

Practical approach to using octave software: heat transfer by one-dimensional conduction in transient regime

Abordagem prática para a utilização do software octave: transferência de calor por condução unidimensional em regime transiente

Enfoque práctico para el uso del software octave: transferencia de calor por conducción unidimensional en régimen transitorio

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ABSTRACT

This study investigates the use of Octave software as a tool to support the learning of concepts of heat transfer by one-dimensional conduction in a transient regime. This mixed-method research proposes and analyzes teaching plans for teachers and students to guide the use of the software in practical activities. The results indicate that integrating Octave into teaching tasks can foster the active construction of knowledge, enabling the visualization of graphical-computational solutions and the development of computational thinking. The analysis suggests that teacher mediation is essential to ensure the effective use of technology in the teaching-learning process. The study also highlights the need for teacher training in the application of digital tools in the modeling and simulation of physical phenomena, promoting more meaningful and contextualized learning.

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Keywords: Open Digital Educational Resources; Octave Software; Heat Transfer; Computational Graphics Solutions; Meaningful Learning.

RESUMO

O presente estudo investiga a utilização do *software* Octave como ferramenta de apoio à aprendizagem de conceitos de transferência de calor por condução unidimensional em regime transiente. A pesquisa, de natureza mista, propõe e analisa roteiros didáticos destinados a professores e estudantes, com o objetivo de orientar o uso do *software* em atividades práticas. Os resultados indicam que a integração do Octave em tarefas didáticas pode favorecer a construção ativa do conhecimento, permitindo a visualização de soluções gráfico-computacionais e o desenvolvimento do pensamento computacional. A análise sugere que a mediação do professor é essencial para garantir que a tecnologia seja utilizada de forma eficaz no processo de ensino-aprendizagem. O estudo destaca, ainda, a necessidade de capacitação docente para a aplicação de ferramentas digitais na modelagem e simulação de fenômenos físicos, promovendo uma aprendizagem mais significativa e contextualizada.

Palavras-chave: Recursos Digitais Educativos Abertos; *Software* Octave; Transferência de Calor; Soluções Gráfico-Computacionais; Aprendizagem Significativa.

RESUMEN

Este estudio investiga el uso del *software* Octave como herramienta para apoyar el aprendizaje de conceptos de transferencia de calor por conducción unidimensional en un régimen transitorio. Esta investigación de método mixto propone y analiza planes de enseñanza para profesores y estudiantes para guiar el uso del *software* en actividades prácticas. Los resultados indican que la integración de Octave en las tareas de enseñanza puede fomentar la construcción activa del conocimiento, permitiendo la visualización de soluciones gráfico-computacionales y el desarrollo del pensamiento computacional. El análisis sugiere que la mediación docente es esencial para asegurar el uso efectivo de la tecnología en el proceso de enseñanza-aprendizaje. El estudio también destaca la necesidad de capacitación del profesorado en la aplicación de herramientas digitales en el modelado y simulación de fenómenos físicos, promoviendo un aprendizaje más significativo y contextualizado.

Palabras clave: Recursos digitales educativos abiertos; Octave *Software*; Transferencia de calor; Soluciones de gráficos computacionales; Aprendizaje significativo.

INTRODUCTION

Understanding and solving heat problems is essential for a genuine comprehension of energy transfer processes, with a view to their optimisation in a technological world facing growing energy demand. In this context, the difficulties related to the adoption and adaptation of innovative didactic strategies (pedagogical alternatives) aimed at constructing solutions for distinct phenomena, among which is heat transfer by conduction, particularly in solid bodies, whose models can be described by differential equations and their conditions may arise in certain settings related to the teaching and learning of Science and related fields. This situation has motivated various researchers to develop tools to energise the teaching process, stimulate and enhance student learning, ensuring

the construction of knowledge in an active and meaningful way. From this perspective, it is understood that:

problem-solving contributes to the acquisition of new knowledge, enabling students to learn in a more thought-provoking manner and to develop an active role in their learning. The Teacher's role is to create and mediate situations, in addition to preparing lessons with themes and directions that emerge from situations brought by the Students. (Castellar & de Moraes, 2016, p. 11)

To meet this need, Educational Digital Resources, particularly Open ones such as the Octave software, have proven to be potential artefacts that, when used appropriately in a given teaching and learning situation, help solve the problem at hand. In turn, these resources can be defined as:

teaching, learning, and research materials fixed in any support or media, preferably on free platforms or formats (free software), that are in the public domain or openly licensed, allowing them to be used or adapted by third parties to support access to knowledge. (Gonsales, 2016, p. 4)

Thus, Iglori and de Almeida (2018) adopt the position of Chevallard (1992), when he highlights that this phenomenon can be understood if we consider two essential conditions to guarantee the reliability of didactic integration. The first condition is that there exists here a well-defined type of didactic exploration scenario (even if it admits several variants, the details of which will not be entered into), which assigns a specific, more precisely defined role to the computer: that of simulating systems and processes, or more exactly, that of supporting the didactic use of clearly designed simulation software.

From this perspective, Cravino (2023, p. 2) argues that "computational simulations are an important tool, both for constructing scientific knowledge, where they originate, and for learning science." This implies that computational simulations can constitute excellent opportunities for the Teacher to mediate student learning in the construction of scientific knowledge, such as the concept of heat. De Oliveira (2014, p. 37) presents the concept of heat as "a modality of energy that is transmitted from one body to another when a temperature difference is verified between them." To this end, Barbosa (2019) argues that it is necessary to awaken in Students something different that motivates their curiosity, understanding, and consequently promotes learning about heat transfer concepts.

Heat transfer in a medium is, in general, three-dimensional, time-dependent, and dependent on the medium's temperature, which varies with position and time $T = T(x, y, z, t)$. Heat transfer in a medium is considered non-permanent (or transient) when temperature varies with time. Heat transfer in a medium is considered one-dimensional when transfer is significant in a single dimension and negligible in the other two, two-dimensional when transfer in the third dimension is negligible, and three-dimensional when heat transfer in all dimensions is significant. (Çengel & Ghajar, 2012).

In general, the models describing heat transfer problems can be described by differential equations. These equations, according to Zill and Cullen (2007, p. 2), “are those that contain derivatives or differentials of one or more dependent variables with respect to one or more independent variables.” These differential equations may be accompanied by certain boundary conditions, forming so-called boundary value problems.

On the other hand, it is noted that:

Octave is free software that shares the GNU philosophy: any user has the freedom to run, copy, distribute, study, modify, and improve it. It was created by John Eaton and several contributors, and provides tools for solving problems related to Linear Algebra, Nonlinear Equations, Differential Equations, and Differential-Algebraic Equations, among others. Its functionalities can be extended by using its own language or by creating modules in other languages. It can be obtained for "Linux" systems at <http://www.archlinux.org>, or for “Windows” systems at <https://ftp.gnu.org/gnu/octave/windows/> . (de Siqueira, 2016, p. 1-2).

From this perspective, Reis et al. (2024) highlight the relevance of using Information and Communication Technologies (including the Octave software) in approaching the Newtonian conception of uniform circular motion. Barbosa et al. (2023) present Octave as a software widely used in academia, arguing that it can help students, assisting them in solving problems encountered in their daily academic life.

However, Medeiros and Queiroz (2018, pp. 2-3) emphasise that:

for the Educator (Teacher) to be capable of using new technologies to support their work, they need to have basic knowledge of Information Technology, as this will allow them to explore the information they need to use it in their area of knowledge, transforming it into a methodological resource and consequently offering better teaching-learning. Thus, teacher training for the use of computers in their daily practice contributes to an improvement in teaching.

On the other hand, “Teacher training must provide conditions for them to build knowledge about computational techniques, understand why and how to integrate the computer into their pedagogical practice, and be able to overcome administrative and pedagogical barriers” (Valente & de Almeida, 1997, p. 25). This practice enables the transition from a fragmented teaching system towards an integrative approach to content (which may involve an Educational Digital Resource) focused on solving specific problems of interest to each Student. To this end, conditions must be created for the Teacher to know how to recontextualise the learning and experience gained during their training to their classroom reality, reconciling the needs of their Students with the pedagogical objectives they aim to achieve.

Thus, the integration of Educational Digital Resources, particularly Open ones, as is the case with the Octave software, into didactic tasks guided by the Teacher, for the construction of problem solutions, can contribute to solving the issue under study, making student learning more effective, active, and meaningful, by resorting to appropriate work strategies.

In this way, the task can be aligned with the intended learning outcomes, always considering, where possible, all the elements that should be associated with a didactic task, such as i) information; ii) challenge; iii) product; iv) learning outcomes; and v) conditions for completion (Lopes, 2023), allowing Students to dedicate more time to the analysis and solution of heat transfer problems than specifically to implementation, reinforcing the idea that discovery learning promotes a better understanding of concepts and procedures.

In the same vein, authors such as Júnior et al. (2024), Cruz et al. (2021, cited by Torres & de Toni, 2024) reinforce the need to use Open Educational Digital Resources in Mathematics, Physics, and related subject classes, not only for the computational simulation of a given problem but also for energising the teaching and learning process. This type of Resource allows Students involved in its use to “construct scientific and technical knowledge effectively, actively, and meaningfully, through the development of essential competences, such as critical thinking, problem-solving, and collaboration, which are vital for their future success” (Maziane et al., 2023, p. 2).

This study aims to evaluate the influence of integrating the Octave software into didactic tasks guided by the Teacher on the construction of concepts and procedures for solving heat transfer problems, in promoting meaningful learning and the development of computational thinking among students.

METHODOLOGY / MATERIAL AND METHODS

In developing this work, a mixed-methods study was used, which, according to Sampieri and Mendoza (2008, Sampieri et al., 2013), represents a set of systematic and critical research processes and implies the collection and analysis of quantitative and qualitative data, as well as their integration and joint discussion to make inferences as a product of all the collected information (meta-inferences) and achieve a greater understanding of the phenomenon under study. To this end, thematic analysis and descriptive statistics were employed in the process of collecting, analysing, and triangulating the obtained data. The technique of constructing learning scripts for Students (Appendix A) and teaching scripts for Teachers (Appendix B) was used. According to de Farias and Mendonça (2019, p. 9), these can be understood as an “instrument intentionally planned by the Teacher to assist Students in autonomous study, thus favouring the apprehension of concepts, task resolution, reading of didactic material, and deepening of study, both inside and outside the classroom.” With this technique, the aim was to elaborate and propose the scripts in the appendices (A and B), which can be adopted and adapted for experimental classroom application in various contexts. The computational simulation of the model describing one-dimensional transient

heat conduction in solid bodies was also made available, using the Octave software, as shown in Figures 1, 2, 3, 4, 5, and 6, which are illustrated in the Example presented in the Results section. The process of constructing the scripts was developed considering the type of didactic activity to be carried out (implemented), the teaching and learning scenario (environment/session), as well as the identification of the Educational Digital Resource. The choice of Octave is due to its potential and the fact that it is free software, versatile to install, and has flexible syntax. The implementation of the scripts can occur in several stages. As the intervention takes place, improvements are made to the scripts based on the results obtained by the participants in their interaction with the epistemic object and in their interaction with others.

To ascertain the state of the art related to the researched theme, several works (articles and books) were screened from different databases, such as Scielo, Web of Science, and others, using Boolean operators such as and, or, and keywords such as Educational Digital Resources, Heat Transfer, Octave Software, Graphical-Computational Solutions, Meaningful Learning, among others. Some inclusion criteria used were: selection of relevant works representative of the line and focus of the research.

RESULTS

In exploring the procedures underlying the chosen Educational Digital Resource (Octave software), specific activities were carried out. These consisted of constructing the code to solve the differential equation describing the investigated heat transfer problem model, implementing this code in the Octave software environment (Figure 1), and subsequently generating the graphical-computational solution within that environment (Figure 2).

Example

By constructing the code for the one-dimensional heat transfer equation (thermal diffusion equation) to be implemented in the Octave software environment, the following was obtained:

$$\frac{\partial^2 T}{\partial x^2} = \frac{1}{\alpha} \frac{\partial T}{\partial t}; \quad \hat{E}_{ger} = 0 \quad (1)$$

Where,

$T(x, t)$ – temperature as a function of one-dimensional space and time

$\frac{\partial^2 T}{\partial x^2}$ - second derivative of temperature in the direction x (thermal diffusion)

$\frac{\partial T}{\partial t}$ – rate of change of temperature at a point over time

α - thermal diffusivity

\hat{E}_{ger} – heat generation term

$\hat{E}_{ger} = 0$ - no heat generation

Figure 1 - Implementation of the code for the heat PDE in the Octave software environment, with $N = 10$ (Number of Points in the Domain) and $M = 50$ (Number of Points in Time)

```

Octave
Arquivo  Editar  Depurar  Ferramentas  Janela  Ajuda  Novidades
Diretório Atual: C:\Users\Albuquerque

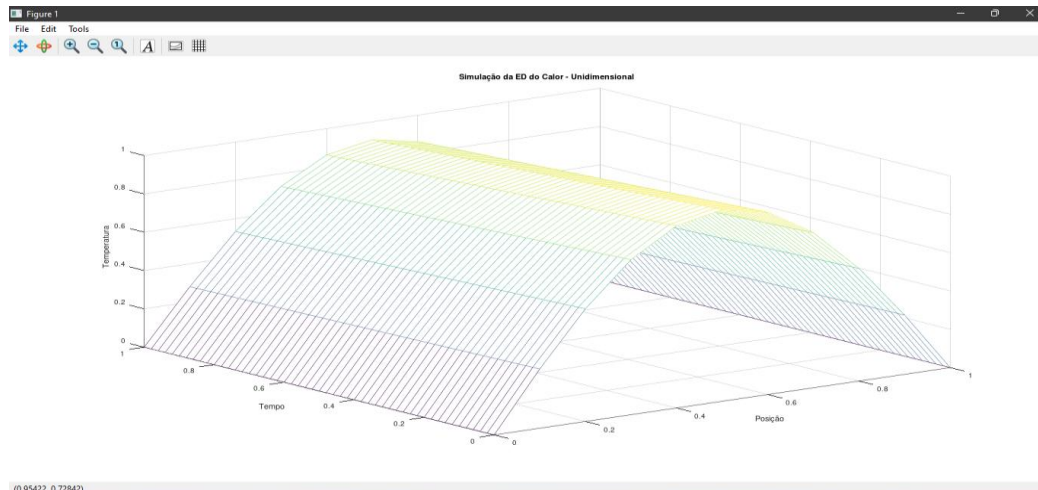
Editor
Arquivo  Editar  Visualizar  Depurar  Executar  Ajuda

ED=Calor.m
1  S% Parâmetros da Simulação
2  L=1; % Comprimento do domínio
3  T=1; % Tempo Final
4  N=10; % Número de pontos no domínio
5  M=50; % Número de pontos no tempo
6  alpha=0.01; % Coeficiente de difusão térmica
7  % Discretização do Domínio
8  dx=L/N; % Incremento Espacial
9  dt=T/M; % Incremento Temporal
10 x=0:dx:L; % Vector de Posição
11 t=0:dt:T; % Vector de Tempo
12 % Condições Iniciais
13 u0=sin(pi*x/L); % Temperatura Inicial
14 % Matriz para Armazenar a Solução
15 u=zeros(N+1,M+1);
16 u(:,1)=u0;
17 % Loop Principal
18 for j=1:M;
19     for i=2:N;
20         u(i,j+1)=u(i,j)+alpha*dt/dx^2*(u(i+1,j)-2*u(i,j)+u(i-1,j));
21     end
22 end
23 % Plot da Solução
24 [X,T]=meshgrid(x,t);
25 mesh(X,T,u');
26 xlabel('Posição');
27 ylabel('Tempo');
28 zlabel('Temperatura');
29 title('Simulação da ED do Calor - Unidimensional');

```

Source: Authors' own elaboration, using Octave

Figure 2 - Graphical-computational solution of the Heat PDE (Simulation with Octave) with $N = 10$ (Number of Points in the Domain) and $M = 50$ (Number of Points in Time)



Source: Authors' own elaboration, using Octave

Figure 3 - Implementation of the code for the heat PDE in the Octave software environment, with $N = 100$ (Number of Points in the Domain) and $M = 50$ (Number of Points in Time)

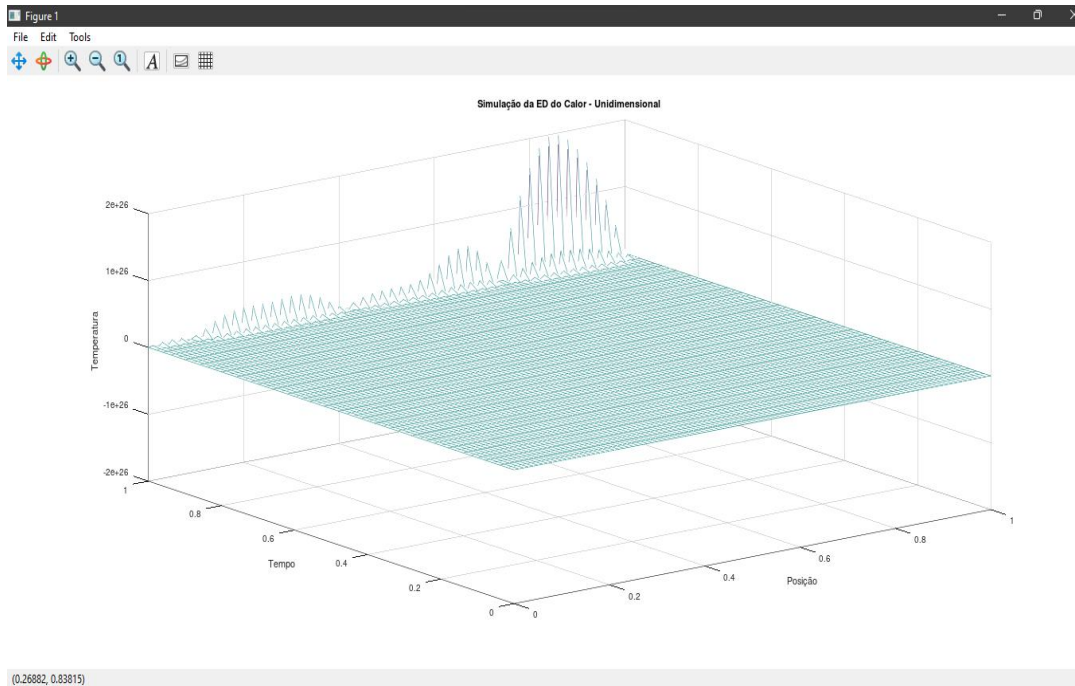
```

1  % Parâmetros da Simulação
2  L=1; % Comprimento do domínio
3  T=1; % Tempo Final
4  N=100; % Número de pontos no domínio
5  M=50; % Número de pontos no tempo
6  alpha=0.01; % Coeficiente de difusão térmica
7  % Discretização do Domínio
8  dx=L/N; % Incremento Espacial
9  dt=T/M; % Incremento Temporal
10 x=0:dx:L; % Vector de Posição
11 t=0:dt:T; % Vector de Tempo
12 % Condições Iniciais
13 u0=sin(pi*x/L); % Temperatura Inicial
14 % Matriz para Armazenar a Solução
15 u=zeros(N+1,M+1);
16 u(:,1)=u0;
17 % Loop Principal
18 for j=1:M;
19     for i=2:N;
20         u(i,j+1)=u(i,j)+alpha*dt/dx^2*(u(i+1,j)-2*u(i,j)+u(i-1,j));
21     end
22 end
23 % Plot da Solução
24 [X,T]=meshgrid(x,t);
25 mesh(X,T,u');
26 xlabel('Posição');
27 ylabel('Tempo');
28 zlabel('Temperatura');
29 title('Simulação da ED do Calor - Unidimensional');

```

Source: Authors' own elaboration, using Octave

Figure 4 - Graphical-computational solution of the Heat PDE (Simulation with Octave) with N = 100 (Number of Points in the Domain) and M = 50 (Number of Points in Time)



Source: Authors' own elaboration, using Octave

Figure 5 - Implementation of the code for the heat PDE in the Octave software environment, with N = 100 (Number of Points in the Domain) and M = 500 (Number of Points in Time)

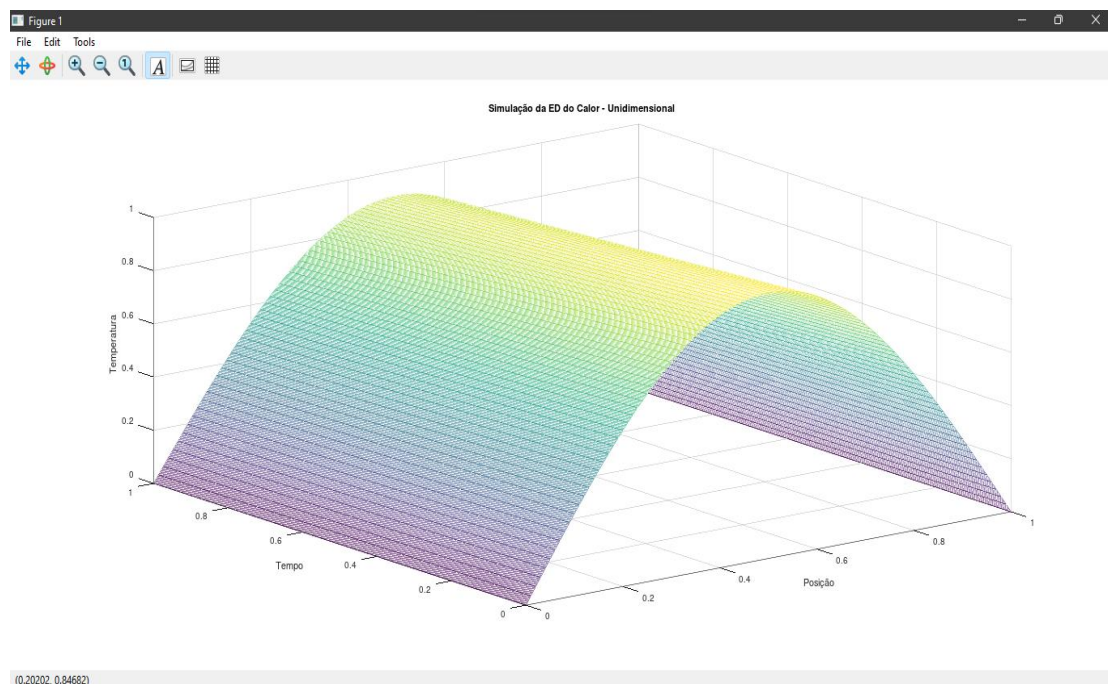
```

Editor
Arquivo Editar Visualizar Depurar Executar Ajuda
ED=Calor.m
1 % Parâmetros da Simulação
2 L=1; % Comprimento do domínio
3 T=1; % Tempo Final
4 N=100; % Número de pontos no domínio
5 M=500; % Número de pontos no tempo
6 alpha=0.01; % Coeficiente de difusão térmica
7 % Discretização do Domínio
8 dx=L/N; % Incremento Espacial
9 dt=T/M; % Incremento Temporal
10 x=0:dx:L; % Vector de Posição
11 t=0:dt:T; % Vector de Tempo
12 % Condições Iniciais
13 u0=sin(pi*x/L); % Temperatura Inicial
14 % Matriz para Armazenar a Solução
15 u=zeros(N+1,M+1);
16 u(:,1)=u0;
17 % Loop Principal
18 for j=1:M;
19     for i=2:N;
20         u(i,j+1)=u(i,j)+alpha*dt/dx^2*(u(i+1,j)-2*u(i,j)+u(i-1,j));
21     end
22 end
23 % Plot da Solução
24 [X,T]=meshgrid(x,t);
25 mesh(X,T,u');
26 xlabel('Posição');
27 ylabel('Tempo');
28 zlabel('Temperatura');
29 title('Simulação da ED do Calor - Unidimensional');

```

Source: Authors' own elaboration, using Octave

Figure 6 - Graphical-computational solution of the Heat PDE (Simulation with Octave) with N = 100 (Number of Points in the Domain) and M = 500 (Number of Points in Time)



Source: Authors' own elaboration, using Octave

According to Figures 1, 3 and 5, the codes that generate the graphical-computational solutions of the presented problem may include the following elements: simulation parameters, domain discretisation, consideration of initial conditions, consideration of the matrix for storing the solution, main loop, and plotting of the solution.

Figures 2, 4 and 6 illustrate, in three dimensions, the computational simulations of the behaviour of solutions to the problem of transient one-dimensional heat conduction in solid bodies, considering the following elements: temperature, time, and position.

DISCUSSION

According to **Figures 1, 3 and 5**, it can be seen that the first step towards constructing solutions to problems, particularly that of heat transfer by conduction in solid bodies using an Educational Digital Resource, such as the Octave software, is the student's familiarisation with the language (syntax) of the chosen Resource, where Teacher mediation can be important in clarifying doubts and motivating Students.

As some parameters of the codes illustrated in **Figures 1, 3 and 5** are altered, such as the number of points in the domain (N) and the number of points in time (M), a change is also observed in the behaviour of the graphical-computational solutions, as can be seen in **Figures 2, 4 and 6**. Through this, the Teacher can guarantee Students, via didactic mediation, opportunities for Students to interact with the epistemic object and with each other.

From this perspective, Teacher mediation can be defined as:

the Teacher's actions and languages (natural and otherwise) constructed and put into practice as a systematic response to the students' learning challenges on their paths to achieving the learning outcomes (capabilities, values, attitudes, knowledge, and competences) intended by a given curriculum (Lopes et al., 2010, p. 5).

Thus, in the process of didactic mediation, the Teacher should pay attention to certain elements, such as:

the work actually requested of the students; the scientific and technological contexts; the epistemic and/or axiological practices; the existing information; the Teacher's awareness and real-time decision-making in the classroom; classroom conversation; the support and authority granted to Students; productive engagement in the subject (or task); assessment and feedback, as well as induced learning (Lopes et al., 2010, pp. 13-15).

This will allow for adequate preparation, execution, and follow-up of the planned didactic task and the effective orchestration of the selected Resource, potentially guaranteeing meaningful learning on the part of the Students, since the Resource by itself may not guarantee the expected learning, as argued by Cravino (2023, citing Lai & Bower, 2020; Singer, Nielsen & Schweingruber, 2012; Webb, 2010), emphasising that "research on the use of various technologies in learning suggests that technology alone does not improve learning; what is done with that technology is crucial."

In this context, the search for didactic strategies that contribute to improving the issue under study becomes relevant, as confirmed by Biasotto et al. (2020, p.

83188), highlighting that “there is a need to know and disseminate pedagogical alternatives, which can be used in formal teaching environments, to facilitate the process of understanding and meaningful learning in the field of Mathematics Education and related areas.”

From this perspective, the use of Educational Digital Resources for modelling and simulation, of which the Octave software is an example, in solving heat transfer problems in solid bodies under transient conditions, through didactic tasks guided by the Teacher, can positively contribute to the development of students' competences, such as code writing, computational thinking, and the construction and interpretation of graphs, among others. In this sense, Wing (2010, cited by Mestre et al., 2023), emphasises that computational thinking, as one of the competences that Students can develop during the process of carrying out a given task guided by the Teacher, can be considered as a thought process that involves formulating problems and the way of searching for solutions, solutions that can be represented in a way that can be effectively carried out by an information processing agent, such as a computer (equipped with software like Octave).

Conversely, one can perceive the infrequent and/or inadequate use of Educational Digital Resources (for example, the Octave software) in certain teaching and learning situations, where they could be employed more frequently and appropriately to stimulate and enhance Student learning. In this perspective, da Silva et al. (2022, p. 2), argue that the “software (Octave) provides an excellent virtual environment for teaching Differential Equations. It helps to spark students' interest and encourage them to explore the content, making them active agents in the learning process.”

The analysis of the activities developed suggests that the successful application of the Octave software depends on effective Teacher mediation, ensuring that students understand not only the operationalisation of the tool but also the theoretical foundation underlying the studied phenomena. Furthermore, the results indicate that integrating digital resources into exact sciences education can expand problem-solving capacity and foster student autonomy in knowledge construction.

However, some limitations must be considered. The implementation of the activities still requires specific teacher training to ensure appropriate use of the technology and to prevent the focus from shifting from conceptual understanding to the mere mechanical execution of commands. Additionally, future investigations could broaden the analysis to other methodological approaches, comparing the impact of Octave with other computational tools and exploring its application in different educational contexts.

CONCLUSIONS

This study enabled an understanding of the potential of the Octave software as a tool for teaching one-dimensional transient heat conduction, contributing to the development of computational thinking and the graphical-computational

visualisation of solutions to the investigated problem. The proposed approach, based on didactic scripts for teachers and students, proved to be a promising strategy for making teaching more interactive and meaningful.

Despite the positive results obtained with the application of the Octave software in simulating one-dimensional transient heat conduction, some limitations inherent to the adopted approach deserve highlighting.

Firstly, the physical modelling was deliberately simplified, restricting itself to a one-dimensional system and neglecting the effects of convection and thermal radiation. This simplification, although didactically valid, limits the applicability of the model to idealised or laboratory contexts, moving away from more complex scenarios.

Additionally, the Octave software itself, despite being a powerful and open-source tool, presents certain limitations when compared to other platforms. These limitations include less developed graphical resources, less integration with specific libraries for thermal analysis, and the need for greater effort in customising scripts and visualisations.

Given these limitations, the following directions for future work are proposed:

- Extension of the model used to two and three dimensions, aiming for simulations more representative of complex thermal systems;
- Incorporation (Integration) of convection and radiation mechanisms, allowing for a more comprehensive thermodynamic analysis;
- Comparisons between different simulation platforms, such as Octave, MATLAB, SciLab, Máxima, COMSOL Multiphysics and ANSYS Fluent, among others, focusing on accuracy, computational performance, and usability;
- Dissemination of the use of teaching and learning scripts to other contexts, in order to serve as potential didactic (pedagogical) alternatives for knowledge construction in different areas of knowledge. These research elements can enrich knowledge in the field of heat transfer, promoting the integration between theory, practice, and technology, and contribute to a more solid formation related to thermal-computational processes and other areas of knowledge.

Therefore, this study reinforces the importance of using open educational digital resources in teaching exact sciences and related fields, encouraging new research and practices that enhance student training and the quality of education through accessible and interactive technologies.

NOTE

The scripts in the appendices were constructed within the context of Angolan Education.

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APPENDICES

APPENDIX A: STUDENT SCRIPT

Context: Formal Learning

Country:

Learning Level: Higher Education

Institution:

Students:

Learning Context: Exact and Natural Sciences, or Other

Subject: Mathematical Methods and/or Differential Equations, or Other.

Age Range:

Academic Year:

Topic(s): Construction of solutions to the problem of one-dimensional transient heat conduction in solid bodies using the Octave software.

Lesson Duration:

Lesson Start Time:

Lesson End Time:

Date of Execution: x of y 20...

Location of Lesson Execution:

Dear Student!

This script will lead you to new learning with challenges and new discoveries about constructing solutions to the problem of one-dimensional transient heat conduction in solid bodies using the Octave software!

Read the task description carefully and pay attention to the instructions provided. They will help you find the answer and show you new things about the topic under study.

By the end of this script, you will be able to:

- Manipulate some commands of the Octave software to construct solutions to the problem of one-dimensional transient heat conduction in solid bodies.
- Explain the procedures used to construct solutions to the problem of one-dimensional transient heat conduction in solid bodies within the Octave software environment.
- Investigate mathematical models (differential equations, etc.) that describe different problems (phenomena), including those of heat conduction in solid bodies under transient conditions, which can be solved using the Octave software.

WORK STRATEGIES:

- Work should be carried out in subgroups of x to y members each.
- Each subgroup should draw on the knowledge they already have about the Octave software
- Each subgroup should use their device(s) (alphanumeric calculator, smartphone, tablet, or computer) where the Octave software is installed, to carry out the didactic tasks, or use the Institution's Computer Laboratory, if available.
- All Students must participate in the execution of the task, regardless of the role assigned to them, to ensure the success of their team, as the work is collective
- All groups must complete the three presented didactic tasks so that, at the end of each task, they can interact with each other after finishing the estimated time for each task.
- The completion of didactic tasks that are not finished within the estimated time, as will likely be the case for task 3, can be continued at other times, such as in the following class, for example, and the knowledge constructed by each subgroup can be compared collaboratively.

SUCCINCT DESCRIPTION OF TASK EXECUTION

For the successful completion of the tasks presented in this guide, it is advisable to consider using the Octave software commands available within the software's workspace.

Learning Objective 1: Manipulate (Execute) some commands of the Octave software to construct solutions for the model (differential equation) describing the problem of one-dimensional transient heat conduction in solid bodies.

Task 1

Description: Construct the solution(s) of the one-dimensional differential equation for transient heat conduction in solid bodies without heat generation

$$\frac{\partial^2 T}{\partial x^2} = \frac{1}{\alpha} \frac{\partial T}{\partial t}; \quad \hat{E}_{ger} = 0 \quad (1)$$

using the Octave *software*.

Duration:

Discussion:

Learning Objective 2: Explain the procedures to be used for constructing different solutions of the one-dimensional transient heat differential equation with heat generation in the Octave software environment.

Task 2

Description: Construct the solution(s) of the one-dimensional differential equation for heat transfer in a solid medium under transient conditions with heat generation,

$$\frac{\partial^2 T}{\partial x^2} + \hat{E}_{ger} = \frac{1}{\alpha} \frac{\partial T}{\partial t}; \quad \hat{E}_{ger} \neq 0 \quad (2)$$

using the Octave software. Justify the procedures used in this construction.

Duration:

Discussion:

Learning Objective 3: Investigate mathematical models involving differential equations arising from different phenomena, including heat transfer problems, that can be solved using the Octave software.

Task 3

Description: Consider a large uranium plate of thickness $L = 4 \text{ cm}$, thermal conductivity $k = 28 \frac{\text{W}}{\text{mK}}$

and thermal diffusivity $\alpha = 12,5 \times 10^{-6} \frac{\text{m}^2}{\text{s}}$, which is initially at a uniform temperature of $200 \text{ }^\circ\text{C}$.

The heat is generated uniformly in the plate at a constant rate of $\dot{E} = 5 \times 10^6 \text{ W/m}^3$. At time $t = 0$, one side of the plate is brought into contact with ice water and is maintained at $0 \text{ }^\circ\text{C}$ at all times, while the other side is subjected to convection to the environment at $T_\infty = 30 \text{ }^\circ\text{C}$, with a heat transfer coefficient $h = 45 \frac{\text{W}}{\text{m}^2\text{K}}$.

a) Derive a mathematical formulation for the presented problem and solve it using the Octave software

b) Investigate the behaviour of this phenomenon for various initial and boundary values; and verify whether it is possible to reach steady state. Under what conditions?

Duration:

Discussion:

APPENDIX B: TEACHER SCRIPT

Context: Formal Learning

Country:

Teacher:

Teaching Context: Exact and Natural Sciences

Teaching Level: Higher Education

Institution:

Subject: Mathematical Methods and/or Differential Equations, or Other.

Age Range:

Academic Year:

Topic(s): Construction of solutions to the problem of one-dimensional transient heat conduction in solid bodies using the Octave software.

Lesson Duration:

Lesson Start Time:

Lesson End Time:

Date of Execution: x of y 20...

Location of Lesson Administration:

Dear Teacher!

This guide will help you to orient your students in carrying out the didactic tasks to promote effective and meaningful learning in constructing the solution(s) for the model (differential equations) describing the problem of one-dimensional transient heat conduction in solid bodies, using the Octave software!

Objectives:

➤ Promote cooperative learning among Students through the construction of the solution(s) for the model (differential equations) of the one-dimensional transient heat conduction problem in solid bodies, using the Octave software.

➤ Construct solutions for the model (differential equations) of one-dimensional transient heat conduction in solid bodies, using the Octave software.

SUGGESTED WORK STRATEGIES:

➤ Divide the group of students into subgroups.

➤ Start from the hypothetical idea that the Students and the Teacher have a notion of how to use the Octave software; otherwise, guide the students.

➤ Verify that each subgroup has at least one device (alphanumeric calculator, smartphone, tablet, or computer) where the Octave software can be installed, which will allow the tasks to be carried

out in the classroom, or use the Computer Laboratory for this work, after installing the Octave software.

➤ Assuming it is the first time Students will perform the procedure to determine the solution(s) for the model (differential equations) of transient heat conduction in solid bodies using the Octave software, all groups should complete the three presented tasks so that, at the end of each task, they can interact with each other after finishing the estimated time for that task.

➤ For tasks where Students do not finish within the estimated time, as will likely be the case for task 3, subgroups can be instructed to continue working on its resolution at other times, such as in the following class, for example, and then compare the knowledge constructed by each subgroup collaboratively, under the Teacher's mediation.

SUCCINCT DESCRIPTION OF TASK GUIDANCE:

Objective 1: Apply the procedures underlying the Octave software necessary for constructing solutions for the model (differential equations) of transient heat conduction in solid bodies (without heat generation), using the Octave software.

Task 1

Description: Construct the solution(s) for the model (differential equation) of one-dimensional transient heat conduction in solids (without heat generation)

$$\frac{\partial^2 T}{\partial x^2} = \frac{1}{\alpha} \frac{\partial T}{\partial t}; \quad \hat{E}_{ger} = 0 \quad (1)$$

using the Octave software.

Duration:

Discussion:

Objective 2: Evaluate the different solutions constructed from models (differential equations) of one-dimensional transient heat conduction in solids (with heat generation), within the Octave software environment.

Task 2

Description: Construct the solution(s) for the model (differential equation) of one-dimensional transient heat conduction in a solid medium (with heat generation),

$$\frac{\partial^2 T}{\partial x^2} + \hat{E}_{ger} = \frac{1}{\alpha} \frac{\partial T}{\partial t}; \quad \hat{E}_{ger} \neq 0 \quad (2)$$

using the Octave software.

Duration:

Discussion:

Objective 3: Create mathematical models involving differential equations from different problems (phenomena), particularly heat transfer in solid bodies, that can be solved using the Octave software

Task 3

Description: Consider a large uranium plate of thickness $L = 4 \text{ cm}$, thermal conductivity $k = 28 \frac{\text{W}}{\text{mK}}$ and thermal conductivity $\alpha = 12,5 \times 10^{-6} \frac{\text{m}^2}{\text{s}}$, which is initially at a uniform temperature of $200 \text{ }^\circ\text{C}$. Heat is generated uniformly in the plate at a constant rate of $\dot{E} = 5 \times 10^6 \text{ W/m}^3$. At time $t = 0$, one side of the plate is brought into contact with ice water and is maintained at a $0 \text{ }^\circ\text{C}$ at all times, while the other side is subjected to convection to the environment at $T_\infty = 30 \text{ }^\circ\text{C}$, with a heat transfer coefficient $h = 45 \frac{\text{W}}{\text{m}^2\text{K}}$.

a) Derive a mathematical formulation for the presented problem and solve it using the Octave software.

b) Investigate the behaviour of this phenomenon for various initial and boundary values; and verify whether it is possible to reach steady state. Under what conditions?

Duration:

Discussion: