Thermo-Fluid Curriculum for Engineering Technology: Learning Outcomes and Industry Needs

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Abstract

Engineering technology programs typically distinguish themselves from engineering by emphasizing hands-on training with a focus on engineering applications. Employers expect (mechanical engineering) technology graduates to be capable of working in such areas as manufacturing, maintenance, production, process, and quality.[1] Technology students are also expected to be suitable for positions related to product and laboratory testing. Typically, curriculum involving Thermodynamics, Fluid Mechanics and Heat Transfer (termed together as thermo-fluids) is generally expected to focus on the application of mathematics and physics to get a strong theoretical background that can be used in the design and analysis of thermo-fluid systems. This theoretical content may not be suitable for an engineering technology curriculum. Furthermore, these courses require multiple pre-requisites in calculus and calculus-based physics that are typically not included in an engineering technology program.[2] The current paper proposes a thermodynamics curriculum that may be suitable for a mechanical engineering technology program. The proposed curriculum is aimed at striking a balance between accreditation requirements[3], student expectations and industry needs. The proposed curriculum also incorporates active student engagement. The assessment of some of the learning outcomes from a junior-level course is used to evaluate student performance in one such course. Active feedback has been collected from industry partners in the form of a survey in order to determine the suitable course content in subject matter pertaining to thermo-fluid areas for an engineering technology program. Results of this survey showed that industry puts less value of theoretical knowledge and more value on useful skills relating to instrumentation and test, when hiring technology students.

Introduction

The similarities and distinctions between an engineering and a technology program have been a frequent topic of discussion for the past few decades.[4,5] While it is commonly agreed that a technology program should emphasize application and implementation, there is little consensus on the content of the curriculum that should be included in a technology program. This is particularly relevant for the curriculum in thermo-fluid systems for Mechanical Engineering (ME) and Mechanical Engineering Technology (MET) students. In a typical ME curriculum, thermo-fluid systems involve 10 to 16 credits with courses and laboratories in

Thermodynamics, Heat Transfer, Fluid Dynamics, Turbomachinery, Power Plant Engineering, etc. All these courses make extensive use of mathematics and physics associated with the design and analysis of thermo-fluid systems, requiring calculus and calculus-based physics as pre-requisites. Since many of these calculus and calculus-based physics courses are not required in an MET curriculum, it is important to deliver thermo-fluid curriculum that is relevant to an MET program and at the same time achieves necessary learning outcomes that meet industry needs and prepare students for career opportunities in these areas.

Project-based learning (PBL) is a well-recognized pedagogical approach that is known to strongly motivate students and enhance student learning.[6] Using PBL allows incorporating open-ended projects into the curriculum. These projects could have multiple solutions, and often require students to make trade-offs. This allows the students to apply the concepts learned in the class and thoughtfully consider project requirements and constraints while seeking possible solutions. PBL also allows the instructor to integrate oral and written communication components into the course through required presentations, project reports and team meetings. The application and hands-on components of PBL are especially crucial in a technology program. Also, it is argued in this paper that an integration of PBL in the thermo-fluid curriculum will allow an instructor to emphasize application, implementation and integration, aspects that are considered to be crucial in a technology program.

This paper proposes thermodynamics curriculum that will achieve the necessary learning outcomes while delivering course content that MET students are expected to learn during an undergraduate program. While the specific course title addressed by the current paper is "Thermodynamics and Heat Transfer", the heat transfer portion, as well as the fluid mechanics part, will be addressed in later studies. The content of the thermo-fluid curriculum is challenging for students since they are not able to relate the content to other more familiar courses such as mechanics, strength of materials, etc. Some of the key components of the proposed curriculum include relating the content of thermo-fluid subject matter with other courses, and emphasizing the relationship between the content and commonly used systems such as refrigeration systems, augmented by the use of PBL. The proposed curriculum particularly focuses on project-based learning and acquisition of hands-on skills. Industry needs are also analyzed by using a survey instrument.

Curriculum and Learning Outcomes

The proposed course content and learning outcomes for a thermo-fluids course that may be suitable for technology students is presented in this section. It may be noted that there are a few studies in the existing literature that have made similar attempts to refine the content of a heat transfer module or incorporate more problem-based content. [7,8]

The course content proposed in this paper is similar to the typical curriculum for engineering students, but there is less emphasis on the development of equations and a greater emphasis on the direct relationship of the content with the working of a refrigeration system. It may be noted that another system such as a steam power generation system could be used for reference as well. A refrigeration system has been chosen in this paper due to its easy availability, and since it is relatively inexpensive. Additional emphasis is placed on the measurement and instrumentation of measurable system parameters such as temperature, pressure, and flow rate. This is because a typical technology student is more likely to find these skills more applicable in their employment upon graduation.

For the course, a real vapor compression refrigeration system has been built and instrumented with pressure transducers and thermocouples. Another system has been cut apart to show the internal components of the compressor, expansion valve, heat exchangers, etc. to the students. This exposure is expected to allow the students to have a context for the typical piston/cylinder-type thermodynamics problems, the heat exchanger problems, and flow device problems to a system that they can relate to. This system is shown, diagramed and discussed on the first day of class with all parts of the system related to the chapters in the book, and the laws of thermodynamics.

It is expected that the first three laws of thermodynamics will be easier to understand when they are related to a real-life system instead of abstract theory. For instance, the first law relates the electrical power needed to compress the Freon to the cooling energy one could get out of the Freon. The zeroth-law relates temperature to energy. The tables and ideal gas equations of state relate pressure and specific volume to temperature, and therefore energy. Subsequently, in the context of systems and cycles, the second law is introduced showing that heat has to flow from higher to lower temperature, thus demonstrating that a cycle would not run without a hot and a cold reservoir.

In addition to this roadmap of the thermodynamics course presented above, students are tasked with assignment problems relating to the refrigeration system, so that they can see what will be necessary to solve these problems. This can be done in a team setting, with an emphasis on problem solving skills.

The fundamentals of heat transfer are covered after wrapping up the thermodynamics content. The basics of heat transfer are then covered with a focus on air cooled heat sinks, and electronics cooling, as well as instrumentation required for measuring variables associated with heat transfer. Table 1 shows the complete course content of the course. The thermodynamics content is emphasized in the current study, however the heat transfer content will be taught with a similar methodology. In the short time allocated for the MET students to learn the basics of heat transfer, only the most basic and practical skills can be covered. For example, the topic of conductive heat transfer leads to the guarded heat plate method of conductivity testing, and the concept of a Q-meter (simple device for measuring heat flow). Convection is explained on a very high level, and for conduction, convection, and radiative heat transfer, empirical explanations and associated analogies such as thermal resistance are the focus.

Table 1. Content for Thermodynamics for technology students.

	Content	Student Deliverables
Week 1	Demonstration and description of the components of a VC refrigeration unit.	Diagram of the system with corresponding book chapters labeled on each component.
Week 2	Class meets in teams of 4 to find subsequent assignment problems that relate to the refrigeration system (R-134a compressed in a piston/cylinder). Instruction begins on topics needed to solve the problems. Basic Concepts, Dimensions.	Teams write down what is given in the problems and what needs to be determined. Student chosen teams work outside of class on assignment problems leading up to solving later chapter problems.
Week 3	Basics of energy, First Law, efficiency	Assignment problems.
Week 4	Phases of matter, specifically gasses and liquids.	Assignment problems.
Week 5	Analysis of closed systems.	Assignment including those identified in the first week.
Week 6	Analysis of closed systems (continued). Students work in teams for part of the class to solve problems identified in first week.	Assignment including those identified in the first week.
Week 7	Class meets in teams of 4, to identify problems in the next chapter on flow work, that pertain to components of the refrigeration system (heat exchangers and expansions).	Teams write down what is given in the problems and what needs to be determined. Student chosen teams work outside of class on assignment problems.
Week 8	Analysis of control volumes and flow work.	Assignment problems.
Week 9	Second Law, cycles, and efficiency.	Assignment problems.
Week 10	Entropy and exergy.	Assignment problems.
Week 11	Mechanisms of heat transfer.	Assignment problems.
Week 12	Steady state conduction.	Assignment problems.
Week 13	Transient conduction.	Assignment problems.
Week 14	Convection.	Assignment problems.

Assessment Results and Data Collection

This section presents responses from industry professionals who may hire students with an undergraduate degree in engineering technology.

The industrial advisory board of the department consists of nine industry professionals. Many of these professionals are managers or directors and hire students graduating from the technology program. Seven of the nine advisory board members participated in the survey. The participants were given a five minute background about the purpose of data collection. The survey was conducted in the print format and participants were given 15 minutes to complete the questionnaire.

Participants were requested to respond to the following (eleven questions) in the questionnaire:

1. Technology (ET or MET) students should learn practical skills in a thermodynamics course.
2. Technology (ET or MET) students will greatly benefit from learning about instrumentation, equipment and sensors in their program of study.
3. Technology (ET or MET) students will benefit from learning about design of a test setup involving thermo-fluid systems.
4. Technology (ET or MET) students need to learn about data collection and data processing in their undergraduate program.
5. Usage of thermocouples, RTDs, flow meters, flow channels and wind tunnels should be learnt by technology (ET or MET) students.
6. The focus of thermo-fluid courses for ET or MET students should be on testing and product development instead of analysis.
7. Technology (ET or MET) students should have a theoretical understanding of heat transfer and fluid dynamics.
8. Learning about the application of thermal and fluid systems is important for technology (ET or MET) students.
9. Technology (ET or MET) students should learn practical HVAC skills in their undergraduate program.
10. Technology (ET or MET) students should learn practical power generation skills in their undergraduate program.
11. Technology (ET or MET) students do not need to have a rigorous theoretical background in thermodynamics.

Three open-ended questions were also included in the survey. These questions are as follows:

1. Does your company hire technology graduates in the areas of thermodynamics, thermal systems or fluid systems?
2. What are your expectations from a technology graduate specific to thermodynamics?
3. What are your expectations from a technology graduate specific to fluids and heat transfer?

The purpose of the open-ended questions is to have some qualitative information that can be used to comprehend the responses from the members of the industrial advisory board.

Fig. 1 shows that 71% of the participants strongly agree (Likert scale 1) or agree (Likert scale 2) about the need to incorporate practical skills in a thermodynamics course for technology students.

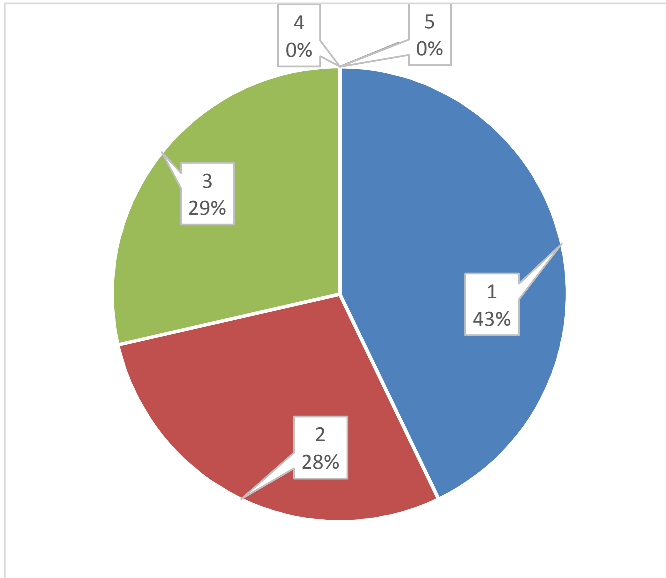

Fig. 1. Survey Response – Question # 1 (Technology students should learn practical skills in a thermodynamics course).

The response to Question # 1 is further reiterated by the response to Question #2. As seen in Fig. 2, 86% either strongly agree (Likert scale 1) or agree (Likert scale 2) with the benefits of incorporating instrumentation, equipment and sensors in the program of study for technology students.

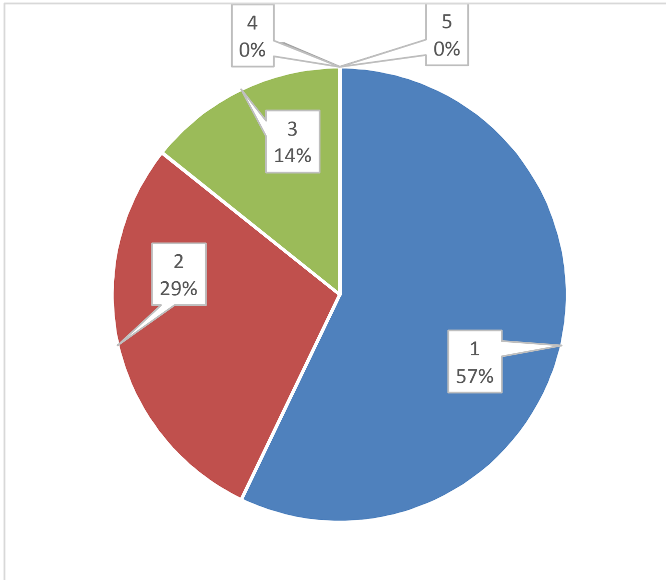

Fig. 2. Survey Response – Question # 2 (Technology students will greatly benefit from learning about instrumentation, equipment and sensors in their program of study).

Fig. 3 shows strong agreement (Likert scale 1) or agreement (Likert scale 2) with the usage of equipment such as thermocouples, flow meters, wind tunnels, etc. in the class (Question # 5), with 71% of the participants agreeing or agreeing strongly.

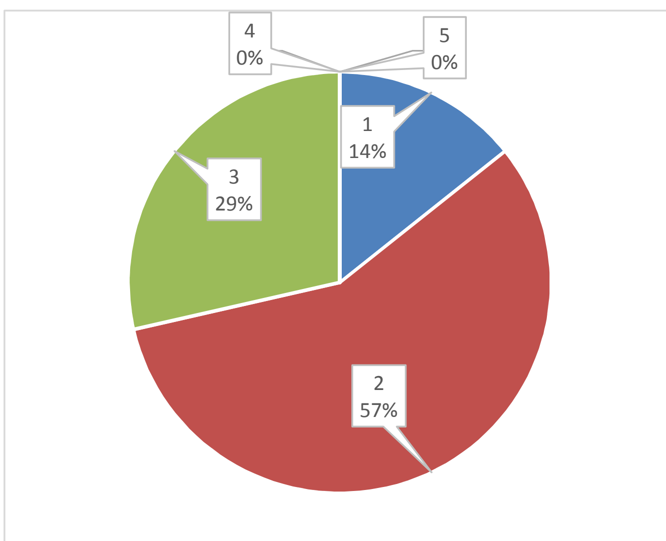

Fig. 3. Survey Response – Question # 5 (Usage of thermocouples, RTDs, flow meters, flow channels and wind tunnels should be learned by technology (ET or MET) students).

A large majority of the participants, 86%, feels that technology students do not need to have a rigorous theoretical background in thermodynamics. This can be seen from the response to Question # 11, shown in Fig. 4.

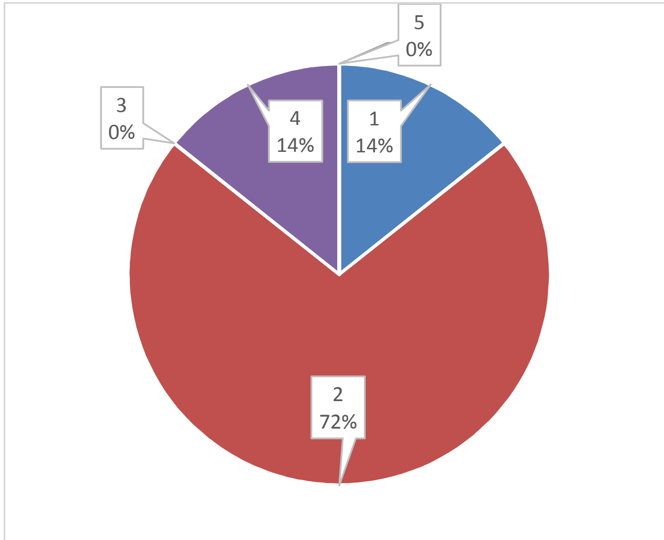

Fig. 4. Survey Response – Question # 11 (Technology students do not need to have a rigorous theoretical background in thermodynamics).

In summary, responses to the questionnaire indicate that the members of the advisory board believe that technology students would greatly benefit from the inclusion of content that involves practical skills in instrumentation, sensors, HVAC, general laboratory, and product testing skills appropriate to thermo-fluids industries. The members of the advisory board also seem to indicate that a rigorous theoretical background in thermodynamics, thermal systems and fluid systems is not necessary for technology students. Some of the responses to open-ended questions include statements such as: 'some familiarity with basic principles of thermal systems is expected', 'technology graduates should have an understanding of state transitions, latent heat, fluid flow', 'students do not need theoretical rigor but an applied understanding'. This is consistent with the curriculum that is being proposed in this paper as a first course in thermo-fluids for technology students.

4. Discussion and Conclusions

From the survey responses, it is clear that regional industry representatives look for more practical skills in graduates from a Technology program. They place less value on a theoretical understanding of thermodynamic principles. The responses indicate that Technology graduates would be performing functions related to test and measurement, rather than design. This not only supports the authors' claim that a Technology-centric course in thermodynamics should be based on commonly used and familiar systems, such as HVAC, but also supports inclusion of active learning techniques that develop useable skills. These skills could include instrumentation techniques, and test methodologies which would also give students hands-on insight into components under more theoretical investigation.

Future work will include implementation of the curriculum, and assessment by collecting test scores and student assessment data, and comparing to old curriculum.

References

[1] Brunhaver, S., Gillmartin, S. K., Grau, M. M., Sheppard, S., Chen, H. L., 2013, "Not All the Same: A Look at Early Career Engineers Employed in Different Sub-Occupations," Paper # 6119, *Proceedings of the ASEE Annual Conference & Exposition, Atlanta, GA*.

[2] Dearing, B., Daugherty, M., 2004, "Delivering Engineering Content in Technology Education," The Technology Teacher: *The Voice of Technology Education, 64*, pp. 8-11.

[3] ABET, Engineering Accreditation Commission, 2010, "*Criteria for Accrediting Engineering Programs*," ABET Inc, Baltimore, MD.

[4] Mott, R. L., Neff, G. P., Stratton, M. J., Summers, D. C. S., 2002, "Future directions for mechanical, manufacturing, and industrial engineering technology programs," *Journal of Engineering Technology, 19*, pp. 8-15.

[5] Froyd, J. E., Wankat, P. C., Smith, K. A., 2012, "Five Major Shifts in 100 Years of Engineering Education," *Proceedings Of The IEEE, 100*, pp. 1344-1360.

[6] Bender, W. N., 2012, "*Project-Based Learning: Differentiating Instruction for the 21st Century*," Corwin Press.

[7] Anderson, J. C., Cooper, H. L., 2003, "Development of a Heat Transfer Module for Design Courses," Session 3648, *Proceedings of the ASEE Annual Conference & Exposition*.

[8] Craft, E. L., Mack, L. G., 2001, "Developing and Implementing an Integrated, Problem-Based Engineering Technology Curriculum in an American Technical College System," *Community College Journal of Research and Practice, 25*, pp. 425-439.

Biographies

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