FROM TERMOGRAF TO THERMONATOR: DESIGN AND DEVELOPMENT OF AN APP FOR E-LEARNING BASED ON PROBLEMS IN THE FIELD OF THERMAL ENGINEERING

A. Martínez-Gracia¹, T. Gómez², J. Pallarés¹, S. Usón¹, A. Del Amo³, P. Lisbona¹, J. Uche¹, A.A. Bayod-Rújula¹, I. Arauzo¹, C. Cortés¹

¹University of Zaragoza (SPAIN)
²Independent Consultor (SPAIN)
³Abora Solar (SPAIN)

Abstract

TermoGraf, a graphic environment with a high-interactivity level was created within the Mechanical Engineering Department at the University of Zaragoza in the nineties. It facilitates the operation and calculus of the states and thermodynamic processes of the most commonly used thermodynamic systems. As a huge advantage in relation to other alternatives, it is based on a graphical interface, so it can be used with the same ease as in a standard vector drawing program. The interface simultaneously displays graphical and numerical information of the system, providing full accuracy for the values of state properties, process information and mass and energy balances evaluation.

In recent years, the rapid proliferation of teaching applications for mobile devices and its acceptance as a useful tool for teaching, made us consider the development of the corresponding app. As a consequence, students have currently not only the computer program but also the application that allows them to quickly make calculations on their phone or tablet. Both the ThermoGraf conceptual framework for the Thermodynamics courses at the Engineering School at the University of Zaragoza (Spain) and the additional opportunities provided by the derived app, Thermonator, are presented in this paper.

Keywords: Thermodynamics simulator, e-learning based on problems, TermoGraf, Thermonator.

1 INTRODUCTION

Thermodynamics is both a branch of physics and an engineering science. It began in the early nineteenth century through consideration of the capacity of hot bodies to produce work. Nowadays its scope is larger and meets the objective of analyse and design energy systems to meet human needs as effectively as possible. Engineering student should therefore be able to manage with Thermodynamic basic concepts without any difficulty after completing the courses.

The European directives over the last decade on higher education [1-5] recommend a pedagogical approach centered on the student as the main player of his own education, emphasizing the importance of an active and collaborative learning and involving the students in their own educational process ("learning to learn") through methodologies that motivate their educational concerns such as the Problem Based Learning or the Discovery Learning. Consequently, the role of the teacher is channeled towards the guidance and assistance of the students along the learning process, as they have to be trained not only on the concepts of the subject but, even more important, in competences for a lifelong learning that allow them to implement their studies into the future context of their professional careers.

These educational competences are usually defined as the sum of knowledge, skills and attitudes, but a close explanation of this term is given by the European Qualification Framework [4] when states that "competence means the proven ability to use knowledge, skills and personal, social and/or methodological abilities, in work or study situations and in professional and personal development. (…) competence is described in terms of responsibility and autonomy". This definition acquires special relevance on Engineering, since the current knowledge becomes more and more obsolete due to the constant advancement of technology, so the learning of skills and attitudes in terms of responsibility and autonomy are a good basis to be prepared for the future world that students will find at the end of their educational process.
Thereby, in Europe, practical lessons and autonomous work of the students increased their recognition through the European Credit Transfer System, which bases its measurement unit "on the workload students need in order to achieve expected learning outcomes" with a broad definition of workload as "the time students typically need to complete all learning activities (such as lectures, seminars, projects, practical work, self-study and examinations)" [5], so reinforcing the weight of the practical preparation on the curriculum.

This context and the effectiveness of interactive software on procedural learning activities suggest that they will probably become the core of technical engineering education [6] both for economic and pedagogical reasons, as they involve an active participation of the students and have the potential of flexible learning, giving access to a large number of experiments at a very low cost. Besides, the distribution of these resources among the students helps make them available wherever students need them and, even more important, at the particular learning pace of each student.

The software presented in this paper was born 20 years ago after a deep analysis of the teaching of Thermodynamics at the Engineering School of the University of Zaragoza. The background referred by the European Union was already covered by the conceptual framework within which TermoGraf was created [7].

The traditional teaching system is based fundamentally on the theoretical classes, in which the students limit themselves to transcribing the knowledge imparted by the teacher, accumulating it for more or less time until the next exam dates arrive. Essentially, students memorize intensely such knowledge in order to overcome the obstacle of the examination. Attempts to change this dynamic from different approaches often encounter difficulties. With the support of the use of Information and Communication Technologies (ICT) and their associated framework, some lecturers of the Mechanical Engineering Department aimed the objective of providing students with a teaching-learning environment that stimulates a methodological change of work, fostering meaningful learning supported by the use of interactive materials used in theory classes, simulation practices and personal work.

The complexity of the equations used to solve thermodynamic problems demand a high level of scientific knowledge not only in the field of thermodynamics but also in mathematics. There are currently numerous computer programs able to help in the management of those demands. Each of them presents some advantages and limitations, mainly determined by the way of focusing the problem. Roughly, they can be divided into two groups: the mathematical approach and the training-focused approach. Half way between both approaches, we have developed a simulation tool, ThermoGraf (http://termograf.unizar.es) which achieves, through a highly interactive graphical interface, to solve virtually all of the problems that are considered in introductory courses in engineering thermodynamics at university level, without losing the friendly interface and mathematical precision.

A graphic environment with a high-interactivity level is created, allowing the user to manipulate the states and thermodynamic processes of the considered thermodynamic system, with the same ease as in a standard vector drawing program. This is not a trivial aspect, since the majority of its models for calculating properties of real substances only provide acceptable values in their limited range of use. Then, it was required to improve those models so that the graphical representation values compensate for the deficiencies of the original standards. There exists a main menu and a toolbar that allow nearly a hundred actions to be performed by selecting an option in the menu and then clicking on the mouse and dragging on the thermodynamics graph. As a consequence, the working procedure only takes some minutes to be learnt. The interface simultaneously displays graphical and numerical information of the system, providing full accuracy for the values of state properties, process information and mass and energy balances evaluation.

2 METHODOLOGY

Regarding the methodology and contributions, the use of a didactic tool, TermoGraf, applied in the subject of Thermal Engineering, allows, on the one hand, attending the teaching environment, the explanation of most of the concepts of the subject in a dynamic and practical way and, on the other hand, attending the learning environment, the resolution of exercises on the students in their own way at home [8-10].
• Teaching environment: The program can be used in class by the lecturer in order to explain most of the concepts in a practical way, using dynamically graphic representations and calculations with the different models and substances, being able to deeply analyse the different thermodynamic processes that take place in thermal systems.

• Learning environment: By using the computer in the practical sessions, as well as during the own study and resolution of exercises.

With both uses, students learn the concepts in a practical way; the intuitive use of TermoGraf allows, firstly, checking directly if the student’s calculations are correct. Then, in a second stage, it facilitates the most tedious work of calculation and the student can focus on the analysis of the concepts and the understanding of them and their interrelations. Finally, the exercises can be shared using the network.

These features suppose, among others, a change of the students’ attitude, since it is promoted that they are who must actively work the subject from the beginning and continuously. Additionally, the continued use of the software facilitates the comprehension of the concepts and their significant learning. The students handle data of processes that can visualize with complete accuracy and precision, being able to analyse very easily the changes in the variables and their influence in the behaviour of thermal systems.

2.1 ThermoGraf main features

Through various work tools, the user can draw directly on two-dimensional graphs the development of processes or cycles, with automatic passage from one diagram to another and simultaneous calculation of the properties of the state being drawn as well as the corresponding energy balances.

Once a process or cycle has been drawn, an exact adjustment of a given state can be made, as well as incorporating or eliminating processes from an existing cycle. The management of the graphics has been tried to be intuitive, with tools that allow easy editing and characterization of the elements drawn.

For example, when calculating the performance of a cycle, the student, acting on the processes on the screen, can establish a value that will be verified by the computer. The interest lies in interpreting the thermodynamic processes represented in the screen and which are the elements that intervene in the expression of performance and how do it. Then, the reinforcement of meaningful learning is evident.

Depending on the three modes of use described above, the program has three different work modes, with different configurations depending on whether it is being used for personal work or for teaching.

For personal work, self-learning mode, allows the development of exercises by teachers, with multiple storage of them before random change of data, so that students access them in an equally random, personal and non-transferable.

Users have the ability to configure the main screen and, therefore, the initial conditions, both individually with the corresponding configuration menus and also in conjunction with the preferences window, including options for choice of units for each physical magnitude, type of system control, sign convention, reference states and the environment conditions...

Attending to the panels’ distribution in the main window (Fig. 1), the thermodynamic diagram can be clearly identified as the most important component, adjusting its size to the window itself. As an example of high interactivity, the range of scales can be easily modified by the user in the corresponding window configuration. Additionally, the program allows some other options as well, such as the rule drag with the mouse, the use of increase and decrease- scale buttons, or the button of automatic adjustment, which focuses the considered installation on the graph.
Fig. 1. Breakdown of the main window: 1) thermodynamic diagram, 2) Information on selected properties and balances, 3) Information on the properties indicated by the cursor, 4) Management screens.

The provision of auxiliary panels around the chart makes the user's attention focuses on the meaning of thermodynamic drawing, more than on their numerical values, thereby directing their efforts to a symbolic understanding of the problem. Similarly, the risk associated with having too much information on the screen when facing a problem (that may distract our attention and unnecessarily complicate the overall vision) is avoided through mechanisms for showing or hiding of any numerical property in the data panel data as a whole.

By following these guidelines, the thermodynamic information of the state associated with the position of the cursor is shown below the diagram. It is very convenient for a quick drawing. Left side, the properties and balances panel provides the necessary information for final adjustment of the magnitudes and values required by the problem. A final panel allows setting various display screens in a single TermoGraf file, in order to serve as a slideshow or as a step by step presentation when solving a problem, when the program is used in educational issues.

3 RESULTS: FROM TERMOGRAF TO THERMONATOR

Thermodynamic courses understood as problem-based learning are fundamental in the scientific disciplines. The problem is that the hours devoted to the face-to-face teaching are quite short. Time limits the examples to be developed, since a long calculation procedure is required to solve the properties of the substances, before moving on to the part relevant to the exercises that want to be presented. The traditional solution to this problem is the use of numerical tables in which the student must interpolate the values and other more complex calculations that, once well understood, only lengthen the resolution time in excess. When one wants to advance in the analysis, for example, of thermodynamic cycles, it is required to obtain quickly the basic thermodynamic properties that characterize each one of the states of the cycle and this requires too much time. Classroom hours are, as mentioned, very limited in the new Engineering studies and the valuable time that is available must be very well used. That is, it must be a time of great quality. An alternative to this situation is the use of the app that is being developed, Thermonator. Its main advantage is that it can be used with mobile devices and it is not required to go continuously to the computer room to use the computers.

From the extensive experience acquired over more than twenty years working with the software TermoGraf, three years ago the possibility of going one step further was considered. The project of developing an application for mobile devices was raised and the design and development of the app Thermonator successfully started. The app can already be downloaded at google play: (https://play.google.com/store/apps/details?id=com.xmuzzers.thermonator&hl=en). It is an advanced thermodynamic calculator (for mobile phones and Android-based tablets) that makes the agile use of ICT resources plausible in the context of active methodologies during lectures. In addition, it can be used by students in their personal study and in group work. The main screen of the app is shown in Fig. 2. From there, the main menu leads to different sections: properties, units, system of analysis, reference environment to calculate the properties and preferences. The possibility of sending comments to the creator is available as well. In this way, the user may configure the information on the main screen before start to work on the exercise to be solved.
The improvement obtained is substantial and, after performing a couple of complete examples of the calculation of properties with the traditional method to illustrate the foundation of the app, they have been able to perform a greater number of exercises in class. Students participate actively with their mobile devices. The fluency to perform the initial calculations has allowed addressing in greater detail the central parts and the conclusions of each proposed exercise. This is a significant improvement over the previous situation.

At this stage, the app is still under construction within a dynamic process fed both from the lecturers and students. Explicative videos are accessed from the app, as well as solved exercises. There exists an innovation project devoted to continue developing aspects of the app that are still pending and to deepen the application and analysis of its benefits in meaningful learning by students of Thermodynamics, a fundamental discipline in the scientific-technical training of the students.

4 CONCLUSIONS

From the experience and reflection of the authors of this article, the great contribution of using the TermoGraf program for teaching is beyond doubt. For twenty years, the team of teachers dedicated to planning and executing the teaching plans in thermodynamics for engineers, have seen that the incorporation of this calculation program helps students to understand the sometimes complex and abstract concepts related to Thermodynamics.
As a complement to the software, which must be run on a computer, the mobile application, Thermonator, makes it possible to speed up the calculations during face-to-face sessions and helps students increase their interest in this discipline.

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