Development of Software Applications for Thermodynamics Related Courses: The THERMOVIEW Project

Dr. Patrick A. Tebbe
The College of New Jersey
tebbe@tcnj.edu

Dr. Christa Weisbrook, Dr. Stephen J. Lombardo, Dr. William Miller
University of Missouri

Abstract

The College of New Jersey and the University of Missouri are collaborating on a NSF Course, Curriculum, and Laboratory Improvement proof-of-concept grant to develop educational software for use in thermodynamics, fluid mechanics, and thermal systems courses. The THERMOVIEW software is being designed within the LabVIEW programming environment. It is hoped that by making use of the visual environment of THERMOVIEW and LabVIEW that students will gain greater insights into the processes involved and the flavor, if not the actual feel, of how systems behave in the real world. The purpose of this paper and presentation will be to provide an overview of the project to date and a description of current evaluation results.

I. Introduction

Advances in technology and pedagogy imply that the engineering curriculum must be periodically reformed or supplemented in order to provide the best education possible for students. Particular shortcomings must be addressed and improvements to the curriculum found. One challenge of engineering education is adequately accounting for different types of learners within a student body. Psychological types are known to exist which partially determine how a person learns. The theory most relevant to this proposal is the Felder-Silverman Learning Style Model, which is commonly applied in engineering education. The Felder model specifies students as having a preference in five different dimensions; perception, input, processing, understanding, and organization [1]. Perception can occur by using external (sensory) input or by internal thought (intuitive). Information can be obtained using an input method of visual or verbal. Processing can be done through some form of "physical" activity (active) or by instrospection (reflective). Understanding can come from putting individual steps together sequentially or looking at the whole picture globally. Finally organization can be done inductively or deductively.

Studies of engineering students using the Felder learning inventory suggest that the majority prefer the active form of processing information. 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 information, 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 some courses, including those in the thermodynamics and fluid mechanics areas, do not take into full account the students' abilities or preferences as determined by the Felder model.

More fundamental concerns come from the field of behavioral psychology, which has for many years studied how individuals and society in general perceive, react to, and understand the world around them. Human beings experience the world differently than it actually exists and each of us experiences the world to a certain extent differently than everyone else does. The factors, or filters, which form and distinguish these individual perceptions include the reduction and modification of physical experience done by the nervous system, social factors such as language, and each individual's history and experience [2]. The combination of these filters allows each person to form a model, or map, of how the world exists and functions. Research conducted on how people learn has confirmed that students come into the classroom with preconceptions about the topics involved [3]. "If their initial understanding is not engaged, they may fail to grasp the new concepts and information that are taught, or they may learn them for purposes of a test but revert to their preconceptions outside the classroom. [4]"

Thermodynamics is particularly prone to the types of difficulties mentioned (i.e. addressing learning styles and preconceptions) because it is commonly viewed as rather abstract and non-visual. Students come into these courses with many preconceptions that hinder their progress [5]. This is complicated by a lack of thermodynamic laboratory experiences that would provide an active, hands-on learning environment [6]. One approach used currently is to employ computational or multimedia components that will supplement or replace the existing course material. This provides opportunities for better visualization that can aid in teaching qualitative concepts [7] and provides simulated experimental experiences. Research has been undertaken as part of a NSF Course, Curriculum, and Laboratory Improvement proof-of-concept grant to develop this type of material for thermodynamic and thermal science courses.

II. THERMOVIEW and LabVIEW

The educational material under development is based on the LabVIEW software environment. LabVIEW was originally developed for data acquisition purposes but has since expanded into a wide range of fields. A brief description of the LabVIEW programming structure has been presented in previous work [8]. Since LabVIEW has so many applications in engineering it serves as a cost efficient software package for academic institutions which already use it for courses or other programs. In fact, the LabVIEW package is used so widely in engineering education that the International Journal of Engineering Education has published a special issue (Vol. 16-3) devoted to "Applications of LabVIEW in Engineering Education."

One of LabVIEW's strengths lies in its ability to duplicate the abilities of other instruments. This duplication not only includes function but appearance and "physical" operation as well. Programs in LabVIEW are called Virtual Instruments (VIs) for this reason. LabVIEW includes a number of controls and indicators which can be placed on the front panel, the LabVIEW version of a graphical user interface (GUI). These items visually represent the real thing and operate in the same manner (Figure 1). Based on these basic data and function types more complicated

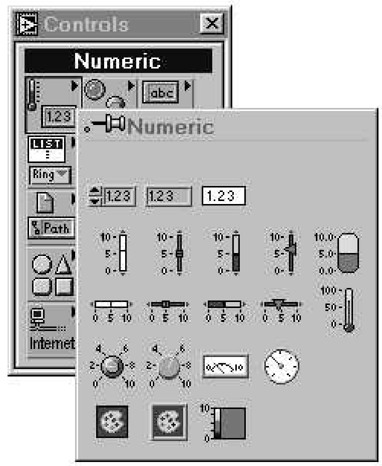

Figure 1: Typical numeric controls and indicators in LabVIEW.

interface items can be constructed. The result is the ability to construct a user interface that mimics real world devices, user interfaces and controls.

It is believed that software can be created in the LabVIEW environment that will help address the visual and active learning styles in thermodynamics courses. In addition, the student's understanding of the physical world, which they bring to class, can be used to facilitate the user interface. The concept of virtual instruments can be extended to thermodynamic components and processes using real world controls and indicators, such as knobs, dials and thermometers. Beyond this use it will be possible to create user interfaces to match real world interfaces. This will allow the software to bolster the "hands-on" active content of the course. The eventual goal is the "construction" of more complex programs such as virtual power plants.

III. Proof-of-Concept Results and Evaluation

To demonstrate and evaluate the potential of the THERMOVIEW concept, a sample program was created for use in thermodynamics courses. The solution and study of a Rankine cycle was selected for the evaluation. The interface was constructed with a temperature versus entropy display for the entire cycle (Figure 2). This allowed students to see changes in the cycle in a more qualitative fashion. A cycle component diagram is also included with key variables indicated next to components. The intent of the program was to facilitate trend analysis of the Rankine cycle. This would allow students to get a better "feel" for how the cycle responds to changes in certain variables. The software was used at the University of Missouri for sections of Engineering Thermodynamics (taken by mechanical, civil, and electrical engineers) and a section of Chemical Engineering Thermodynamics.

Students were asked to take the Felder Inventory of Learning Styles, a pre-assessment (to determine any prior knowledge of the Rankine cycle), and a post-assessment after covering the topic in class. The software was used to verify hand calculations and to work additional problems. By varying parameters the software allowed trend and sensitivity analyses to be performed. This semester's students were also asked to fill out an Attitude Survey concerning the software and its integration into the course. Out of 202 total students, the number of total student participants who turned in all the required information was 93. Based on the Felder

Proceedings of the 2001 American Society for Engineering Education Annual Conference & Exposition

Inventory of Learning Styles results it was determined that there was a definite tendency towards the Active and Visual styles in these students. With the software a slight improvement was seen in the performance indicators for the Rankine cycle material. Based on student surveys and input from the student software assistant the concept material was extremely easy to use. Students were able to use and understand the graphical interfaces with minimal instructions and without prior demonstration. In fact, the software assistant commented that she spent more time assisting with the related use of Excel than the LabVIEW software.

The attitude surveys also provided insights. The course instructors were in agreement that they would not only use the software again but would expand its use in their classes. On the student side, use of the graphical interface was justified and well liked. Some problems did arise, however. Responses from visual learners indicate that they keyed to graphical mistakes in the interface, such as mislabeled units. Comments from several students revealed that the software was being used merely as a solution aid, not an instructional aid. As of December 2000 use of the software and analysis of the assessment data was still ongoing. However, the initial conclusion is that the proof-of-concept material achieved its goals but did not meet all expectations due to the manner in which it was implemented.

IV. Conclusions and Current Work

Based on the proof-of-concept results, research is continuing. Efforts are now proceeding in two areas; further program development and improved pedagogical uses. A more robust programming structure is desired to expand the simulation capabilities. It is anticipated that with sufficient simulation modules this type of material can be developed for a number of courses spanning mechanical, chemical, and nuclear engineering. On the pedagogical side, further work is being devoted to the user interface. It was determined that the interfaces to date were designed with programmatic thoughts in mind rather than pedagogical ones.

The bigger issue to address is how the material is used in class. Other researchers have found that educational software will be used in various and unpredictable ways [9]. The danger with software of this type is that it will only be used for problem solution and will become a "black box" to the students. The choice of a Rankine cycle for the evaluation may have been too simple in retrospect. Solution of problems with more complicated cycles is often prohibitive by hand. This would make the software more useful in the area of trend analysis. By providing key variables throughout the process, the software could also be used by students to check the steps in their work. It is also possible to construct the user interface so that it prompts the student for comparison values thereby serving more as an interactive tutorial. An additional application which is being explored is to create a simulation of campus power plants, complete with realistic control panels. This would allow further instruction to be linked to plant tours and visits. The last use which is anticipated is in the area of design. It is anticipated that software of this format can also be tailored into design problems and projects. Design projects offer advantages in addressing many learning styles and promoting development of cognitive thought processes.

At the time of this writing work was still progressing in each of these areas. The software developed to date is still be tested in classroom settings. In addition, a variant of the software is being proposed for engineering open house purposes. Efforts are underway in preparation for a NSF CCLI Full Development proposal to continue development of this educational software.

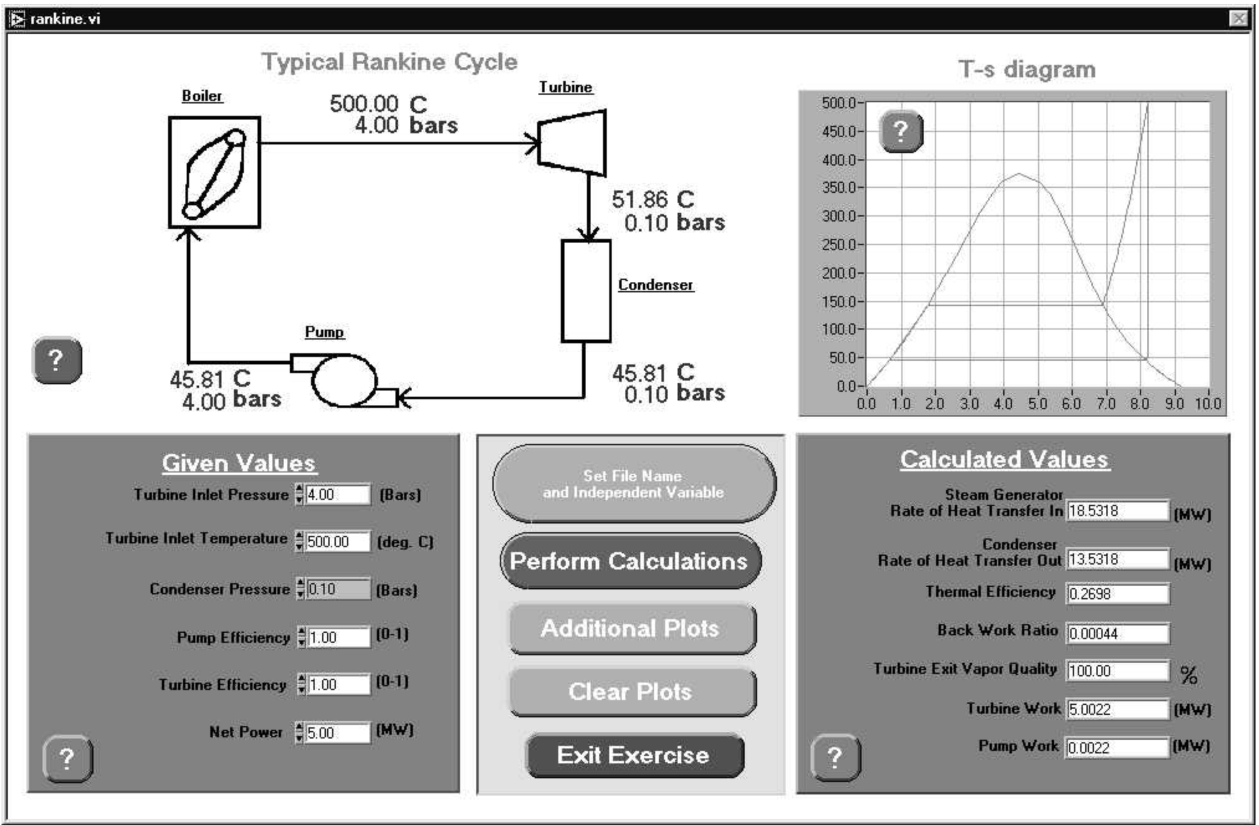

Figure 2: Front panel (GUI) for the proof-of-concept Rankine cycle simulation. This program was used for both mechanical and chemical engineering classes.

References

[1] Felder, R. and Silverman, L., "Learning and Teaching Styles in Engineering Education," Engineering Education, April, pp. 674-681 (1988).

[2] Bandler, R. and Grinder, J., The Structure of Magic, Science and Behavior Books, Inc. (1975).

[3] Reiner, M., Slotta, J., Chi, M., and Resnick, L., “Naïve Physics Reasoning: A Commitment to Substance-Based Conceptions,” Cognition and Instruction, Vol. 18 (2000).

[4] Donovan, M., Bransford, J., and Pellegrino, J., How People Learn: Bridging Research and Practice, National Academy Press (1999).

[5] O’Connell, J., and Scott, T., “Workshop Exercises for Connecting Fundamentals to Equipment in the First Thermodynamics Course,” 2000 ASEE Annual Conference Proceedings, American Society for Engineering Education.

[6] Baker, D., Jones, C. and Liu, M., "ThermoNet: A Web-Based Learning Resource for Engineering Thermodynamics," 2000 ASEE Annual Conference Proceedings, American Society for Engineering Education.

[7] Christie, R. and Trinidad, P., "Visualizing Pedagogical Circuits," 1998 ASEE Annual Conference Proceedings, American Society for Engineering Education.

[8] Tebbe, P. and Weisbrook, C., "A Visual Software Concept for the Thermo-Fluids Discipline," 2000 ASEE Annual Conference Proceedings, American Society for Engineering Education.

[9] Baher, J., "Articulate Virtual Labs in Thermodynamics Education: A Multiple Case Study," Journal of Engineering Education, Vol. 88, No. 4 (1999).

Acknowledgments
Credit is due to the undergraduate and graduate students working on this project at the University of Missouri and at The College of New Jersey. The assistance of the entire project team at the University of Missouri is also appreciated, including the work of Dr. James Laffey and Gayla Neumeyer. This research is supported by the National Science Foundation through grant DUE-9950869.

PATRICK A. TEBBE
Patrick Tebbe is an Assistant Professor of Mechanical Engineering at The College of New Jersey. Patrick teaches undergraduate thermodynamics and thermal sciences laboratories. He received his Ph.D. in Mechanical Engineering from the University of Missouri-Columbia in 1997. Before moving to New Jersey he served as an Adjunct Assistant Professor at Missouri and also pursued a M.S. in Nuclear Engineering.

CHRISTA WEISBROOK
Christa Weisbrook is an Assistant Professor of Mechanical Engineering at the University of Missouri – Columbia as well as the Undergraduate Program Director for the Department of Mechanical Engineering. She received her M.S. from the University of Wisconsin – Madison and her Ph.D. in Mechanical Engineering from the University of Missouri in 1994.

WILLIAM MILLER
William Miller is a Professor of Nuclear Engineering at the University of Missouri – Columbia as well as the Director for the Energy Systems and Resources Center. He received his M.S. from Kansas State University and his Ph.D. from the University of Missouri.

STEPHEN J. LOMBARDO
Stephen Lombardo is an Assistant Professor of Chemical Engineering at the University of Missouri – Columbia. He teaches undergraduate thermodynamics and unit operations laboratories. He received his Ph.D from the University of California – Berkeley.