AC 2007-1995: ENHANCING LIFELONG LEARNING AND COMMUNICATION ABILITIES THROUGH A UNIQUE SERIES OF PROJECTS IN THERMODYNAMICS

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Enhancing Life-Long Learning and Communication Abilities through a Unique Series of Projects in Thermodynamics

Abstract

Mechanical engineering courses in Thermodynamics typically provide a detailed treatment of the first and second laws of thermodynamics from a classical viewpoint in order to prepare students for subsequent courses and ultimately, engineering practice. Therefore, thermodynamics courses aim to strengthen a student's theoretical base and improve analytical skills while focusing on the relevant and timely subject matter of how energy transfer in the form of heat is converted to energy transfer in the form of work. For many students in a thermodynamics class, this is their first opportunity to gain an understanding of how various cycles' operate and how these same cycles can be analyzed, evaluated, and assessed. A certain level of excitement and enthusiasm can be associated with this new found insight and this paper presents two projects which have been designed to prolong and strengthen students' interest in areas related to thermodynamics. In 2001, the projects were introduced into thermodynamics courses and over the past five years, each has been refined through an assessment process in order to improve student learning while achieving intended learning objectives. The first is an individual project within Thermodynamics which requires the student to critically read a technical book (selected by student and approved by professor), technically review the book in written form, and orally present results to the class in an informal setting. The second is a team project within Advanced Thermodynamics which requires student teams to create and present a fifteen to thirty minute long presentation/demonstration for a non-technical audience of their choice (pending professor approval). The content of the presentation must strongly relate to Thermodynamics and have direct relevance to the audience. Past student teams have presented to a variety of audiences ranging from college level liberal arts classes to middle and high school science, math, and technology classes.

This paper includes an overview of both projects in their current forms; results of project assessment, including samples of student feedback, which have been collected and analyzed over the past five years; the strategy used during department-level assessment to support outcomes related to life-long learning, communication, and team work abilities; experience gained through translation of projects to other courses; and future plans for project refinement.

I. Introduction

Rochester Institute of Technology (RIT) has one of the oldest cooperative education programs in the country and therefore RIT firmly believes in learning through doing. The RIT Mechanical Engineering Department offers an Accreditation Board for Engineering and Technology (ABET) accredited degree in mechanical engineering (ME). Each fall, approximately 165 entering first year students select mechanical engineering as a major. All ME majors enroll in Thermodynamics (ME 413) during their second or third years while a subset enrolls in Advanced

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Thermodynamics (ME680) during their fourth or fifth years. Like their peer institutions, RIT has the desire and requirement to improve curriculum structure, integration, and assessment. ME 413 and 680 form a progression in course work into the study of Thermodynamics and, therefore, the courses are carefully integrated. This integration is achieved through a course assessment process conducted by the faculty leads from both courses.

The goal of Thermodynamics is to provide students with practical and relevant engineering science background in thermodynamics. The course also provides the groundwork for subsequent courses in engineering sciences and advanced energy topics such as ME 680. ME 413 is designed to provide a solid foundation in classical thermodynamics through the study of three broad topical areas including preliminary topics, methods and tools of analysis, and relevant applications. The topics covered include definitions, pure substances, ideal equation of state, conservation of mass and energy, and the second law as shown on Table 1. Table 2 lists the course grading plan. In order to enhance the student's learning several application related areas are studied in detail including steam power plants, air standard cycles, emissions, and vapor compression refrigeration systems. The course is further augmented by a project which involves an individual-based technical book review and discussion. The *technical book review* project is highlighted in subsequent sections of this paper.

Table 1. Summary of Topics Explored in Thermodynamics (ME 413)

Topical Areas	Lessons
Exams	3
Introductory Concepts	3
Properties of Pure Substances, Vapor Dome, Ideal Gas Law	2
Internal Energy, Enthalpy, and Specific Heat for Ideal Gases	2
Conservation of Energy Principles and Applications	4
Introductory Concepts of the Second Law	1
The Carnot Cycle and Carnot Principles	1
Entropy the Property and Entropy Change for a Pure Substance	1
The Increase in Entropy Principle and the Second Law for Closed Systems	2
Isentropic Relations and Efficiencies	2
Applications of the First and Second Law of Thermodynamics	2
Ideal Rankine/Steam Vapor Power Cycle	4
Internal Combustion Engines and The Air-Standard Otto & Diesel Cycles	2
Environmental Impact	1
Cycle Reviews	2
Gas Turbine Engines and the Brayton Cycle	2
Jet Propulsion Cycles: Actual and Ideal	2
Vapor Compression Refrigeration Cycles	3
Project Discussions	1
TOTAL	40

Because ME 413 is one quarter long (10 weeks of instruction including 40 lessons, each with 50 minute duration), there are certain topics that are not included due to time limitations. Some of the more notable omissions include exergy, transient systems, thermodynamic property relations, chemical reactions, and phase equilibrium, and thermodynamics of high-speed gas flow [1].

Table 2. Grading Plan for Thermodynamics (ME 413)

REQUIREMENT	DATE	POINT VALUE	PERCENTAGE
Homework/Quizzes		225	22.5%
Exam 1	***22 September***	125	12.5%
Exam 2	***10 October***	125	12.5%
Exam 3	***26 October***	125	12.5%
Project	***Per project admin. memo***	150	15%
Cumulative Final	***Exam Week***	250	25%
TOTAL		**1000**	**100.0%**

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Several of the topics omitted in ME 413 due to lack of course time are studied within Advanced Thermodynamics (ME 680). The two courses share a common textbook [2]. However, unlike ME 413, ME 680 is not a required core course within the mechanical engineering curriculum and typically has an audience of approximately twenty mechanical engineering students in either their fourth or fifth years of study.

Table 3. Summary of Topical Coverage in Advanced Thermodynamics (ME 680)

Topical Areas	Lessons
Exam	2
Introductory Concepts	1
COM and First Law of Thermodynamics – Transient Analysis	1
Second Law and Exergy Applied to Open and Closed Systems	10
Thermoeconomics	1
Vapor Cycles and Exergy Accounting	2
Gas Power Cycles and Exergy Accounting	3
Combined Power Cycles (Gas and Vapor) and Exergy Accounting	2
Project Related Lessons - In Progress Review with Professor, Peer Reviewed Presentation	4
Reacting Systems: First and Second Law Analyses	8
Property Relations	6
TOTAL	40

Over the past few years, ME 680 has evolved into a series of lessons that address exergy, transient systems, thermodynamic property relations, chemical reactions, and thermodynamics of high-speed gas flow. Table 3 includes a topical area listing for the Advanced Thermodynamics course and Table 4 describes the course grading plan. In the first portion of the quarter, advanced thermodynamic topics including exergy and reaction systems are studied. Due to the topics' importance to the mechanical engineering curriculum, exergetic and reaction system analyses are used throughout the remainder of the course to evaluate exergetic efficiencies of energy conversion systems and combustion processes. Students then begin a series of lessons on the more advanced analyses of various mechanical systems including internal combustion engines, boilers, and fossil fuel-fired steam and gas turbine power plants. The coverage of these topics within ME 680 builds upon an introductory mechanical device portion presented in ME 413. As shown in Table 4, the course includes a unique project which strengthens the student's overall experience within Advanced Thermodynamics. This project involves creating a *team-based presentation* based on topics learned in the thermodynamics course sequence. The presentation must be suitable for a non-technical target audience and is the focus of later sections within this paper.

After successfully completing Advanced Thermodynamics, students can choose to continue the study of classical thermodynamics by selecting a capstone design experience which incorporates advanced thermodynamics principles as discussed in George et al, 2006 [3]. A select group of students also conduct thermodynamic related research in their pursuit of a Masters of Science degree [4, 5, and 6].

Table 4. Grading Plan for Advance Thermodynamics (ME 680)

REQUIREMENT	DATE	POINT VALUE	PERCENTAGE
Homework/Quizzes		200	20%
Exam	Wednesday, 19 APR 2006	300	30%
Project	*See memo*	200	20%
Cumulative Final	Week 11	300	30%
TOTAL		**1000**	**100.0%**

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The *Overview of Course Projects* section of this paper focuses on the technical book review and team-based presentation projects assigned during Thermodynamics (ME 413) and Advanced Thermodynamics (ME 680), respectively. Included in this section are learning objectives, deliverables, and grading rubrics for each project. Further descriptions regarding project evolution issues are included in the *Discussion of Course Projects* section. The *Survey of Student Opinions Regarding Course Projects* section presents results of project assessment, including student feedback, collected and analyzed over the past five years. The final section, *Ongoing Refinement of Course Projects*, discusses a large-scale roll out plan for the technical book review project, problems anticipated, proposed solutions, and other project refinements planned.

II. Overview of Course Projects

The technical book review project, assigned in Thermodynamics, is a 150-point, individual assignment that involves critically reading a technical publication, reviewing the publication, and presenting the results to the class in an informal setting. The technical publications selected by the students include books from a wide variety of topics, ranging from artificial intelligence to hybrid vehicle design and infrastructure issues. A page-long list of suggested books (included as Appendix A) is provided to the students at the time of project assignment. Detailed information on the project's purpose, objectives, scope, and milestone schedule is included as Figure 1.

By their final year in college, most students have written several book reports; however, few engineering majors have written critical book reviews. Therefore, the scope and details section of Figure 1 is supplemented with an attached handout on how to successfully prepare a book review [7, 8]. This summary explains that a book review describes not only what a book is about, but also how successful the book is at what it is trying to accomplish. Reviewers answer not only the WHAT but the SO WHAT question about a book. ME 413 students must also relate topics explored within the book with topics learned in Thermodynamics. Thus, in writing a review, the student combines the skills of describing what is on the page, analyzing how the book tried to achieve its purpose as well as how it relates to Thermodynamics, and expressing personal reactions. Performance criteria used to assess and evaluate the student's performance on the technical book review are included as Figure 2.

The recommended body of the technical book review includes the following sections:

- Introduction in which student describes the book type; summary of written book review; book overview and purpose; book intended audience; brief personal reaction
- Background Information which includes book's context and the criteria used by the student for evaluation
- Summary section listing the book's thesis; main points; primary supporting points; and a thermodynamics related discussion
- Evaluation portion which describes the student's reaction to book with explanation and any personal effect
- Conclusion where students summarize ideas and offer advice to potential readers

The project's performance criteria (Figure 2) clearly show these expectations in order to aid students in the creation of the written document and expedite evaluation of written work.

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Purpose: This quarter in ME 413, students will complete a project worth 150 Points (15% of the overall course grade). The project is an **individual assignment** that involves critically reading a technical book, reviewing the book, and presenting your results to the class in an informal setting. *(Refer to Enclosure 1 for book selection ideas.)*

Objectives:

- Promote scholarly curiosity and research.
- Strengthen careful analytical reading and technical writing abilities.
- Enhance life long learning abilities.
- Enhance creativity through the creation of a relevant and appropriate review and discussion.
- Relate the study of thermodynamics to application(s) and/or topic(s) explored within approved technical book.
- Improve understanding of the impact of engineering solutions in a global, economic, environmental, and/or societal context.
- Deepen knowledge of contemporary issues.

Scope and Details: *(Refer to Enclosure 2 for more information.)*

- Critically read a technical publication (approved by course instructor).
- Prepare a book review (1000 words MAX, 900 words MIN).
- Present your findings in an informal setting to your classmates.

Grade Plan and Project Milestone: Deliverables are graded events that are required no later than the dates specified.

PART II	Due Date	POINTS
Book Selection and Approval	Wednesday, 20 DEC 2006	10
Book Review Rough Draft	Monday, 5 FEB 2007	100
Final Book Review Submission	Friday, 16 FEB 2007	40
Oral Discussion	Friday, 23 FEB 2007	-
TOTAL		**150**

Figure 1. Purpose, Learning Objectives, and Deliverables Associated with Technical Book Review Project Assigned in Thermodynamics (ME 413)

The team-based presentation project, assigned in Advanced Thermodynamics, is a 200-point, team (3 or 4 person) assignment that involves creating and giving a fifteen to thirty minute long presentation/demonstration for a specified audience. The content of the presentation must strongly relate to Thermodynamics and relevance must be established with the audience. Typical target audiences are non-technical; past examples include middle and high school math, science, technology classes or liberal arts classes. Administrative support is provided for teams who elect to present off-campus to area schools, including assistance with locating an appropriate class and organizing details regarding the visit. Detailed information on the project's purpose, objectives, scope, and milestone schedule is included as Figure 3.

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BOOK SELECTION MEMO ***Score: /10***

Performance Criteria	Score	Strengths/Insights	Areas for Improvement
Appropriate Memo Format (3)			
Book Selection (3)			
Reason(s) for Book Selection(4)			
TOTAL (10 Points)			

ROUGH DRAFT ***Score: /100***

Performance Criteria	Score	Strengths/Insights	Areas for Improvement
Appropriate Length – 1000 word(5)			
Spelling/grammatical errors (1 each)			
Late penalty			
General Structure and Organization (5)			
Heading (5)			
Introduction (10) book type; summary of review; book overview and purpose; intended audience; personal reaction			
Background Information (15) context; criteria for evaluation			
Summary (25) book thesis; main points; primary supporting points; thermodynamics related discussion			
Evaluation (20) reaction to book with explanation; personal effect			
Conclusion (10) summarize ideas; advice for potential readers			
Reference all Sources (5) correct format and completeness			
TOTAL (100 Points)			

FINAL BOOK REVIEW ***Score: /40***

Performance Criteria	Score	Strengths/Insights	Areas for Improvement
Comments from Rough Draft (10)			
Spelling/grammatical errors (3 each)			
Late penalty			
Heading (2)			
Introduction (4)			
Background Information (6)			
Summary (6)			
Evaluation (6)			
Conclusion (4)			
References (2)			
TOTAL (40 Points)			

Figure 2. Performance Criteria for Technical Book Review Project Assigned in Thermodynamics (ME 413)

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Performance criteria used to assess and evaluate the student's performance on deliverables associated with the project are included as Figure 4. Student teams are required to submit a preliminary work plan which includes topic to be taught and specific target audience information. Half-way through the quarter, team-based In-Progress Reviews are scheduled in order for the team to walk-through the presentation with the professor. Detailed feedback is provided. Prior to the final presentation, each team does a mock presentation to the class where peers provide assessment. Phases (0, 1, 2, and 3) indicated on the milestone schedule (Figure 3) and within the performance criteria (Figure 4) refer to a design methodology that the mechanical engineering students learn during their multidisciplinary senior design capstone experience [9, 10]. Because many of the students in ME 680 are concurrently enrolled in the Multidisciplinary Senior Design course, this element of the project is added to tie curriculum and reinforce the usefulness of a detailed design methodology. In this case, understanding the technical level and background of the audience is crucial for project success and this "understanding the customer's needs" activity can be tied to Phase 0 in the methodology taught in design.

III. Discussion of Course Projects

Both the technical book review and team-based presentation projects were created and piloted by the author in the fall semester of 2001 at the United States Military Academy (USMA) at West Point. The projects were first assigned to fourth year mechanical engineering cadets enrolled in Energy Conversion Systems (ME 472). A paper presented at the ASEE 2002 National Conference described the evolution of this course at West Point and included information regarding both projects in their earliest forms [11]. Table 5 includes a summary of the technical book review assignment history, from its initial pilot at USMA until current.

Table 5. History of Technical Book Review Assignment

Date	**Number of Students**	**Course (Institution)**
Fall 2001	8	ME 472: Energy Conversion Systems (USMA)
Fall 2002	18	ME 472: Energy Conversion Systems (USMA)
Fall 2003	18	ME 413: Thermodynamics (RIT)
Spring 2004	19	ME 660: Air Conditioning and Refrigeration (RIT)
Fall 2004	50	ME 413: Thermodynamics (RIT)
Fall 2005	38	ME 413: Thermodynamics (RIT)
Winter 2005/06	170	ME 413: Thermodynamics (RIT)

As indicated in Table 5, the technical book review project has been assigned in at least one course per year since its inception to varying audience sizes and year groups. Students who have completed this project range in year level from second through fifth year standing. The author has found that the greatest successes on this project come from lower year level students. There have been many examples of the project sparking an interest in a second or third year student which has lead that individual towards a certain coop, capstone design project, or research. For example, one student who read The Car That Could: The Inside Story of GM's Revolutionary Electric Vehicle [12] interviewed at General Motors for a coop shortly after finishing the book and attributes getting the job with a discussion he had based on the book with the interviewer.

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Purpose: This quarter in ME680, students will complete a team (3 or 4 person) project with a total point value of 200 Points, roughly 20% of the overall course grade. The project assignment involves creating and giving a 15-30 minute long presentation/demonstration for a specified audience. The content of the presentation must strongly relate to Thermodynamics and have direct relevance to the audience.

Objectives:

- Enhance creativity through the creation of a relevant and appropriate presentation.
- Practice a systematic design process.
- Design presentation with your audience in mind.
- Create activities to stimulate audience interest and involvement.
- Assess presentation (following classroom interaction) while focusing on strengths, areas of improvements, and insights gained.
- Enhance life long learning abilities.
- Apply and strengthen Thermodynamic knowledge through teaching others.
- Improve communication abilities through written, verbal, and graphical means.
- Strengthen teamwork abilities.
- Deepen knowledge of contemporary issues.

Scope and Details:

- Design a 15-30 minute presentation/demonstration for an identified target audience.
- Create a relevant, interesting talk.
- Include computer simulations, adequate graphics, and/or hands-on activities.
- Establish relevance with audience.
- Create activities that engage your audience. (If a student falls asleep during your presentation it is an automatic point deduction!)
- Assess experience, focusing on strengths, areas of improvements, and insights gained.

Project Milestones with Grade Information:

Date	Deliverable (Point Value)
27 MAR 2006	**Team Deliverable: Proposal Memorandum (20 Points)** Phase 0. Recognize and Quantify the Need, Develop Preliminary Work Plan, Establishing Design Objectives and Criteria Phase 1. Concept Development (50% Complete)
10 APR 2006	**Team Deliverable: In Progress Review (40 Points)** Phase 1. Concept Development (100% Complete) Phase 2. Detailed Design (Develop Presentation) 50% complete
24 APR 2006	**Team Deliverable: Peer Review (40 Points)** Phase 3. Detailed Design (Develop Presentation) 95% complete
26 APR-10 MAY	**Team Deliverable: Thermodynamics Presentation (60 Points)**
2 days after presentation	**Individual Deliverable: Assessment (40 Points)** Memo includes all relevant materials and experience assessment.

Figure 3. Purpose, Learning Objectives, Grading Plan, and Deliverables Associated with Team-Based Presentation Project Assigned in Advanced Thermodynamics (ME 680)

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Team Proposal Memo **Score: /20**

Performance Criteria	**Score**	**Strengths/Insights**	**Areas for Improvement**
Memo Format (2)			
Grammar, sentence structure, overall structure, spelling, etc.			
Phase 0. Recognize and Quantify the Need (4)			
Phase 0. Develop Preliminary Work Plan for the project (4)			
Phase 0. Establish Design Objectives and Criteria (4)			
Phase 1.Concept Development - 50% Complete (4)			
Signatures from All Members (2)			
Total (20 Points)			

Team In-Progress Review **Score: /40**

Performance Criteria	**Score**	**Strengths/Insights**	**Areas for Improvement**
Presentation Format (4)			
Grammar, sentence structure, overall structure, spelling, etc.			
Total Team Involvement (4)			
Final Work Plan - presentation time/audience details (4)			
Phase 0. Comply with Established Design Objectives and Criteria (5)			
Phase 1. Concept Development – 100% (10)			
Phase 2. Develop Presentation, demos, handouts - 50% (8)			
Address Comments/Suggestions from Memo Feedback (5)			
Total (40 Points)			

Peer Review Performance Criteria **Score: /40**

Performance Criteria	Score	Strengths/Insights	Areas for Improvement
Total Team Involvement (5)			
Establish relevance with audience(5)			
Quality of Oral Presentation (5)			
Adequate, Clear Graphics (5)			
Create Activity or Questions that Engage Your Audience (15)			
Appropriate Length (15-30 min) (5)			
Total (40 Points)			

Team Presentation **Score: /60**

Performance Criteria	Score	Strengths/Insights	Areas for Improvement
Total Team Involvement (10)			
Introduction (5)			
Establish relevance w/ audience (10)			
Quality of Oral Presentation (10)			
Adequate, Clear Graphics (10)			
Create Activity or Questions that Engage Your Audience (10)			
Appropriate Length (15-30 min) (5)			
Total (60 Points)			

Individual After Action Report Memo **Score: /40**

Performance Criteria	Score	Strengths/Insights	Areas for Improvement
Memo format (3)			
Include Attachments (2)			
Grammar, Spelling, Readability (5)			
Discuss at least three strengths, three areas for improvement, and two insights gained (30)			
Total (40 Points)			

Figure 4. Performance Criteria for Team-Based Presentation Project Assigned in Advanced Thermodynamics (ME 680)

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The larger course size has introduced challenges with managing resources to handle grading, especially the rough draft. This winter quarter, the project has been assigned to all students studying thermodynamics which includes 170 primarily second year mechanical engineering students who are enrolled in five different sections, each taught by a unique faculty member. The grading rubric has made grading consistency easier to achieve across sections; however the grading burden is ominous. There is no writing related graduate program within the College of Liberal Arts where teaching assistants could be recruited. Therefore strategies are being explored in which upper class engineering and liberal arts students with writing background and talent will be hired to assist in this effort.

Class size effects not only grading requirements, but also administration of the book discussion at the end of the project. The intent of this discussion has always been to create an informal gathering, away from campus, where ideas could be exchanged regarding books read. Typically the professor asks for a student volunteer to arrange this gathering in exchange for bonus points equivalent to one homework assignment (fifteen assignments are usually given per quarter). At West Point, cadet volunteers arranged evening outings to local restaurants where these types of discussions ensued as shown in Figure 5. The cadets welcomed the opportunity to venture off-post for an evening and typically made necessary arrangements to be excused from various military or athletic requirements the evening of the discussion.

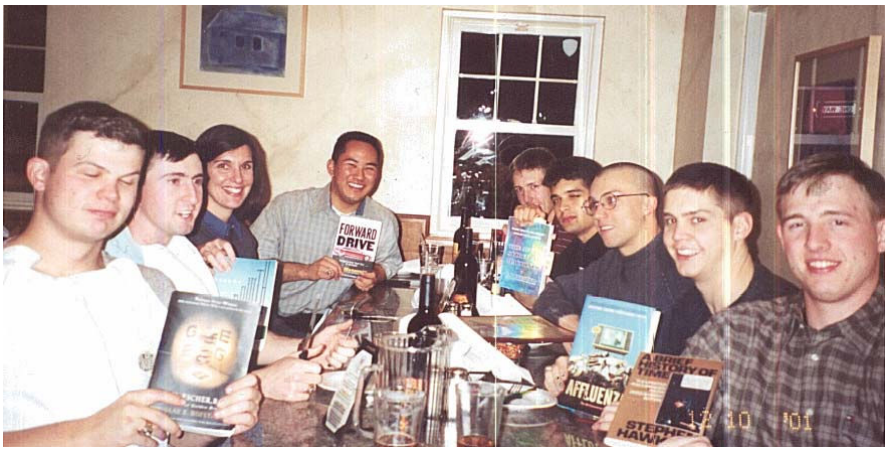

Figure 5. Photo from the First Technical Book Review – Small Group Discussion (Fall 2001)

At RIT, students have more freedom to venture off-campus whenever they choose (and many live off campus), therefore their preference is to remain on-campus for this event. However, the discussion does not occur in the classroom but instead in outside courtyards or interior atriums. Food and beverage are provided and the discussion remains informal. Because of the class size, rather than each student speaking individually for several minutes about their book, students are grouped into common groups based on their book (such as alternative fuels, renewable energy, design practices, automotive, aerodynamics, biomedical, etc.) and they present together. A leader is assigned to each group and through discussions prior to the event team members compare and contrast their books. At the book discussion, the team describes their discussions; some teams have the leader represent their viewpoints while others involve all members. Figure 6 is a photo from a group presentation during the end of quarter book discussion in the fall of 2006.

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Figure 6. Photo from a Typical Technical Book Review – Large Group Discussion (Fall 2006)
Note: Interpreter featured in photo providing services for deaf and hard of hearing students in the course

Over the past five years, steady improvements in student performance on this graded event have occurred due to changes in feedback and grading structures as well as student expectations. The rough draft is now due at a relatively slow time in the ten week quarter (beginning of week eight). Because students have nearly two months to read the book and write the rough draft, its graded weight has been increased significantly to encourage students to produce a near-final product which has been carefully edited. In order to assist students in this task, a thorough set of expectations are provided in the project's performance criteria (Figure 2). Typically the student's product is nearly complete in the rough draft form and only minor edits are necessary for the final submission.

Some of the technical book review project learning objectives relate to enhancing life-long learning, understanding of societal impact, knowledge of contemporary issues, creativity, and written communication abilities (refer to Figure 1 for a complete listing). In creating the course ABET syllabus for ME 413, the course learning objectives reflected many of these same objectives due to the inclusion of the project. The technical book review project therefore can be shown to assist engineering students attain attributes defined through ABET Criterion 3 Program Outcomes and Assessment which are challenging to reinforce in a conventional Thermodynamics course. These ABET criterion include (d) regarding teamwork, (g) regarding communication, (h) relating to impact of engineering solutions, (i) discussing life-long learning, and (j) regarding knowledge of contemporary issues [13].

Resembling the technical book review, the team-based presentation project assigned in ME 680 allows that course to document its support of several ABET criteria that conventional Advanced Thermodynamics courses would not support (such as those related to communication, teamwork, contemporary issues, and life-long learning). Since the project's inception in 2001, it has intentionally been limited in its inclusion as a course project to only more advanced mechanical engineering courses with upper level students and smaller class sizes. The project has been an integral part of Energy Conversion Systems at West Point for two consecutive fall semesters in 2001 and 2002 (class sizes of 8 and 18, respectively) as well as Advanced Thermodynamics at RIT for two consecutive spring quarters in 2005 and 2006 (class sizes of 3 and 18, respectively).

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Significant improvements have occurred over the years in student performance during final team presentations. This is largely attributed to the addition of an in-progress review and a peer reviewed presentation completed by the team before the final team presentation, which occurs outside of the normal classroom and often in a high school or middle school math, science, or technology classroom. For example in the spring of 2006, one team visited a high school chemistry classroom to discuss alternative fuels, another visited a middle school technology classroom to discuss the difference between gasoline and diesel engines with a focus on efficiency, a third visited an all-women's high school math class to discuss hybrid vehicle development, and a fourth visited a College of Liberal Arts course at RIT to discuss ethanol production related issues.

In addition, the role of leader on each team has become more defined and important over the years, adding a positive dimension to most of the team's experiences. It has certainly helped with the administration of this project due to the responsibilities that the leader assumes in team planning and scheduling. This past year, a materials science course added a version of this project to that course, however it was individual rather than team-based and the in-progress and peer reviews were not included. According to the course lead instructor, the final presentation results held much room for improvement.

IV. Survey of Student Opinions Regarding Course Projects

Example student opinion results from the individual technical book review project assigned in Thermodynamics during the fall quarter of 2005 are included in Table 6 with a student respondent sample size of 24. Student opinion data has been collected during all offerings of this project, however because the associated learning objectives have evolved over time, consistent data for comparison purposes is unavailable. Based on the results of opinion data collected in the fall of 2005 for questions associated with a subset of project learning objectives (Figure 1 and Table 6), students tend to make a connection between the project and its promotion of intellectual curiosity (4.1), careful analytical reading (4.2), and assessment/evaluation skills (4.1), where a rating of five reflects a strong agreement and one represents a strong disagreement with the provided statement. They tend to make a less strong connection between the project and its promotion of life long learning (3.7) and creativity (3.8), although both are still on the positive side of neutral. On future feedback forms, the question related to "life long learning abilities" will be rewritten to reflect attributes associated with an individual who possesses this type of ability. Comments written on feedback forms also provide insight into the student's opinion of this project. Examples are included below:

- *"The project is a great idea…might want to offer a wider selection of texts to read…overall a fun project"*
- *"I wasn't expecting to be doing a book review in Thermo, but it turned out to be a very rewarding experience. It gives students the opportunity to broaden their horizons..."*
- *"This book review was good in that it was designed to open our horizons to other fields of engineering. The only problem is that it was a lot of work along with all of the work we already had to do for the course."*
- *"Good to do something other than normal engineering problem solving."*

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Table 6. Student Opinions Regarding Technical Book Review Project (n=24)

Question **Scale: 1 = strongly disagree; 2 = disagree; 3 = neutral; 4 = agree; 5 = strongly agree*	**Average Rating**
Through completion of the ME 413 project….	
Promoted scholarly curiosity and research.	**4.1**
Practiced careful analytical reading.	**4.2**
Enhanced life long learning abilities.	**3.7**
Enhanced creativity through the creation of a relevant and appropriate review and discussion.	**3.8**
Strengthened assessment and evaluation abilities through preparation of book review.	**4.1**

Example student opinion results from the team-based presentation assigned in Advanced Thermodynamics during the spring quarter of 2006 are included in Table 7 with a respondent sample size of thirteen. Based on the results of opinion data collected in the spring of 2005 for questions associated with a subset of project learning objectives (Figure 3 and Table 7), students tend to make a strong connection between the project and its promotion of understanding contemporary issues (4.5), communication abilities (4.5), teamwork abilities (4.3), and thermodynamic understanding (4.2), where a rating of five reflects an excellent and four represents an above average relationship between the question and the project experience. They also tend to make a connection between the project and its promotion of creativity (3.9 and 3.8), design process use (3.9), and self-assessment (3.7), where a rating of three reflects a satisfactory relationship between the question and the project experience. The After Action Memo required on this project after the team's final presentation is an excellent means to assess student learning and impact. Select quotes from memos and feedback forms are included below.

- *"Project definitely improved team work abilities"*
- *"I used to be confident in my communication effectiveness - this project showed me my flaws and need to tailor presentation based on audience"*
- *"Really need to know it to teach it"*
- *"Peaked my interest in this area"*
- *"I improved my presentation skills a lot"*
- *"Gained valuable insight into hybrids and other alternative energy sources"*
- *"Learned a lot and had fun"*
- *"Sharing knowledge with future engineers makes me feel good inside. The feeling that you get for helping someone out is priceless. Also, I gained a wealth of knowledge myself in researching this topic. It reinforced what I previously learned in my engineering classes and taught me other uses of gas turbine engines that I can relate to."*
- *"It is vital for an engineer to learn how to bridge this gap" (between technical and non-technical audiences when discussing engineering related issues)*

Some of the more surprising quotes were in regards to the importance of student leaders on each team. The below observations were made by either team members or team leaders as indicated.

- *"The most important thing that I learned from this project was the importance of having a team leader. I have never really done a group project with an identified team leader and it does help to have one person that is in charge of keeping the project on track."* (from a team member)

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- *"Originally I had no intention of being a team leader for the project; however I am glad that I was given this opportunity. My skills as a team leader were enhanced and will continue to grow. Another plus is that when I start working fulltime, my job responsibility is to be a team leader for a manufacturing department. This project has given me the ability to coordinate project logistics, delegate responsibilities, and personally adjust to the needs of the team*." (from a team leader)

Table 7. Student Opinions Regarding Team-Based Presentation Project (n=13)

Question **Scale: 1 = unsatisfactory; 2 = marginal; 3 = satisfactory; 4 = above average; 5 = excellent*	**Average Rating**
Through my involvement with the ME680 Team Presentation….	
I enhanced my creativity through the creation of a relevant and appropriate presentation.	**3.9**
I used a design process to create a presentation with my audience in mind.	**3.9**
I enhanced my creativity by creating an activity to stimulate audience interest and involvement.	**3.8**
I improved my self-assessment skills by completing a self-assessment based on my presentation.	**3.7**
I have improved my understanding of contemporary issues associated with the field of mechanical engineers.	**4.5**
I have improved my communication effectiveness by written, verbal, and/or graphical means.	**4.5**
I have improved my teamwork abilities.	**4.3**
I applied and strengthened my Thermodynamic knowledge through teaching others.	**4.2**

V. Ongoing Refinement of Course Projects

Both projects will continue to be offered within the mechanical engineering curriculum at RIT for the foreseeable future. Enhancements will continue in order to improve student learning and satisfaction. Many of these enhancements will fall into the "logistics" category, such as establishing grading support for rough draft book reviews, continuing to expand the list of suggested books, handing out the assignment as close to lesson one as possible to allow ample time for reading and reviewing or planning the presentation, providing sample book reviews and presentation examples which are high caliber, creating a more stream-lined approach to organizing middle and high school presentations, etc.

Other refinements may affect project learning objectives, such as how to best handle the book review discussion in a limited time frame. By the end of the quarter, students want to talk about these books but the current set-up does not allow for each person to present their ideas to the group. Also, project memos and performance criteria must be carefully reviewed each time there is a modification to the project's learning objective set in order to ensure the students will clearly understand the appropriate expectations.

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Appendix A: Table A-1 Book Ideas Provided for Technical Book Review Project Assigned in Thermodynamics (Partial Listing)

Environmental, Policy, and Global Energy Supply Issues:

- Affluenza by DeGraaf, Wann, and Naylor
- Beyond Growth by Daly
- Forward Drive by Motavalli
- Natural Capitalism by Hawkens, Lovins, and Lovins
- Hubbert's Peak: The Impending World Oil Shortage by Deffeyes
- Tomorrow's Energy : Hydrogen, Fuel Cells, and the Prospects for a Cleaner Planet by Hoffmann and Harkin
- The Ecology of Commerce: A Declaration of Sustainability by Hawken
- Cradle to Cradle: Remaking the Way We Make Things by McDonough and Braungart
- Biomimicry: Innovation Inspired by Nature by Benyus
- The Natural Step for Business: Wealth, Ecology and the Evolutionary Corporation (Conscientious Commerce) by Nattrass
- Eco-Economy: Building an Economy for the Earth by Brown
- The New Economy of Nature by Daily and Ellison
- Mid-Course Correction: Toward a Sustainable Enterprise: The Interface Model by Anderson
- The Future of Life by Edward Osborne Wilson
- Energy Revolution: Policies for a Sustainable Future by Howard Geller
- Natural Home Heating: The Complete Guide top Renewable Energy Options by Greg Pahl
- Energy Revolution: Policies for Sustainable Future by Howard Geller

Design:

- To Engineer Is Human by Petroski
- Inviting Disaster, Lessons From the Edge of Technology by James Chiles
- The Evolution of Useful Things by Henry Petroski
- Design for the Real World by Victor Papanek
- The Green Imperative – Ecology and Ethics in Design and Architecture by Victor Papanek

Aero:

- Skunks Works: A Personal Memoir of my Years at Lockheed
- Lockheed Martin's Skunk Works

Automotive Issues:

- Fuel from Water: Energy Independence With Hydrogen by Peavey
- Hubbert's Peak: The Impending World Oil Shortage by Deffeyes
- Taken for a Ride: Detroit's Big Three and the Politics of Air Pollution by Doyle
- Powering the Future: The Ballard Fuel Cell and the Race to Change the World by Koppel Breaking Gridlock: Moving Toward Transportation That Works by Motavalli
- The Electric Vehicle and the Burden of History by Kirsch
- The Car That Could: The Inside Story of Gm's Revolutionary Electric Vehicle by Shnayerson
- History of the Electric Automobile by Wakefield
- Biodiesel: Growing A New Energy Economy

Non-reactive Energy Conversion Technologies:

- The Solar Electric House: Energy for the Environmentally-Responsive, Energy-Independent Home by Strong and Scheller
- Achieving Energy Independence - One Step at a Time by Yago
- Reaping the Wind: How Mechanical Wizards, Visionaries, & Profiteers Helped Shape Our Energy Future by Peter Asmus

Nuclear Energy:

- Megawatts and Megatons: A Turning Point in the Nuclear Age by Garwin and Charpak

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