

A Visual Software Concept for the Thermo-Fluids Discipline

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Introduction

This paper gives an overview and preliminary results of a project to design new educational software for use in thermodynamics and fluid-related disciplines. In the past, educational software has been created for use as teaching aids, design tools, and even electronic textbooks. Where this project differs is in its emphasis on integration into the existing thermodynamics curriculum while simultaneously allowing improvement in teaching methods. Factors influencing the improvement of any course include a clear determination of course objectives and evaluative procedures. Comparison of the teaching and learning styles is another factor. Research shows that traditional teaching methods for thermodynamics leave gaps in the educational landscape. Whereas some software is designed independent of these considerations, the goal of this project is to fully integrate the curriculum objectives and knowledge of cognitive styles into the software development. Built around the programming environment of LabVIEW this material is intended to provide flexibility in the mode of presentation. Specifically, more active hands-on experience will be possible as well as a greater use of visual input. Most engineering students do not gain substantial hands-on experience in thermodynamics classes, due to time and equipment constraints. It is anticipated that use of the virtual instrument capabilities of LabVIEW will give students a closer approximation of real world experience through simulation.

Learning and Teaching Styles

Before presenting a description of the educational software it is necessary to review the basis for its use. Research has long shown that individuals behave and learn according to certain cognitive styles. The Myers Briggs Type Indicator (MBTI) is one well known method of analyzing personality traits and behavior. It has been widely used in education to explore how students behave with regard to learning. Other methods exist which provide more emphasis on the individual's learning strengths and weaknesses. One such learning style inventory is the

Kolb Learning Cycle. In this description learning is modeled as a four stage cyclic process. The four stages in the process relate to Concrete Experience, Reflective Observation, Abstract Conceptualization, and Active Experimentation¹. Depending on the level of usage for each of these stages student profiles will fall within one of the four quadrants of the cycle. Divergers learn by using concrete experience and reflective observation. Assimilators prefer reflective observation and abstract conceptualization. Convergers rely heavily on abstract conceptualization and active experimentation. And finally, Accommodators make use of active experimentation and concrete experience. In order to make maximum advantage of the educational environment it is believed that teaching and learning should encompass all four stages of the cycle. The first advantage to this is that it ensures that all types of learners are addressed. Secondly, it has been suggested that students learn best when their abilities in all four stages are utilized^{1,2}.

Another model of learning has been developed by Felder which describes the student as having a preference in five different dimensions: perception, input, processing, understanding, and organization³. Perception can occur by using external (sensory) input or by internal thought (intuitive). Information can be obtained using a visual or verbal input method. Processing can be done through some form of "physical" activity (active) or by introspection (reflective). Understanding can come from putting individual steps together (sequential) or looking at the whole picture (global). Finally, organization can be done inductively or deductively. It should be apparent that there are certain similarities between this learning inventory and the Kolb Cycle, as well as the MBTI.

Studies using the Felder learning inventory suggest that the majority of engineering students prefer the active form of processing information¹. Many thermodynamic and fluid mechanics courses are organized along traditional methods of lecture and note taking, supplemented by problem solution. Typical courses are therefore organized for a passive reflective learning environment. In terms of processing, engineering students have been shown to rely heavily on visual input. Since most classes are organized along the lecture method, however, teaching is done primarily verbally. While the majority of students prefer the sequential method of understanding more than a quarter would make better use of a global method. Classroom emphasis is seldom on the overall picture thereby ignoring this segment's learning needs. It is evident that the commonly used teaching methods for many courses, including those in the thermodynamics and fluid mechanics areas, do not take into full account the students abilities or learning preferences. What is also apparent is that there is room for improvement in how courses are taught. Since the learning preferences of many students are not being fully addressed, great improvement could result from additions and/or modifications to the existing curriculum in these areas. There are many teaching techniques that can be used to address these deficiencies, including the use of computers in the classroom for simulation and multimedia presentation.

The LabVIEW Programming Environment

The educational material described here has been developed around the LabVIEW software package. LabVIEW was originally developed for the purposes of data acquisition. The package's powerful programming features have allowed its expansion into the areas of simulation, controls, and automation. While LabVIEW is not generally thought of as a general

created with LabVIEW will be capable of being directly linked to the outside world. This link could involve control of an instrument or input of sampled data. The capability therefore exists to use the software as a stand alone tool or in combination with laboratory experiments and other software.

The THERMOVIEW Concept

The graphical structure of the LabVIEW programs suggests certain similarities to the process and cycle diagrams commonly used in thermodynamics courses. The basis of the software concept is a series of VIs that can be "wired" together by a student or instructor in the same way they would draw the cycle. Each VI represents a cycle component, such as a turbine, heat exchanger, or pump. Based on the graphical programming method process modelers do not have to do extensive text programming to simulate the cycle but merely construct a picture of it. A comparable programming concept for the design and simulation of thermal cycles is in use by industry⁶. Similar graphical programs have also been proposed for education but without an analysis of their possible learning style impact^{7,8}.

The simulation capabilities of these programs are useful for student design studies, problem solution, and classroom examples. However, these applications do not take full advantage of the available on the cognitive side. In our LabVIEW programming method the simulation of the cycle is done at the wiring diagram (or coding) level. This leaves the front panel GUI free for other uses while being directly linked to the simulation. There is flexibility in how the GUI is designed and for what purpose. It could simply be a data interface for the simulation or alternatively it could take the form of an electronic textbook or tutorial. Commonly with other programs system parameters are input through windows or dialog boxes as numbers. Using the front panel capabilities of LabVIEW, interfaces can be created out of virtual representations of familiar physical controls, such as knobs, slides, and switches, or out of cycle schematics (Fig. 2). Thus the level of computer experience required to use the program is less, making it very student user friendly. GUIs of similar form are often used in industry for process control. For instance, the electric power utilities use interfaces very similar to those in this project. Students will very seldom have the opportunity to operate a power plant to see how things actually work. However, by linking front panels which mimic an actual plant and the simulation programming students can get a real world feel for thermodynamic principles in action. This aspect of the software addresses the cognitive issues of active and global learning styles, while the graphical interface and programming method simultaneously allow the visual learners to be addressed.

Preliminary work involved simulation of the components of a simple Rankine cycle to test the feasibility of the project concept. VI modules for a turbine, pump, condenser and boiler were created and linked together to form a Rankine cycle simulation. The programs allowed many types of problems to be solved both for individual components and for the whole cycle. Extra attention, however, was paid to the simulation of the turbine¹⁰. Although the simulation and interface were kept simple it did demonstrate the feasibility of the simulation. Next information was gathered on the cognitive styles present in the local beginning thermodynamics courses. A simple survey, similar to the Felder Inventory of Learning Styles, was given to students in the Mechanical Engineering thermodynamic course. The results compared well with the published data. The majority of engineering students were found to be Visual, Sequential, Active, Sensing

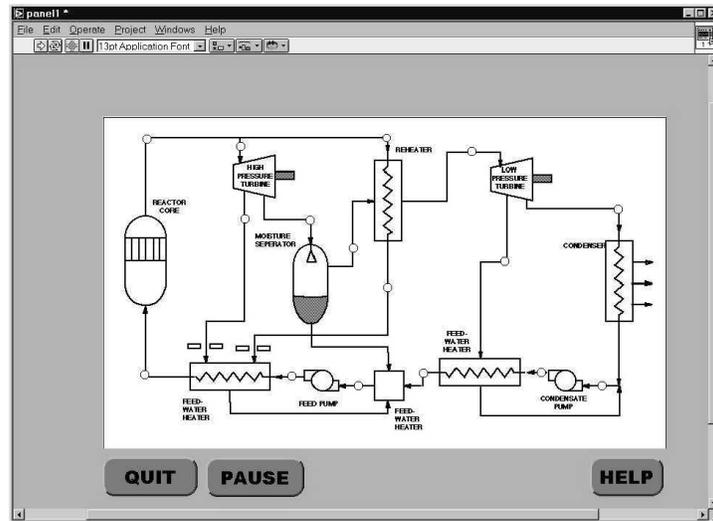


Figure 2: LabVIEW front panel depicting a power plant schematic⁹.

learners. This supported the belief that the software could make its biggest impact by addressing the visual and active learners which are commonly neglected.

Current work has been multi-faceted and addresses a number of issues. The beginning thermodynamic courses in both Chemical and Mechanical Engineering at the University of Missouri-Columbia have been studied to determine educational objectives and typical teaching/evaluative methods. Based on this information areas have been identified where the software could make a positive impact in both classes. It was found that analysis of a simple Rankine cycle was present in both classes. Use of the program to supplement or replace normal assignments in this area was found to be a suitable testing scenario for software accuracy, use, and pedagogical concerns.

Program Structure and Use

The solution portion of each component VI is designed to allow a variety of possible inputs. This design allows for flexibility of use. For instance, when working thermodynamic problems sometimes the turbine work is known, while at other times it must be determined. Each component VI therefore has a Case structure implemented which determines what values should be solved. It also indicates if there is not enough input data to get a solution. Since the first version of the basic component VIs were created, substantial thought has gone into improving the program structure and sub-VI interfacing. A common sub-VI setup has been devised which allows for a common connection format between component VIs. It has been necessary to define several different types of input and output. Each component VI receives a set of property values which defines the conditions of the entering fluid. These cycle inputs include pressure, temperature, quality, and mass flow rate. All four variables are grouped in an array which allows a single connection wire between components, maintaining the similarity to process diagrams. In a similar manner, cycle outputs exit the VI which describe the condition of the fluid leaving the component. The use of the quality values is only valid for saturated states and is included for completeness. The arrays are expandable if it is later determined that

passing extra variables, such as enthalpy or entropy, would be more efficient. An optional input array is also provided for initial values, for cases where an iterative solution is necessary or transient behavior is being studied. Component parameters and specifications, such as efficiency for a turbine, can be specified on the front panel of the VI. However, there may be instances when one of these values will be controlled from a main front panel (i.e. for the whole cycle or process). To accommodate this feature individual input lines are provided on the component VI which may or may not be connected, depending on the problem. Some component parameters may also be desired as output values for the main control panel, such as turbine work. These output values are provided in the same manner as individual output connections.

As an example, consider the problem of modeling a process where fluid first goes through a compressor and then a nozzle. The compressor sub-VI is first placed on the wiring diagram. The cycle input array for the sub-VI can be created from specified constant values on the wiring diagram or from front panel controls. The nozzle sub-VI is then placed on the wiring diagram. A connecting wire is placed from the compressor cycle outputs to the nozzle cycle input points. The cycle output of the nozzle is then wired to indicators on the front panel. The characteristics of the compressor and nozzle can then be specified from each sub-VI's own front panel.

In order to construct a suitable teaching aid for both the Chemical and Mechanical Engineering courses a general solution VI was created for the Rankine cycle first. The front panel for this VI is shown in Fig. 3. This front panel has been tailored to the specific types of problems for which it will be used, namely cases which have turbine inlet pressure and temperature as well as exit pressure as input values. The key output is the cycle thermal efficiency. This front panel has been kept fairly generic. On the left, slide controls allow the user to specify the input values. When the Calculate button is pressed the bar indicators for Steam Generator Heat Transfer, Thermal Efficiency, and Back Work Ratio are updated for the new values. The option also exists to save the data to a text file or to plot successive data points automatically. Front panel indicators and controls can be easily changed from one to another (with the click of a mouse). The front panel was therefore easily modified for each class, dependent on its specific objective.

Conclusions

Preliminary results indicate that LabVIEW can be used for simulating thermodynamic processes and cycles. Based on student and faculty input at the time this paper was written, user interfaces can be created which are simple and intuitive to use, providing the underlying code is robust enough. One aspect which quickly became apparent is that the simulation algorithms must be capable of handling many diverse usage situations. The benefits of the software will be greatly diminished if students are burdened by limited capabilities, excessive error conditions, or inaccurate results. From the educator's point of view, the method of actual use will determine if it addresses the gaps in learning to teaching styles in the class. It is intended that this product be more akin to a multimedia teaching aid or a hands-on experience than a problem solver.

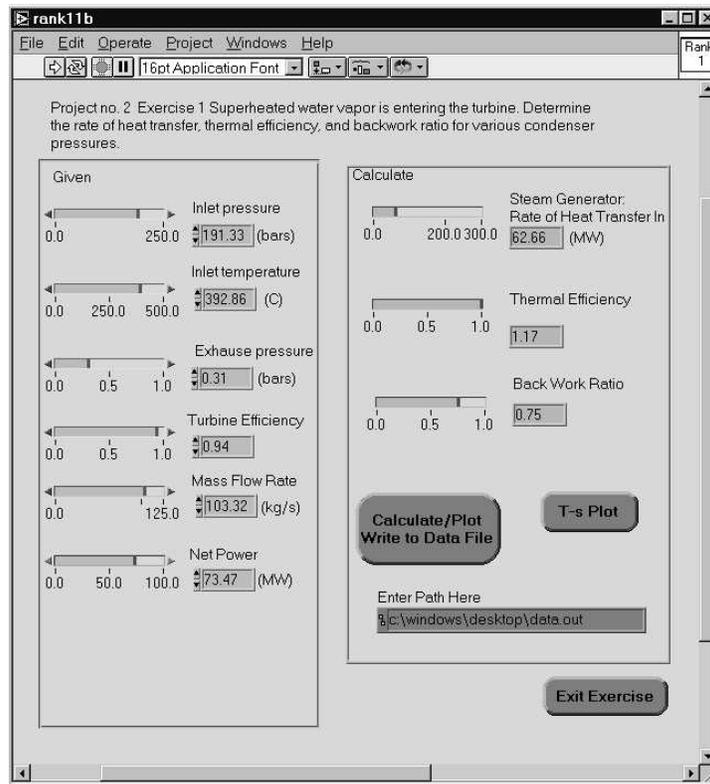


Figure 3: Generic front panel for Rankine cycle test problems.

To get a complete evaluation of student impact with the software surveys are currently underway. These surveys fall into two categories. The first consists of the Felder Inventory of Learning Styles which is being used to determine the cognitive make-up of the class. The second survey has been designed to evaluate the students knowledge of thermodynamics, specifically with regards to the areas in which the software will be used. During the Fall semester of 1999 these surveys were given to students at the University of Missouri – Columbia. The students in this semester have had no contact with the educational software and have not used it in class. These results will serve as a comparison basis. During the Winter semester 2000 the same class assignments will be given to the students, only this semester the software will be available. The same surveys will then be given and the data analyzed. The intent of this testing is to determine if using the software actually aids the students in understanding the topic. A secondary intent is to obtain student input, concerning ease of use of the software. Lastly, the evaluative portion of this research will help identify any previously undetermined class influences or software problems.

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Acknowledgments

Credit is due to the undergraduate and graduate students working on this project: Jim Hakanson and Tim Smith at the University of Missouri, and Justin McCullough and Anthony Cotroneo at The College of New Jersey. The assistance of the entire project team at the University of Missouri is also appreciated. This research is supported by the National Science Foundation through grant DUE-9950869.

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