A METHODOLOGY FOR TEACHING HEAT TRANSFER USING THE FINITE DIFFERENCE METHOD AND OCTAVE

Caires Alberto Sassupe[1,*], Armando da Assunção Soares[2], Manuel José Cabral do Santos Reis[3], Paula Maria Machado Cruz Catarino[4]

[1]*Department of Exact and Natural Sciences, Higher Educational Sciences Institute of Bié, Bié-Angola*
[2]*Department of Physics, School of Sciences and Technologies, University of Trás-os-Montes and Alto Douro, Vila Real, Portugal*
[3]*Department of Engineering, School of Sciences and Technologies, University of Trás-os-Montes and Alto Douro, Vila Real, Portugal*
[4] *Department of Mathematics, School of Sciences and Technologies, University of Trás-os-Montes and Alto Douro, Vila Real, Portugal*

ABSTRACT

This study presents a computational methodology integrating the Finite Difference Method (FDM) and Octave to teach heat conduction in solids. The articulation between mathematical theory, physical modeling, and computational practice constitutes a pedagogical strategy that can promote a deeper understanding of thermal phenomena and the development of skills in scientific programming, computational thinking and numerical thinking.

FDM approximates derivatives through finite-difference operators derived from Taylor series expansions, transforming differential equations into discrete algebraic systems that describe temperature and heat flow. Spatial and temporal discretization allows systematic analysis of numerical stability, convergence, and numerical errors. Such analysis is essential for ensuring that the discrete solution reliably represents the underlying physical behavior, particularly in transient or highly non-linear thermal processes. Octave, an open-source *software* with Matlab-like syntax, significantly expands the possibilities for numerical experimentation. Its flexibility allows the use of different types of meshes, parameter variation (e.g., thermal diffusivity, step sizes), and graphical visualization of results.

The integrated approach emphasizes teacher mediation, guiding students through the physical interpretation of the problem, the formulation of appropriate mathematical modeling, and computational implementation. This mediation is essential to ensure the meaningful use of technology, avoiding the mechanical execution of code without understanding the underlying physical principles.

This study follows a quasi-experimental research design, conducted in the 2023/2024 academic year with 17 fourth-year students of the Bachelor's Degree in Mathematics and Physics Teaching at the Higher Pedagogical School of Bié (Angola). The data, of a mixed nature through questionnaires, pre- and post-tests, and analyzed using content analysis and statistical techniques were collected. Academic performance was assessed using Hake's normalized gain equation revealing a 70 % average improvement in student performance.

Teacher mediation ensured meaningful technology use, promoting skills in computational modeling, critical thinking, and interdisciplinary integration.

Integrating FDM with Octave in heat transfer studies links theory to practice, reinforcing essential mathematical skills such as discretization, numerical stability analysis, and interpretation of differential equations. This approach prepares students for the challenges of thermal engineering, and computational modeling, promoting active and meaningful leaning supported by simulation and experimentation. It also allows students to relate mathematical reasoning to physical interpretation and computational implementation. As a scalable methodology, it offers an alternative to traditional lectures, aligned with contemporary active learning methodologies.

Keywords Integrated Approach. Finite Difference Method. Octave *Software.* Heat Transfer Problems.

References

[1] Abdulack, S. A., Heat transfer in cylindrical geometry: an interdisciplinary approach to a real-world problem. Brazilian Journal of Physics Education, 46: 1-11, 2024.

[2] Almeida, J. F., Souza, M. R., and Ferreira, L. H., Computer simulation of thermal conduction using finite differences in GNU Octave. Journal of Applied Engineering and Technology, 5(2): 34–48, 2021.

[3] Anuraj, P., and Kumar, P., Computer Simulations in Science Education based on Simulation and Learning: A Model-Centered Approach. International Journal of Advanced Research and Multidisciplinary Trends (IJARMT), 2(3): 658-667, 2025.

[4] Bergman, T. L., and Lavine, A. S., Fundamentals of Heat and Mass Transfer. 8th Edition, John Wiley and Sons, Inc., 2017.

[5] Carmo, H, and Ferreira, M. M., Research Methodology: A Guide for Self-Learning. Open University, 2nd Edition, 2008.

[6] Çengel, Y. A., and Ghajar, A. J., Heat and Mass Transfer-Fundamentals and Aplications, 4th Edition, 2012.

[7] Çengel, Y. A., Boles, M. A., and Kanoglu, M., Thermodynamics: An Engineering Approch. 9th Edition. Mc Graw Hill Education, 2019.

[8] Hake, R. R., Interactive-Engagement vs. Traditional Methods: A Six-Thousand-Student Survey of Mechanics Test Data for Introductory Physics Courses. *Reports-Research*, ERIC, 143: 1-2, 1998.

[9] Lopes, J. B., and Costa, C., Digital Resources in Science, Mathematics and Technology Teaching–How to Convert Them into Tools to Learn. In M. Tsitourridou, J. D. Diniz, T.A. Mikropoulos, Technology and Innovation in Learning, Teaching and Education, 2019.

[10] Lopes, J. B.; Silva, A. A.; Cravino, J. P.; Viegas, C.; Cunha, A. E.; Saraiva, E.; Branco, M. J.; Pinto, A.; Silva, A.; Santos, C. A., Research on the Mediation of Physical Science Teachers in the Classroom. University of Trás-os-Montes and Alto Douro, 2010.

[11] Lopes, R. P., & Araújo, F. J., The use of the finite difference method in the development of skills in thermal engineering: a computational didactic approach. Physics Teaching Notebooks, 36(1): 120–137, 2019.

*Corresponding Author's E-mail: cairesalbertosassupe@gmail.com