Session 2266

A Thermal-Fluid Science Course for EE and CE Students

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Abstract

Mechanical Engineering (ME) faculty members are often called upon to teach service courses to non-ME majors. In courses such as statics and strength of materials, existing ME courses work well to satisfy student needs from other departments. However, the traditional ME thermal-fluid science courses are often not a good match for the non-major. Special courses are then used to present the material to these students.

This paper documents the creation of such a hybrid Thermal-Fluid Sciences course at Western Kentucky University (WKU) that has been developed to satisfy the needs of Civil (CE) and Electrical (EE) Engineering students. The four-hour course offered each fall presents a blend of thermodynamics, heat transfer, and fluid mechanics.

The course has been offered twice, and is still evolving. The paper also presents some of the struggles to balance a solid engineering science experience with a perceived need for coverage for the FE exam materials only. In addition, lessons learned with respect to various student-learning styles in the course are shared. The results of faculty self-assessment and student course assessment are presented and compared.

1. Introduction

In the traditional ME curriculum, the study of thermal fluid sciences is categorized into three major subject areas: thermodynamics, heat transfer and fluid mechanics, where they are commonly taught as four separate three credit hour courses over three or more semesters. This approach is administratively convenient but not necessarily pedagogically effective since it creates the false impression among the students that the design of a thermal system is simply a combination of these loosely related disciplines and requires student integration of these difficult subjects. To address these issues, the integration of the traditional thermal fluid sciences curriculum has been implemented at numerous institutions and discussed in the literature.[1,2] This integration typically consolidates the traditional topic-specific courses into a two course sequences each consisting of four credit hours, often representing a reduction of credit hours in the curriculum. More importantly, it provides vertical integration of the thermal fluid sciences curriculum so the student does not receive these experiences as loosely related topics. Thermal

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fluid system design can be more easily incorporated into the curriculum as a result of this integration.

Non-mechanical engineering majors at institutions with the traditional ME thermal sciences curriculum are faced with a challenge of gaining some understanding of the thermal fluid sciences since a four course sequence for them is typically not required or feasible within the constraints of their respective curricula. To satisfy their needs, these curricula often will allow the CE and EE majors to select a two-course sequence, six credit hours, which can either consist of three credit hour fluid mechanics, thermodynamics, fluid mechanics or heat transfer courses for CE and EE majors, respectively. Either of these choices is potentially inadequate and have the same shortcomings experienced by the ME major in their traditional four-course sequence. A review of the literature was inconclusive regarding this inadequacy.

To alleviate this curriculum deficiency, a Thermal-Fluid Sciences course (ME 362) was developed in fall 2002 at WKU to address and satisfy the needs of CE and EE students. CE and EE students are required to take in this course in the fall semester of their junior or senior year (5^{th} semester for CE students; 7^{th} semester for EE students) to expose the students to the language and application of the engineering sciences of thermodynamics, fluid mechanics, and heat transfer. This course is a four credit hour experience, which is intended to prepare the student tactically for the Fundamentals of Engineering examination and strategically for professional practice and interaction on cross disciplinary teams that might include these aspects.

This paper documents the creation of such a hybrid course. Unlike the two-course sequence integration described above for ME majors and their associated curriculum, this course is a four credit hour course offered each fall, and presents a blend of thermodynamics, heat transfer, and fluid mechanics. The course has been offered twice, and is still in the process of evolving. The paper also presents some of the struggles to balance the need for a solid engineering science experience with a perceived need for coverage for the FE exam. In addition, lessons learned with respect to various student-learning styles in the course are shared. The results of faculty self-assessment and student course assessment are presented and compared.

2. Course Description and Structure

ME 362 was developed in fall 2002 to address and satisfy the needs of CE and EE students at WKU. Coverage of thermal fluid sciences at other institutions is often handled by offering traditional ME courses in thermodynamics, fluid mechanics and heat transfer to non mechanical engineering majors. The advantage of this approach is the multi disciplinary learning environment created; the disadvantages are the credit hours required, which can consists of either 2 or possibly 3 three credit hour courses, and the subject matter depth, which is possibly not needed by this student audience.

In ME 362, students are taught the fundamental aspects of thermodynamics; fluid mechanics and heat transfer as applied to engineering practice. Emphasis is placed on the conservation laws (Mass, Momentum, and Energy), properties of materials/substances and applications of the first and second laws of thermodynamics. The overall goal is to teach the students how to recognize categories of thermal-fluid problems and correctly use engineering principles to approach and solve problems. The course is also intended to develop and stimulate independent problem solving skills applied to complex engineering problems, investigation of thermodynamics, fluid mechanics and heat transfer principles, and effective communication of multidisciplinary engineering work. To address the specific needs of the non-mechanical students, the following student outcomes were developed in concert with civil and electrical engineering faculty:

1. Explain the terminology and principles of thermodynamics, fluid mechanics and heat transfer.
2. Apply equations of state for pure substances.
3. Recognize and apply appropriate conservation equations to analyze thermodynamic, fluid flow and heat transfer problems.
4. Use empirical data in the form of tables and figures to solve open-ended problems.
5. Analyze the performance of typical Gas and Vapor Power and Refrigeration Cycles.
6. Explain the statements of the second law of thermodynamics and use the second law of thermodynamics to predict system efficiency.
7. Analyze forces and pressures for static fluid problems.
8. Analyze the fluid velocity profile and pressure drop for laminar and turbulent internal pipe flow.

The above course outcomes support both CE and EE program outcomes and ABET Criterion 3 a, d, e, and k.[3] To meet these outcomes, a four credit hour course was developed with the topical content as outlined in Appendix A. Major topical areas included: Introduction to Basic Concepts, The First Law of Thermodynamics, The Second Law of Thermodynamics, Gas and Vapor Power Cycles and Vapor Compression Cycles and Introduction to Fluid Mechanics. Given the expansive topical content and the desire to minimize student financial impact, a single textbook was sought to support this topical coverage. A single textbook was identified: Fundamentals of Thermal-Fluid Sciences by Y.A. Cengel and R.H. Turner[4], which met the course and student needs and covered these topical areas in a coherent manner.

The course was scheduled to meet four times a week for fifty minutes during a fifteen-week semester. A typical course lecture outline is shown in Appendix B, which details approximately fifty class periods of instruction, four class periods for test preparation and review, four in-class tests, and one class for course assessment and final examination preparation and review. In addition to the formally scheduled class periods, optional problem sessions were held during selective weeks, typically prior to a test or examination. In the course lecture outline, the instructional class periods and their topical coverage are also mapped into the appropriate chapter and section from the textbook. In the fall 2003 offering, the textbook was supplemented with video clips, particularly in the fluid mechanics subject areas, and with practical application examples of various thermal systems such as a coal fired steam power plants (Rankine Cycle), an on demand domestic water heater (Heat Exchangers), a TRANE vapor compression chiller (Vapor Compression Refrigeration) and GE turbojet and turboprop engines (Brayton Cycle).

3. Course Assessment and Lessons Learned

Course assessment is an integral part of providing a quality education that endeavors to continuously improve instruction and ensuring that the appropriate program outcomes are being met through the course. Assessment is a different than evaluation. In evaluation, the student assesses how well the instructor delivered the content to the students; while in assessment, the students and instructor assess how well the goals of the course were achieved in terms of student learning and the student's ability to apply the learned skills and knowledge.

The students used the student self-assessment survey given in Appendix C to determine the success of the course in enabling them to achieve the course outcomes, with a 0 indicating no mastery and 10 very proficient. The course goals are to provide students with initial fundamental experiences in the stated outcomes and a level of competence with these outcomes. The course outcomes reflect intended exposure to the appropriate terminology and principles for further study, establishment of the problem solving methodologies, and extension beyond the course materials via open-ended problem resolution. The instructor assessed student performance on these outcomes via student grades on four one-hour in-class tests and on the final two-hour exam, which have been matched with the course outcomes. A target score of 7.0 for all outcomes is based on the grading methodology. The results of the student survey instrument and the course grade based assessment as performed by the instructor of the course outcomes are shown in Figures 1 and 2 for fall 2002 and 2003, respectively. The results indicate that student performance, assessed by the instructor and by the student self-assessment survey, achieved these course outcome targets.

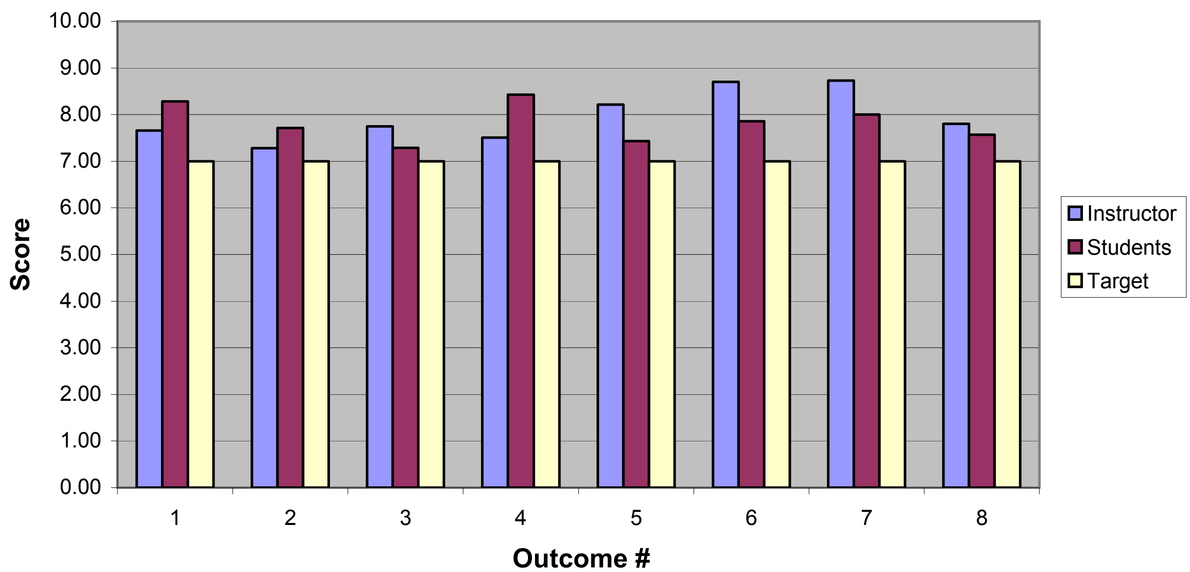

Figure 1: ME 362 Course Outcomes Assessment for Fall 2002

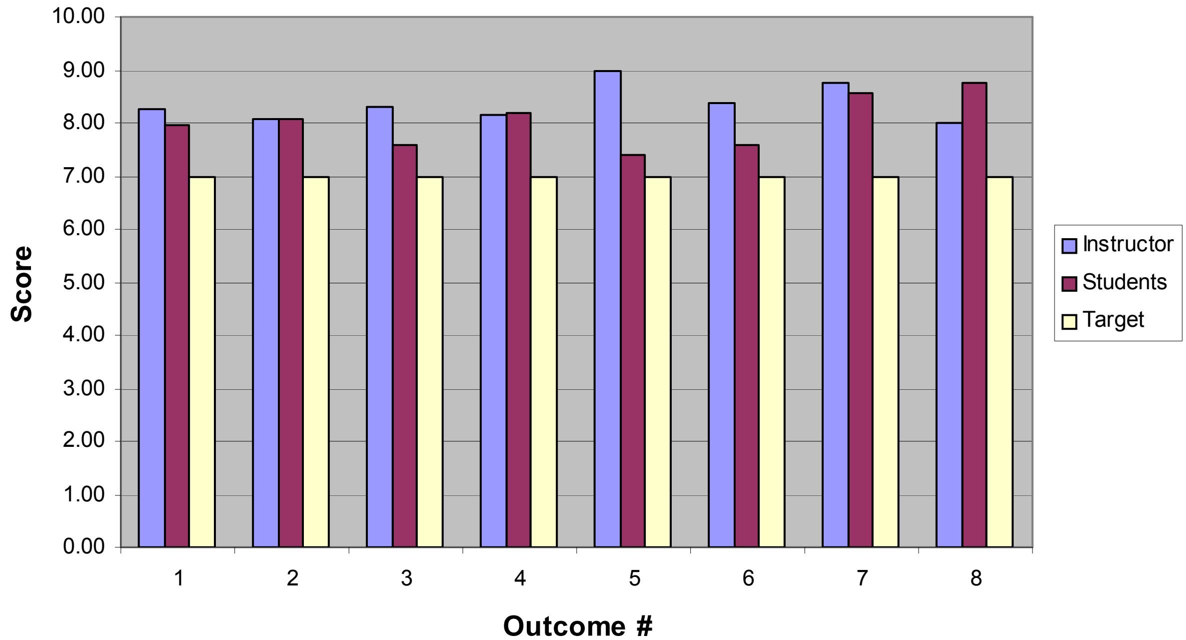

Figure 2: ME 362 Course Outcomes Assessment for Fall 2003

The engineering programs at WKU are new, with the initial cohorts of junior and senior students smaller than the freshmen and sophomores. Although intended for both CE and EE students, the first student cohort in fall 2002 consisted exclusively of CE students, and the majority of the second student cohort was also from the CE discipline, 16 out of 22. The CE (fall 2002) and EE (fall 2003) student cohorts represent the first graduating classes of the new engineering program at WKU. Students comments on "Do you have suggestions to improve the accomplishment of course outcomes?", which was incorrectly interpreted by numerous students as "Do you have any suggestions to improve … the course?", indicated improvement could be achieved by an alternative distribution of topical content, less thermodynamics and more fluid mechanics. Given the disproportionate population of CE students in both course offerings to date, the comments on alternative topical distribution are considered biased and potentially ignore the needs of a smaller EE student population.

A measure of the appropriateness of the topical content and distribution of the course was identified in the fall 2003. The current topical content and distribution apparently met the needs of the first CE student cohort of students as all four students successfully passed the Fundamentals of Engineering examination, which has a typical composition of approximately 10-15% in the thermal fluids discipline areas. Therefore, the current topical and distribution content will be unaltered until additional collaboration of student success or failure can be obtained. Fundamentals of Engineering data on student performance on specific thermal fluids questions was not available at this time.

Any quantitative comparison of the outcome assessments from the two offerings is difficult given the limited data and biased population and its size. A qualitative comparison indicates an improvement in six outcomes from year to year based on faculty grade based assessment. This improvement is attributed to incorporating visual and active learning exercises in the fall 2003 offering, based on techniques learned at the National Effectiveness Teaching Institute Workshop.[5] Student suggestions on how to improve the accomplishment of course outcomes also reflect this modification as the general consensus in fall 2002 was for the inclusion of more worked examples during the in-class periods; while, the fall 2003 student suggestions were minimal in this area with one very insightful student comment on example problem structure – "let the class do the algebra, if we can't do it by now, we need to learn". Blackboard™ was also used extensively in the fall 2003 offering, which enhanced the learning experience by facilitating information exchange between the instructor and students.

4. Summary

An integrated thermal fluids sciences course, ME 362: Thermal-Fluid Sciences, for non-mechanical engineering majors has been developed and demonstrated to meet the tactical needs of CE and EE students. This course, unlike numerous integrated ME major thermal fluid courses, is only four credit hours, which significantly constrains material coverage. Course outcomes were developed in concert with CE and EE faculty to support the CE and EE program outcomes and ABET Criterion 3 a, d, e, and k.

These course outcomes were assessed by instructor grade based assessment and a student self-assessment survey. The outcomes assessment indicated that student performance targets were met. In fall 2003, four CE students, who were in the first cohort, passed the Fundamentals of Engineering Examination (FE). These students had attended and passed the fall 2002 offering of ME 362. A qualitative assessment of the subject area results for both morning and afternoon sessions of the FE in Fluid Mechanics and Thermodynamics indicated that these four students performed significantly better than their peers at the national level in these two subject areas. These results further validate the course outcome assessment.

Based on techniques outlined at the 2003 National Effectiveness Teaching Institute Workshop, course deployment in fall 2003 was altered slightly from the fall 2002 approach, and the course outcomes assessment indicated a more effective learning environment. Alternative deployment consisted of incorporating visual and higher-level overview of thermodynamic systems and fluids phenomena, and of actively engaging students through worked example problems by instructor, individual students and student groups.

Bibliography

1. C. Shih and F. Alvi, "An Integrated Thermal and Fluids Curriculum," Proceedings of the 2000 American Society for Engineering Education Annual Conference & Exposition.
2. R.N. Smith, D.A. Kaminski, M.K. Jensen and A. Hirsa, "Development of an Integrated Thermal-Fluid Engineering Curriculum," Proceedings of the 2000 American Society for Engineering Education Annual Conference & Exposition.
3. 2004-05 Engineering Criteria, Accreditation Board for Engineering and Technology, Baltimore. (http://www.abet.org/criteria.html)
4. Y.A. Cengel and R.H. Turner, Fundamentals of Thermal-Fluid Sciences, McGraw Hill, 2001.
5. R. Brent, R.M. Felder and J.E. Stice, National Effective Teaching Institute (NETI) Workshop, 2003 Annual Conference of the American Society of Engineering Education.

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Appendix A: ME 362 Course Topical Outline

Topical Outline for ME 362	% of time spent
Introduction to Basic Concepts	12.5%
The First Law of Thermodynamics	12.5%
The Second Law of Thermodynamics	20%
Gas and Vapor Power Cycles and Vapor Compression Cycles	20%
Introduction to Fluid Mechanics	35%

Introduction to Basic Concepts — 12.5%

- Thermodynamics
  - Processes & Cycles, the State Postulate, Zeroth Law
  - Properties of Pure Substances
  - Property Tables and Equations of State
  - Internal Energy, Enthalpy and Specific Heats
- Fluid Mechanics
  - Pressure, Manometer and Pressure Measurement
- Heat Transfer
  - Mechanisms of Heat Transfer
  - Conduction, Convection and Radiation Heat Transfer Governing Equations (One Dimensional and Steady State)

The First Law of Thermodynamics — 12.5%

- Heat Transfer and Work
- First Law - Closed Systems
- First Law - Steady flow processes and devices - Open systems
- First Law - Unsteady flow processes - Open systems

The Second Law of Thermodynamics — 20%

- Heat engines, Perpetual Motion Machines, Reversible and Irreversible Processes
- The Carnot Principles
- Carnot Heat Engine, Refrigerators and Heat pumps
- Entropy Changes and Balance
- Problems Involving Entropy

Gas and Vapor Power Cycles and Vapor Compression Cycles — 20%

- Otto, Diesel and Brayton Cycles
- Brayton Cycles with Regeneration, Intercooling and Multistage Compression
- Rankine Cycle and Improvements
- Reheat Rankine and Regenerative Rankine Cycles
- Second Law Analysis of Power Cycles

Introduction to Fluid Mechanics — 35%

- Fluid Properties and Velocity Measurements (Manometer Review)
- Fluid Statics on Plane and Curved Surfaces
- Integral Conservation Equations – Energy (Bernoulli), Momentum and Mass
- Flow in Pipes and Networks, Losses and Pump Characterization

Appendix B: ME 362 Course Lecture Outline

Lecture	Chapter / Sections*	Topics
1	1-1 to 1-5	Introduction to Thermal-Fluid Science; Thermodynamics, Heat Transfer and Fluid Mechanics
2	1-6 to 1-10	Closed and Open Systems; Properties; Conservation of Mass
3	2-1 to 2-5	Basic Concepts of Thermodynamics; Processes/Cycles; State Postulate; Temperature and Pressure
4	2-5 to 2-8	Pressure; Manometer; Barometer
5	3-1 to 3-6	Properties of Pure Substances; Property Tables
5	3-6 to 3-11	Property Tables; Equations of State
6	4–1 & 14-1 to 14–3	Mechanisms of Heat Transfer; Conduction; Thermal Conductivity
7	14-3 to 14-4	Thermal Conductivity; Convection; Radiation; Mixed Modes
8	4–2 to 4–3	Energy Transfer: Heat, Work, Mass
9	4-3 to 4-6	Energy Transfer Continued
10		Problem Session/Review for TEST 1
11		TEST 1
12	5–1	The First law of Thermodynamics
13	5-2	Energy Balance for Closed Systems
14	5–3 to –4	Steady Flow Processes and Devices
15	5-5	Energy Balance for Unsteady Flow Processes
16	6–1 to 6–2	The Second Law of Thermodynamics
17	6-3 to 6-5	Heat Engines, Refrigerators and Heat Pumps
18	6–6 to 6-8	Perpetual motion machines; Reversible and Irreversible Processes; Carnot Cycle
19	6-8 to 6-10	Carnot Cycle and Principles; Thermodynamic Temperature Scale
20	6-11 to 6-13	Carnot Heat Engine; Carnot Refrigerator and Heat Pump
21	7–1 to 7-3	Entropy Balance; Clausius Inequality
22	7-3 to 7-6	Entropy Change of Pure Substances; Isentropic Processes
23	7–7 to 7-8	Entropy Changes
24	7-9 to 7-10	Reversible Work; Problems Involving Entropy
25	7-11	Problems Involving Entropy
26		Problem Session/Review for TEST 2
27		TEST 2
28	8-1 to 8-4	Gas Power Cycles
29	8–4 to 8–5	Otto Cycle
30	8-5 to 8-6	Diesel Cycle
31	8–7	Brayton Cycles
32	8-8	Brayton Cycles
33	8–9 to 8–10	Vapor Power Cycles; Rankine Cycles
34	8-10 to 8-	Rankine Cycles

	13	
35	8–14 to –16	Refrigeration and Heat Pump Cycles
36	8-17 to 8-19	Vapor Compression Cycles
37		Problem Session/Review for TEST 3
38		TEST 3
40	9–1 to 9–3	Introduction to Fluid Mechanics; Behavior; History
41	9-4 to 9-5	Properties; Types of Problems
42	10–1	Fluid Statics; Introduction
43	10-2	Forces on Plane Surfaces
44	10-3	Forces on Curved Surfaces
45	10-4	Buoyancy and Stability
46	11–1 to –4	Energy and Bernoulli Equations
47	11-5	Reynolds Transport Theorem
48	11-5; 1-10	Reynolds Transport Theorem; Review Conservation of Mass
49	11–6 to –7	Linear Momentum Equations
50		Fluid Energy and Momentum Problems
51	12-1 - 2	Flow in Pipes; Laminar and Turbulent Flow
52	12-3	Fully Developed Laminar Flow in Pipes
53	12-4	Fully Developed Turbulent Flow in Pipes
54	12-5	Minor Losses; Piping Networks
55	12-6	Piping Networks; Pump Selection
56		Applications; Problem Session; Questions
57		Problem Session/Review for TEST 4
58		TEST 4
59		Course Assessment; Review for Final Examination

Appendix C: ME 362 Student Self-Assessment Survey

Student Self-Assessment Survey

Course assessment is an integral part of providing a quality education that endeavors to continuously improve instruction in all the courses. Assessment is a little different than evaluation. In evaluation, we are trying to gauge how well the instructor delivered the content to the students, while in assessment, we are trying to gauge how well we achieved our goals in terms of student learning and his/her ability to apply the learned skills and knowledge.

Course: ME362 Thermal Fluid Sciences **Semester:**

Please answer the following questions:

A. Review the course outcomes listed below and state if the course **did or did not** meet the course outcomes using a scale of 0 (can't do at all) to 10 (very comfortable doing). Please **explain why** it did or did not accomplish the outcomes.

1. Explain the terminology and principles of thermodynamics, fluid mechanics and heat transfer. Score: ___________
2. Apply equations of state for pure substances. Score: __________
3. Recognize and apply appropriate conservation equations to analyze thermodynamic, fluid flow and heat transfer problems. Score: __________
4. Use empirical data in the form of tables and figures to solve open-ended problems. Score: _______
5. Analyze the performance of typical Gas and Vapor Power and Refrigeration Cycles. Score: _______
6. Explain the statements of the second law of thermodynamics and use the second law of thermodynamics to predict system efficiency. Score: __________
7. Analyze forces and pressures for static fluid problems. Score: _________
8. Analyze the fluid velocity profile and pressure drop for laminar and turbulent internal pipe flow. Score: _________

B. **GIVEN A REASONABLE AMOUNT OF TIME**, do you feel comfortable in approaching a general thermal fluids problem where you must select the most appropriate solution technique, and then successfully apply that technique? Explain your response.

C. Do you have suggestions to improve the accomplishment of course outcomes?