and learning habits to the class. It may not be possible to change every student's individual study approach. However, considering these learning strategies in lesson design and providing guidance can greatly benefit students' learning experiences.

IV. REFERENCES

Dunlosky, J. (2013). Strengthening the Student Toolbox. *American Educator*, *37*(3), 12–21. Retrieved from http://www.aft.org/sites/default/files/periodicals/dunlosky.pdf

Hadzigeourgiou, Y. (2006) Humanizing the teaching of physics through storytelling: the case of current electricity. *Physics Education* 42(1)

Mäntylä, T. (2011) *Didactical reconstructions for organizing knowledge in physics teacher education.* Academic dissertation at the University of Helsinki.

Mazur, E. (1997). *Peer Instruction: A User's Manual.* Prentice Hall.

Dictionary by Merriam-Webster.com. (2011). Retrieved from: https://www.merriam-webster.com (30 June 2017).

Moreira, B.F.T., Pinto, T.S.S., Starling, D.S.V. and Jaeger, A. (2019) Retrieval practice in classroom settings: a review of applied research. *Frontiers in Education Educational Psychology*. https://doi.org/10.3389/feduc.2019.00005

Oficina de Orientación (2021) *Ficha carrera de Física.* Recuperado de http://orientacion.ucr.ac.cr/fichaprofesiograficacienciasbasicasfisica/

Özdemir, S. (2018) The effect of summarization strategies teaching on strategy usage and narrative text summarization success. *Universal Journal of Educational Research* 6 (10) pp 2199-2209.

Patel, F, Sooknanan, P. Rampersand, G. and Mundkur, A. (2012) *Information technology, development and social change.* First Edition. Routledge Taylor and Francis Group.

Koriat, A., & Bjork, R. A. (2005). Illusions of Competence in Monitoring One's Knowledge During Study. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 31*(2), 187–194. https://doi.org/10.1037/0278-7393.31.2.187

Roediger, H. L., & Pyc, M. A. (2012). Inexpensive techniques to improve education: Applying cognitive psychology to enhance educational practice. *Journal of Applied Research in Memory and Cognition*, *1*(4), 242–248. https://doi.org/10.1016/j.jarmac.2012.09.002

Rohrer, D., Dedrick, R.F and Stershic, S. (2015) Interleaved practice improves mathematics learning. *Journal of Educational Psychology* 107 (3) pp 900-908.

Suciu, A. & Mata, L., (2011). Pedagogical Competences – The Key to Efficient Education. *International Online Journal of Educational Sciences*, *3*(2), 411–423. Retrieved from www.iojes.net

Westover, J. H. (2009). Lifelong learning: Effective adult learning strategies and implementation for working professionals. *International Journal of Learning*, *16*(1)

Vogel, S. and Schwabe, L., (2016) Learning and memory under stress: implications for the classroom. *Nature Partner Journals Science of Learning.*

ACKNOWLEDGMENTS

The author expresses their gratitude to Laura Padilla, Lonie Salkowski, and Michael Kissick for their insightful discussions on educational theory and lesson planning. The contributions and input from Ronald Carrillo and Marco Rodríguez regarding their experiences in teaching basic Physics courses are also acknowledged and appreciated. Their valuable discussions have undoubtedly enriched the understanding and development of effective teaching strategies in the field of Physics education.