"Virtual Assembly" – A Web-Based Student Learning Tool for Thermodynamics Concepts Related to Multistaging in Compressors and Turbines

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Abstract **– Simulation and visualization have been used to develop "virtual assembly" as a student learning tool for comprehension and reinforcement of concepts in basic engineering thermodynamics course in undergraduate engineering curriculum. Using a web-based module described in this study, students are able to assemble on a computer screen a multistage compressor or turbine from a number of elemental building blocks or stages. The module is interactive and requires students to input data such as overall compressor ratio, stage efficiency, stage pressure ratio, and compressor inlet temperature and pressure. A computer program embedded in the module calculates total number of stages, and temperature and pressure at exit section of each stage. It also displays visual images of all stages to be assembled, and prompts students to use the clicking and dragging action of computer mouse to assemble elemental compressor stages into a multistage axial compressor. During the assembly process, a temperature-entropy diagram is generated, displaying thermodynamic state of air as it traverses through the compressor. These visual images allow students to explore relationships between overall compressor efficiency, stage efficiency and compressor pressure ratio. The module is assessed by comparing the performance of a "control" group (no exposure to module) with an "experimental" group (using the module) for an identical quiz administrated to both groups. Results described in the paper show improvement in the average score for the "experimental" group over the "control" group.**

Index Terms – Multistage compressor, Simulation, Virtual assembly, Visualization.

INTRODUCTION

Engineering education is transforming rapidly due to paradigm changes in computer and web technologies. Students of the era predating computer and internet revolutions were educated primarily in conventional classroom setting in which professors transmitted course related knowledge and information through lecturing. This teacher-centric approach has been the preferred model for educating engineers during a major part of the 20th century. The teacher-centric educational model, as past experience has shown, can be very effective, especially for small size classes in which instructors are able to maintain effective two-way communication with students. However, emerging societal and technological factors are changing the way engineers will be educated in the twenty-first century. For instance, in many urban institutions engineering lecture classes are becoming large enough in size to preclude effective two-way communication between teachers and students, leading to high drop-out and low retention rates in many engineering programs. Also, the student demographics in many urban institutions is undergoing transformation from mostly four-year full-time student population to a student population that has a much larger proportion of non-traditional students who pursue engineering education on a part-time basis while holding either full-time or part-time jobs. There is also a growing demand from these non-traditional students for delivery of engineering education in anytime-anywhere mode whose inherent flexibility helps them strike a balance between academic pursuits and job related responsibilities. Another interesting characteristic of current students worth noting is the fact that their learning style has also evolved due to their familiarity with computers, internet and videogames. Unlike their counterpart of a generation ago, current students learning style is

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becoming more and more interactive and visual. In order to accommodate computer and internet savvy students it is imperative that computer and internet-based resources be integrated with classroom instruction to enhance and sustain students interest in learning engineering concepts, principles and various aspects of engineering skills.

Factors discussed above have posed both challenges and opportunities to engineering educators who have responded by developing a variety of information technology-based educational tools such as virtual classrooms, video-streaming of courses, virtual laboratories, web-based multi-media educational resources for distance learning to mention a few [1-10]. A recent study commissioned by the National Academy of Engineers (NAE) titled "The Engineer of 2020: Visions of Engineering in the New Century" also recommends integration of technology-based tools in engineering curricula for enhancing student learning [11].

Technology enhanced learning tools are opening new pathways to knowledge and information. They are also slowly transforming engineering education from being teacher-centric to student-centric-a modality in which students are the focal point of learning process. Using unfettered access to web-based resources, students in general and non-traditional students in particular can also learn in anytime-anywhere mode.

PROPOSED PROBLEM AND PEDAGOGY USED FOR SOLVING THE PROBLEM

Proposed Problem:

The present study, funded by the National Science Foundation engineering education grant, describes a web-based interactive learning environment created through application of simulation and visualization software. The main thesis of this work can be stated as follows: "Since current students are more attuned to visualization due to their familiarity with computers and video gaming, they are more likely to use and benefit from web-based modules or other resources for learning provided these modules are interactive, visual and user-friendly. The web-tools once created will constitute an alternate pathway for learning, and will encourage students to explore further the subject matter presented in conventional classroom setting". In the present study a "virtual assembly" sequence is developed as a student learning tool for illuminating advanced and often difficult to understand concepts in undergraduate engineering thermodynamics courses. "Virtual assembly" is a useful methodology for assembling virtual probes and devices into a virtual experiment set-up. We have ushered this technique into the theoretical realm to help students learn concepts related to multistaging in axial compressors and turbines. We contend that student learning can be enhanced by creating visual images of complex thermodynamic devices such as multistage axial compressors and turbines, and allowing students to relate these images to thermodynamic processes on temperature-entropy diagrams. By assembling elemental units or stages for compressors and turbines on a computer screen, students are expected to achieve better understanding of overall performance of assembled (complex) devices in terms of characteristics of elemental stages that are used to build these devices.

Pedagogy Used to Solve the Proposed Problem:

Interactive simulation and visualization are powerful modern technology tools that can facilitate student learning in distributed virtual domain. We have used the pedagogy of "Learning by Doing in Virtual Environments" (LDVE) to develop web-based educational tools for enhancement of student learning. For instance, Dede [12] has used this pedagogy for distance education applications. However, in the current work, "LDVE" pedagogy has been used in conjunction with classroom instruction to enhance student understanding of basic concepts in the first course in engineering thermodynamics. This pedagogy (LDVE) is an extension of the pedagogy of "Learning by Doing" in physical domain to virtual (computer-based) domain. The "LDVE" pedagogy recognizes and incorporates an important tenet of engineering education that holds that students learn better by performing hands on activities which in virtual domain refer to student interactions with a web-based module via a computer keyboard or mouse.

DESCRIPTION OF MODULE STRUCTURE AND ITS FEATURES

A web-based module (www.mem.odu.edu/virtualassembly) has been developed and integrated into the basic engineering thermodynamics (ME311) course in mechanical engineering undergraduate curriculum. The module requires students to perform hands-on activities such as inputting of data, and assembling of elemental stages to build multistage systems etc.

For example, in one case students can input data and build a multistage axial compressor. As shown in Figure1, students input overall compressor pressure ratio, stage pressure ratio (assumed same for all stages), stage compression efficiency (assumed same for all stages), compressor inlet temperature and pressure, and specific heat ratio of chosen flow medium, with air being the default medium.

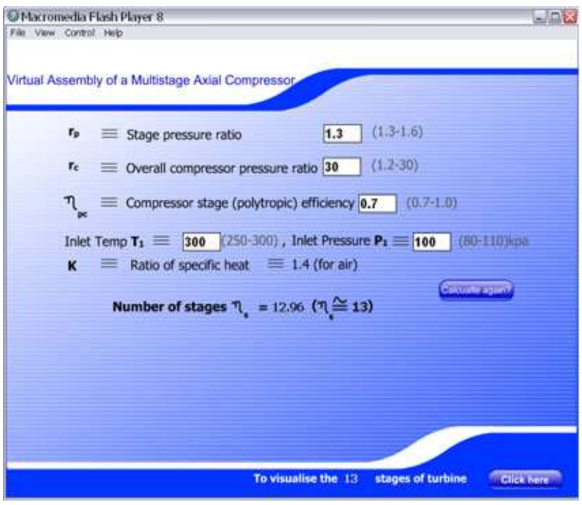

FIGURE 1
INTERACTIVE MENU OF THE COMPRESSOR MODULE (INPUTS AND OUTPUTS)

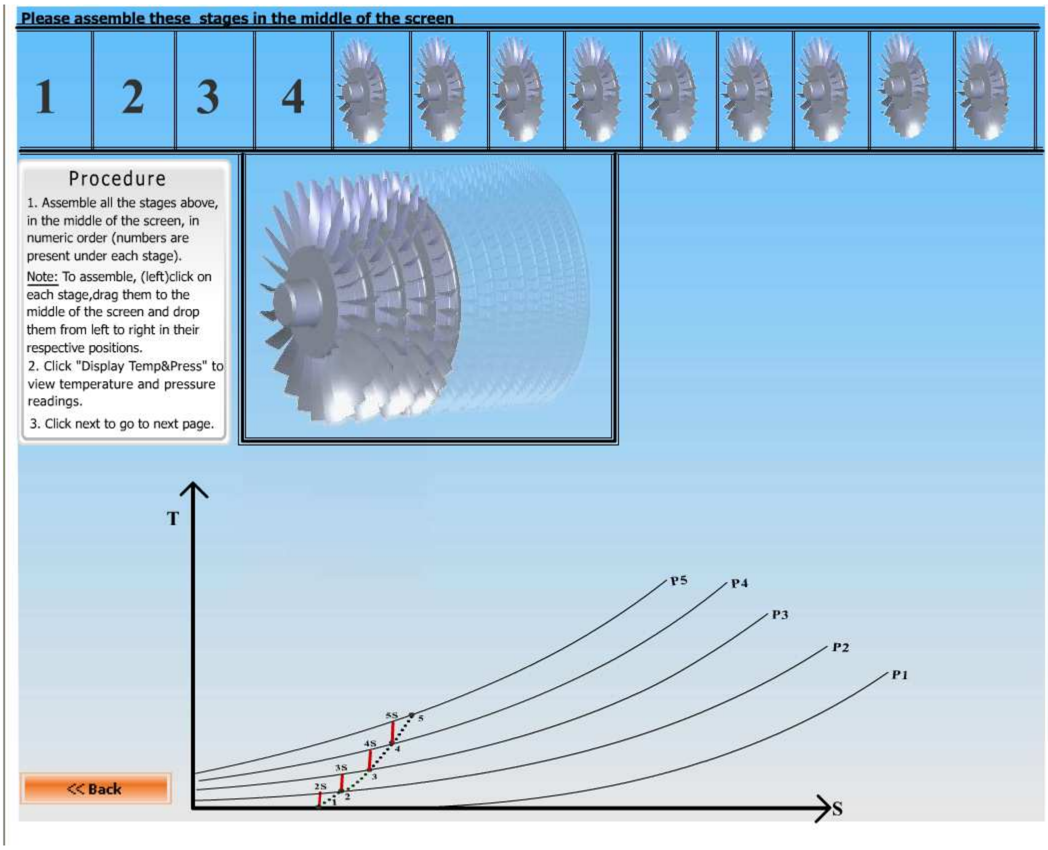

FIGURE 2
VIRTUAL ASSEMBLY MODULE OF A 13-STAGE AXIAL COMPRESSORS

A computer program written in "Flash" Macromedia "Flash" scripting language calculates number of compressor stages, and temperature and pressure at the exit section of each stage. The module also displays visual images of each stage, and prompts students to use the clicking and dragging action of the mouse to assemble individual stages into a multistage axial compressor. As the virtual assembly process continues, a temperature-entropy diagram is created, displaying thermodynamic state of air as it passes through each stage (Figure 2). This figure also shows the virtual assembly in an intermediate state of assembly process when four out of a total of thirteen compressor stages have been assembled. After completion of the virtual assembly process, temperature and pressure values at exit sections of each stage are displayed in a tabular form. The module has the capability of assembling axial compressor with stages ranging from 2 to 13. A similar virtual assembly process can be accomplished for multistage turbines. After completion of the assembly process, students use computer generated (virtual) air temperature and pressure data to determine overall compressor and turbine efficiencies as a function of number of stages and stage efficiency. In order to develop further students understanding of relationship between overall compressor efficiency and overall compressor pressure ratio and compressor stage efficiency, a web-based project was assigned to students who used the "virtual assembly" module to generate virtual data for calculation of overall compressor efficiency. The web project was made part of graded activities in the course to encourage students to use the web module. Students also wrote a project report, detailing their findings concerning interrelationships between multistage compressor performance, and performance parameters characterizing building blocks of the compressor, namely the number of compressor stages. Figure 3 shows results from a typical project, showing the variation of overall compressor efficiency as a function of number stages and stage efficiency. This two part process of generation of virtual data from the module, and its use to calculate (manually) the overall performance parameters such as the compressor efficiency, is a unique feature of this module. Students are spared from performing repeat calculations for a large number of stages. These calculations are performed through the simulation program embedded in the web-based module. Using computer generated results, and relevant governing equations, students calculate manually, the final results concerning overall compressor efficiency. This two-part procedure keeps students active in their interaction with the module. It also addresses effectively a criticism often leveled against web-based modules that input and automatic

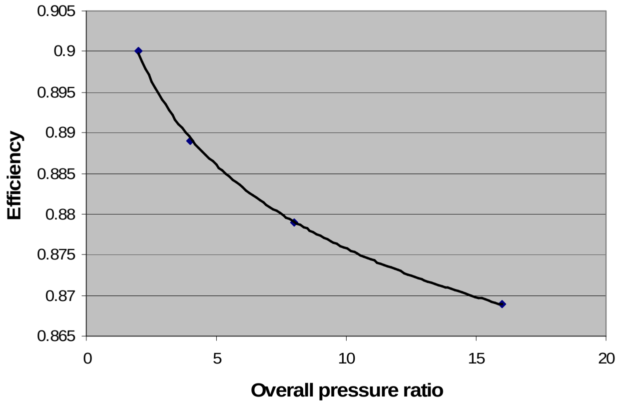

FIGURE 3
OVERALL COMPRESSOR EFFICIENCY VS. PRESSURE RATIO

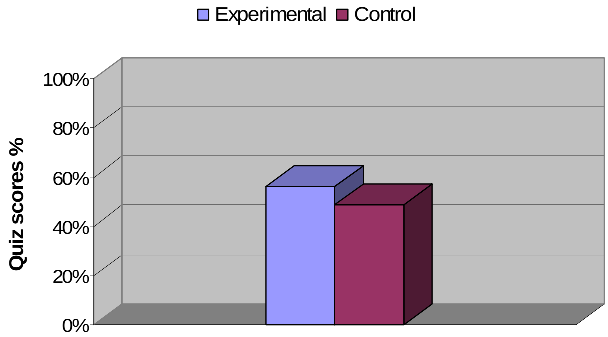

FIGURE 4
COMPARISON OF QUIZ RESULTS FOR BOTH GROUPS

output features of many web-based modules often promotes passivity among students since they often remain oblivious to how the solution is obtained and what governing equations are used to solve the problem.

ASSESSMENT OF THE MODULE

Student learning achieved through the module has been measured by the "Intact-Group Assessment" method [13]. This method compares the performance of a "control" group and an "experimental" group. The "control" group is defined as a population of students who are taught conventionally, without being introduced to the web-based module. The "experimental" group includes those students who have used the web-based module to supplement learning achieved through conventional classroom teaching. Both groups were administered an identical multiple choice quiz that tested them for concepts related to subject matter covered in the web-based module. The entire thermodynamics class taught during summer 2006 semester was used as the "control" group while the entire class taught during fall 2006 semester constituted the experimental group. Figure 4 shows the comparison of quiz results for both groups. It is noted that performance of "experimental" group as measured by average score is the quiz represents about 14 percent improvement over the "control" group average quiz score. This improvement in quiz score, though modest, does point to usefulness and effectiveness of the web based module as a student learning tool. More assessments and detailed statistical analysis are planned as future activities for the module.

CONCLUSIONS

The authors have developed and implemented a web based module for their undergraduate thermodynamics course. This multimedia module uses simulation and visualization to generate a "virtual assembly" sequence to enhance student learning of thermodynamics concepts related to multistaging in axial compressors and turbines. The module has been used in the supplementation mode allowing students to augment their learning over and above the level obtained through conventional classroom setting. Assessment of the module was done by comparing performance of a "control" group (no exposure to module) and an "experimental" group that used the web based module. Based on comparison of average score in an identical quiz given to both groups, one can conclude that "experimental" group on the average performed better than the "control" group. This study demonstrates that the virtual assembly methodology has significant potential as a student learning enhancement tool. More student assessments and statistical analysis of collected data are planned in future to establish the virtual assembly technique on a firmer footing.

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REFERENCES

[1] Whittington, C. D., and Schacter, N., "Building and Testing a Virtual University", *Computers in Education*, Vol. 30, Nos.1,2, 1998, pp. 41-47.

[2] Williamson, C., Bernhard, J. T., and Chamberliin, K., "Perspective on an Internet-based Synchronous Distance Learning Experience", *Journal of Engineering Education*, Vol. 89, No. 1, 2000, pp. 53-61.

[3] Rojas, E. M., "Use of Web-Based Tools to Enhance Collaborative Learning", *Journal of Engineering Education*, Vol. 91, No. 1, 2002, pp. 89-95.

[4] Bourne, J. R., et al., " A Model for On-Line Learning Networks in Engineering Education", *Journal of Engineering Education*, Vol. 85, No. 3, 1996, pp. 256-260.

[5] Latchman, H. A., and Latchman, S. M., "Bringing the Classrooms top Students Everywhere", *Journal of Engineering Education*, Vol. 89, No. 4, 2001, pp. 429-433.

[6] Wallace, D. R., and Mutooni, P., "A Comparative Evaluation of World Wide Web-Based and Classroom Teaching", *Journal of Engineering Education*, Vol. 86, No. 3 1997, pp. 211-219.

[7] Bjorklund, S. A., and Colebeck, C. L., "The View from the Top: Leaders' Perspective on a Decade of Change in Engineering Education", *Journal of Engineering Education*, Vol. 90, No. 1, 2001, pp 13-19.

[8] Hodge, H., Hinton, H. S., and Lightner, m., "Virtual Circuit laboratory", *Journal of Engineering Education*, Vol. 91,No.4, 2002, pp. 507-511.

[9] Chaturvedi, S.K, Bawab, S., Akan, H., and Abdel-Salam, T., "Development of a Methodology to Visualize and conduct a Physical Experiment as a Web-based Virtual Experiment", Proceedings of the Fourth IASTED International Conference on We-Based Education, Grindelwald, Switzerland, February 2005.

[10] Pennfield, Jr. P., and Larson, R. C., "Education Via Advanced Technology", IEEE Transactions on Education, Vol. 39, No. 3, august 1996, pp. 436-443.

[11] National Academy of Engineers, "The Engineer of 2020: Visions of Engineering in the New Century", 2005.

[12] Dede, C., "The Evolution of Distance Education: Emerging Technologies and Distributed Learning", *The American Journal of Distance Education*, Vol. 10, No. 2, 1996.

[13] Tuckman, B. W., "Conducting Educational Research", Harcourt Brace Jovanovich Publishers, Orlando, Florida, 1988.