



Collaborative Research: vObjects - Understanding their Utility to Enhance Learning of Abstract and Complex Engineering Concepts

Dr. Diana Bairaktarova, Virginia Tech

Diana Bairaktarova is an Assistant Professor in the Department of Engineering Education at Virginia Tech and the Director of the Abilities, Creativity and Ethics in Design [ACE(D)]Lab. Bairaktarova's ongoing research interest spans from engineering to psychology to learning sciences, as she uncovers how individual performance and professional decisions are influenced by aptitudes and abilities, interest, and manipulation of physical and virtual objects.

Dr. Scott T. Huxtable, Virginia Tech

Mr. Sathyanarayanan Subramanian, Virginia Tech

I am a Graduate Mechanical Engineer at Virginia Tech, specializing in Thermal-Fluid Sciences.

Prof. Zahed Siddique, University of Oklahoma

Zahed Siddique is a Professor of Mechanical Engineering at the School of Aerospace and Mechanical Engineering of University of Oklahoma. His research interest include product family design, advanced material and engineering education. He is interested in motivation of engineering students, peer-to-peer learning, flat learning environments, technology assisted engineering education and experiential learning. He is the coordinator of the industry sponsored capstone from at his school and is the advisor of OU's FSAE team.

Collaborative Research: vObjects - Understanding their Utility to Enhance Learning of Abstract and Complex Engineering Concepts

Introduction

Research over the years has inferred that presence of physical objects enhances pedagogy of complex engineering concepts [1 -3]. However, on numerous occasions, it is not feasible to use physical objects because of its size, cost, safety, and other restrictive issues. There arises a need for virtual objects (vObjects) to facilitate instruction of abstract engineering concepts. vObjects are two-/three-dimensional virtual objects with functional, geometric, behavioral characteristics that simulate their real-world counterparts, similar to a digital game.

In this paper (poster), the rationale and the process involved in developing an interactive vObjects tool to solve an undergraduate thermodynamics course project is explained. Further, the contents of the tool and the relevant concepts are elaborated.

Overview of the Project

The increasing demand for energy across developing countries will require construction of high-efficiency power plants. Apart from the fundamental thermodynamics concept, the task of constructing a power plant involves a broad knowledge from multiple disciplines. To provide an overview of the entire process of constructing a power plant, the undergraduate courses of Thermodynamics at Virginia Tech and the University of Oklahoma include a project that requires students to design a conceptual power plant, in one of the three countries: Jamaica, Panama, or Rwanda. In the past semester, participants completed the project without the use of any (virtual) tool. To aid students in completing the project with a sound understanding of the basic thermodynamic concepts, the current virtual learning environment tool is developed.

The thermodynamics course of the engineering curriculum includes complex concepts that are difficult to comprehend (and abstract at certain times). Students tend to have significant misconceptions on these topics. A wide range of objects (of different scale and complexity) are needed to address conceptual understanding of Thermodynamics. To address these issues, our project aims at creating a virtual learning environment to explain fundamental concepts such as the Rankine cycle and Brayton cycle, using instructive features such as animations, videos, and preliminary equations for design calculations. These elements of the vObjects are focused on explaining the concepts and physics behind the working of all components associated with the thermodynamic cycles. Furthermore, datasets in the form of graphs and charts are used to describe the physical, economic, political, and environments scenarios of different geographical areas chosen for construction of the virtual power plant.

Tool Development Process

The basis of the tool development process is based on explaining the concepts involved (both engineering or statistical data associated with various aspects of the countries) in each stage of the project.

The vObject tool is developed using the commercial tool, LabVIEW from National Instruments, which is apt for both embedding vObjects (animations and videos) and to write equations for calculations.

The following sections of the paper explain the development of the tool, pedagogical choices, and rationale involved decision making at every stage of the tool development.

Selection of country for conceptual power plant

The preliminary step a student needs to take in the project is to choose a country in which the conceptual power plant is to be located. To aid in this selection process, statistical data of the geographic, economic, environmental, and importantly energy issues are provided. These data include all aspects under each category required to infer the location of the conceptual power plant, such as the population, energy consumption per capita, the GDP of the country, to name a few. They are given in the form of comparable graphs, and charts from which the student is allowed to draw a conclusion on the choice of country. An example of the process and the charts are shown in Figure 1, Figure 2, and Figure 3 below.

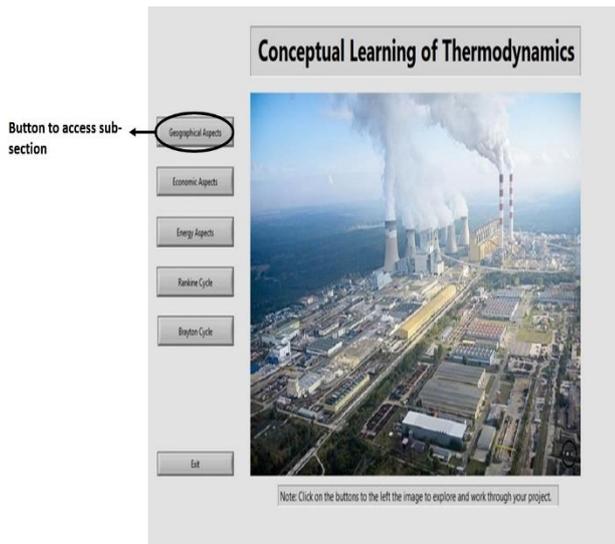


Figure 1: Main page with buttons to navigate to specific aspects of design

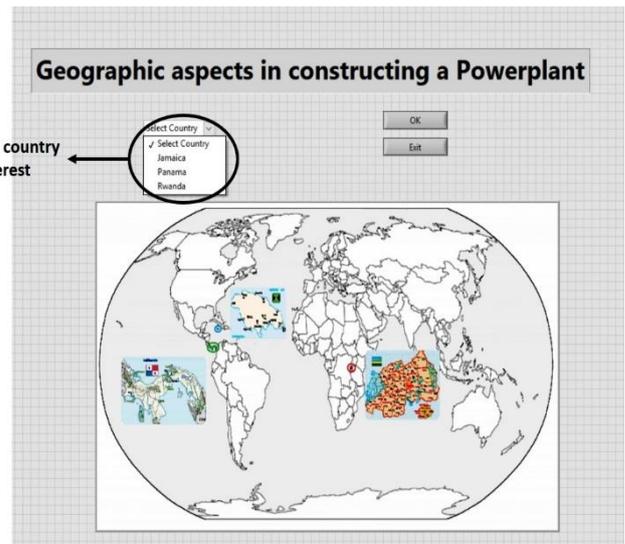


Figure 2: An example page of geographic aspects, that allows the user to select the country of choice

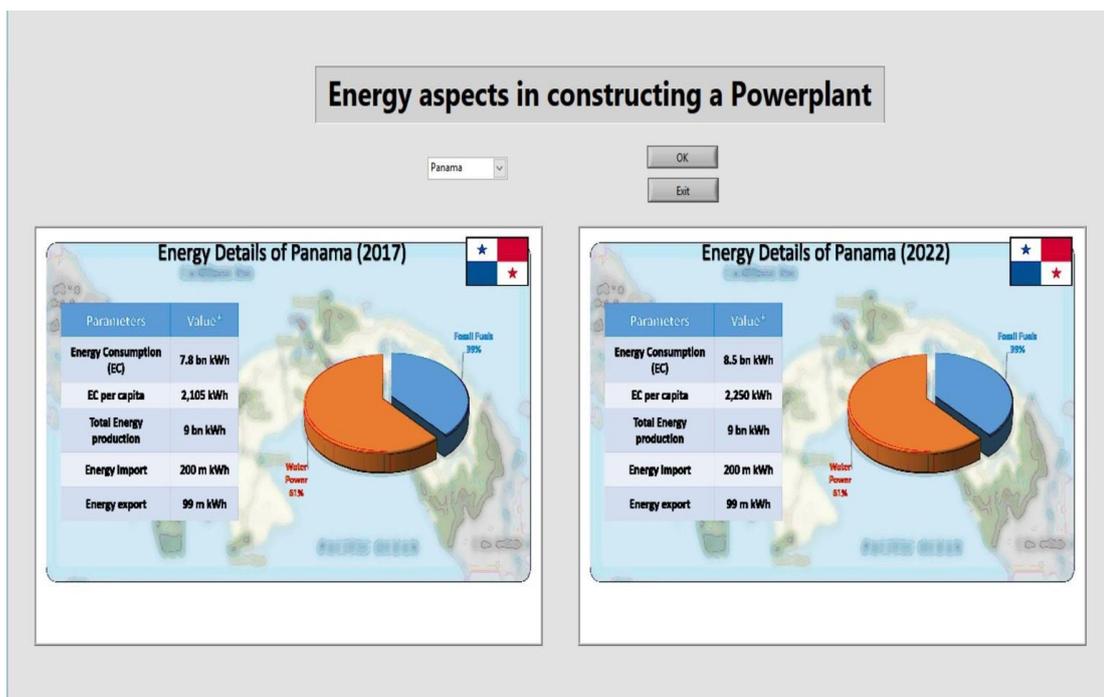


Figure 3: A sample window comparing the energy needs of Panama during 2017 and the predicted values during 2022

Based on the statistics, the student is allowed to decide the location of the conceptual power plant. To provide additional information, the location of the countries on the world map and their respective flags are displayed in the primary image.

Understanding the Thermodynamic cycles and their components

As the participant decides on the location of the power plant and mainly the power demand in the chosen country, he/she will have to conceptually design the power plant based on the predicted demand. As a primary step of this process, the participant decides on the source for power generation (for e.g. coal, nuclear or natural gas, to name a few). Power generation from a majority of these sources is based on either of the two main thermodynamic cycles: Rankine and Brayton cycles. To help understand the working of these cycle and the components involved in the power generation process, an animation is added that explains the working of each of the cycles on a step-by-step basis. Simultaneous to the animation, the thermodynamic graphs (h-s and P-v charts) used in textbooks to explain the processes are also shown as animations, which helps the participant understand the process thoroughly. The charts provide the properties (temperatures, pressures, and specific volume) of the working fluid, which aids in design calculations required to achieve the desired power output. The window of the tool which had the thermodynamic cycles explained also includes buttons to navigate to multiple sub-windows each of which explains the component involved in the cycle as shown in Figure 4.

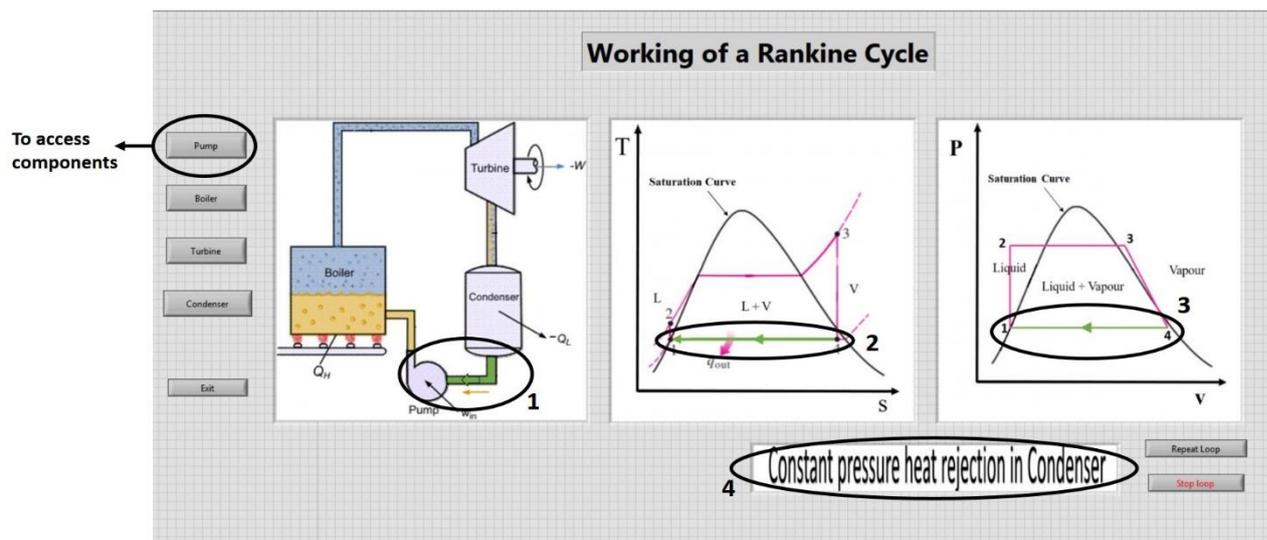


Figure 4: Window with animated tabs of concepts of Rankine cycle. The circled entity in each tab explains the process undergone by the fluid

As the working of the thermodynamic cycles is instructed, a more detailed, component level concepts are further explained.

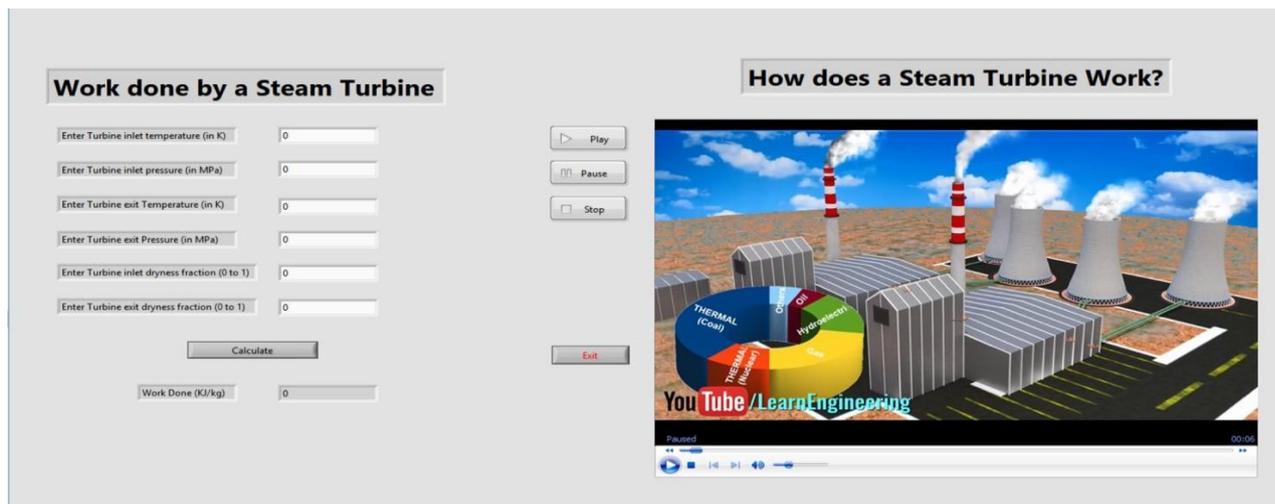


Figure 5: A sub-window for tutoring the working and calculation associated with a steam turbine

As an example, the window explaining the working of the steam turbine and its associated calculations is shown in Figure 5. The main objective of this section is to understand the working of the component chosen and it is achieved through an animated video which thoroughly explains the principle and working of the component. Further, to aid the participant in his/her design calculations, the window also includes equations and a calculation space. The process of the calculation is given by the equation block whereas the calculation results are obtained from the click of the button. The input to the calculations is based on the requirement of the particular country.

Tool development method and Testing

As mentioned, the tool is developed using the software, LabVIEW. LabVIEW comes with built-in options to embed video, develop animations with a sequence of images and mainly to write equations (following syntax of 'C') to solve the equations associated with thermodynamic cycles. Each module (or sub-routine) is called as Virtual Instruments (VI). Therefore, modules such as 'Energy aspects' (Figure 3), 'Rankine cycle' (Figure 4), and 'steam turbine' (Figure 5) are Sub-VIs which can be called from the main VI (Figure 1) with a click of a button. A few significant methods used to develop the tool are:

Ring Control – for animation: Ring control allows the user to add a sequence of images and allow them to be played at a predefined speed. This aspect is used in animating the thermodynamic cycle charts

Event Structure – to navigate to SubVIs: Event structure is a generic coding method where a click on each button is assigned an event, in this program to navigate to SubVIs.

ActiveX controller – to play videos: the ActiveX controller is an add-on to the LabVIEW software, which enables it to play video files. It also provides the basic controls of 'Play', 'Pause' and 'Stop' to the user during runtime. An additional control file (.ctl) is to be downloaded to enable this.

Invoke node – A unique option in LabVIEW that allows the programmer to specify properties of the objects in the main window. For example, an invoke node provides options to adjust the dimensions of the images.

Along with these significant options, the code was developed using the LabView's basic features such as using buttons, loops, and calculators.

Testing

Two aspects of testing (validation and testing) are performed. The equations and the calculations involved in the Thermodynamic cycles are validated against standard published results. The data pertaining to the various aspects of the three countries are taken from the latest numbers displayed in the official (government) websites of the countries.

To pilot the tool, undergraduate student volunteers will be allowed to participate and work on the project using the tool. The effectiveness will be compared with that of the reports (documents) from students who had completed the project in the previous semesters without the help of the vObject tool. The tool will be improved based on the feedback.

Overall, the concepts were developed keeping in perspective the step-by-step procedure required for the project and mainly the concepts involved in each stage of the project.

Acknowledgment

This research is supported by the NSF under IUSE #1712210. The contents of this manuscript do not necessarily reflect the views and opinions of the funding agency.

Reference

- [1] Dalrymple, O., Sears, D., & Evangelou, D. (2011). The motivational and transfer potential of disassemble/analyze/assemble activities. *Journal of Engineering Education*, 100, 741-759
- [2] Grantham, K., Okudan, G., Simpson, T. W., & Ashour, O. (2010). A study on situated cognition: product dissection's effect on redesign activities. In *ASME 2010 International Design Engineering Technical Conferences and Computers and Information in Engineering Conference*, (pp. 617-626). American Society of Mechanical Engineers.
- [3] Simpson, T. W., Stone, R. B., Lewis, K. E., & Regli, W. C. (2007). Using cyberinfrastructure to enhance product dissection in the classroom. In *IIE Annual Conference. Proceedings* (p. 643). Institute of Industrial Engineers-Publisher.