

## Thermal Science Course Development Using Industry Input

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### Abstract

This paper discusses the use of an industry survey as a tool for course development in thermal sciences. The thermal science portion of the Mechanical Engineering Technology curriculum at Purdue University includes two core courses, both of which have traditionally included topics in applied thermodynamics only. In recent years, a minimal amount of heat transfer content has been added to the introductory course to help offset the removal of a heat transfer elective from the program.

A survey was completed to assess the need for even more heat transfer coverage in the thermal science curriculum, by investigating how frequently various thermal science topics and applications are encountered in industry. This paper outlines the survey process and describes how the input from industry is being used to guide the development of new lecture and laboratory materials in both heat transfer and combined thermal systems topics. An initial assessment of the effectiveness of the new course materials is also presented.

### Introduction

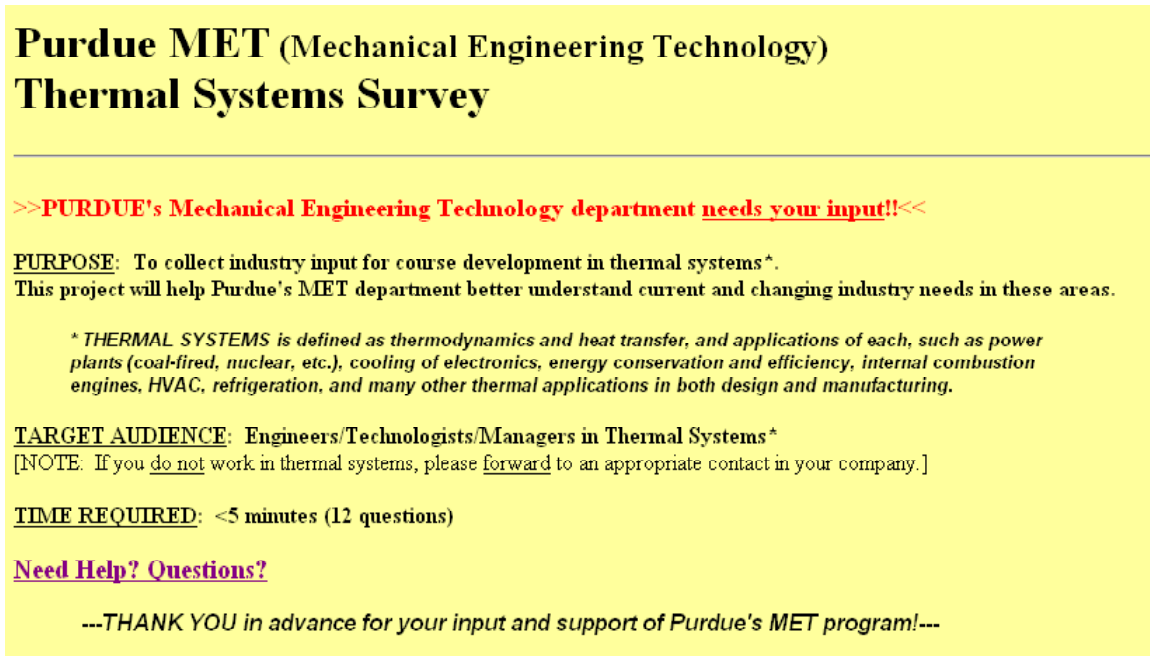
Continuous evaluation and revision of courses is a standard part of engineering and engineering technology education. Specific to engineering technology curricula, the accreditation criteria include technical currency and continuous improvement as two of the requirements for accreditation<sup>1</sup>. Therefore, updates to the thermal science portion of the Mechanical Engineering Technology (MET) curriculum at Purdue University are normal and expected. The current program includes two core thermal science courses, an introductory course at the sophomore level and a second course at the junior level. Both courses have traditionally covered topics in applied thermodynamics only, but in recent years, heat transfer content has been added to the introductory course to offset the removal of a heat transfer elective from the curriculum.

Within the context of continuous improvement, it was desired to further increase the amount of heat transfer content in the program. Several MET faculty teaching thermal science courses at various Purdue locations expressed the perception that increased heat transfer background would help maintain the technical currency of the courses. The logical placement of the additional coverage would be within the introductory course, so that graduates of the associate's degree program would have heat transfer knowledge to carry into their industrial experiences, regardless of whether they continued on for the bachelor's degree. Since changes to the introductory course content could ultimately affect the later applied thermodynamics course, a survey was developed to assess the need for additional heat transfer material in the program. The primary goal of the survey was to ensure that course updates would reflect current needs in industry and minimize impact to the junior-level course. The following discussion presents the development and results of the survey, issues encountered in the survey process, and the effectiveness of the survey process in guiding the enhancement of course materials.

## Survey Development

Initial survey design tips were obtained from web-based resources<sup>2-3</sup>. The survey used in this project was developed with typical industry engineers, technologists, and managers in mind. To maximize the number of returns, two key features considered in the design were accessibility of the survey and time required to complete the survey. Since most industry practitioners use e-mail as a standard form of communication, the survey was designed as a web page that could be sent to participants as a link within an e-mail announcement. The length of the survey was minimized such that it would take most respondents less than five minutes to complete: eleven multiple-choice questions, a section for comments, and a place to provide contact information if desired.

In addition, it was necessary to provide some means of ensuring only people with an appropriate background would complete the survey. A header paragraph was developed to help define the scope of the survey and clarify the target audience to make sure only those persons involved in thermal systems work responded. The survey header, shown in Figure 1 below, identifies the purpose, target audience, and required completion time for the survey.

The image shows a screenshot of a survey header on a yellow background. At the top, it reads "Purdue MET (Mechanical Engineering Technology) Thermal Systems Survey" in bold black text. Below this is a red line of text: ">>PURDUE's Mechanical Engineering Technology department needs your input!!<<". The "PURPOSE" section states: "To collect industry input for course development in thermal systems\*. This project will help Purdue's MET department better understand current and changing industry needs in these areas." A footnote defines "THERMAL SYSTEMS" as thermodynamics and heat transfer, and applications of each, such as power plants, cooling of electronics, energy conservation, internal combustion engines, HVAC, and refrigeration. The "TARGET AUDIENCE" is "Engineers/Technologists/Managers in Thermal Systems\*". A note says: "If you do not work in thermal systems, please forward to an appropriate contact in your company." The "TIME REQUIRED" is "<5 minutes (12 questions)". There is a link for "Need Help? Questions?". At the bottom, it says: "--THANK YOU in advance for your input and support of Purdue's MET program!--".

**Purdue MET (Mechanical Engineering Technology)**  
**Thermal Systems Survey**

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>>PURDUE's Mechanical Engineering Technology department needs your input!!<<

**PURPOSE:** To collect industry input for course development in thermal systems\*.  
This project will help Purdue's MET department better understand current and changing industry needs in these areas.

\* THERMAL SYSTEMS is defined as thermodynamics and heat transfer, and applications of each, such as power plants (coal-fired, nuclear, etc.), cooling of electronics, energy conservation and efficiency, internal combustion engines, HVAC, refrigeration, and many other thermal applications in both design and manufacturing.

**TARGET AUDIENCE:** Engineers/Technologists/Managers in Thermal Systems\*  
[NOTE: If you do not work in thermal systems, please forward to an appropriate contact in your company.]

**TIME REQUIRED:** <5 minutes (12 questions)

[Need Help? Questions?](#)

--THANK YOU in advance for your input and support of Purdue's MET program!--

**Figure 1. Header information from the web-based thermal systems survey.**

Survey content was limited to general inquiries, to ensure that respondents could complete the survey quickly and to provide a broad overview of the topics typically encountered in industry. Survey questions were divided into three categories: (1) thermal systems, (2) thermodynamics, and (3) heat transfer. "Thermal systems" was defined as the disciplines and applications of thermodynamics and heat transfer, and was used to encompass the entire realm of thermal science applications. Thermodynamics and heat transfer were then considered to be individual disciplines within the broader scope of thermal systems. The first set of survey questions simply asked how frequently each discipline or topic is encountered in the work of the participant, as shown in Figure 2 below.

1. How frequently do you encounter problems/projects dealing with THERMAL SYSTEMS overall?

Almost always    Often    Occasionally    Seldom    Almost never    Don't know or N/A

2. How frequently do you encounter/use THERMODYNAMICS?

Almost always    Often    Occasionally    Seldom    Almost never    Don't know or N/A

a. How frequently do you encounter/use phase diagrams and/or property tables?

Almost always    Often    Occasionally    Seldom    Almost never    Don't know or N/A

b. How frequently do you encounter/use ideal gas principles?

Almost always    Often    Occasionally    Seldom    Almost never    Don't know or N/A

c. How frequently do you encounter/use conservation of mass/energy principles (First Law)?

Almost always    Often    Occasionally    Seldom    Almost never    Don't know or N/A

d. How frequently do you encounter/use power production cycles (Otto, Rankine, etc.)?

Almost always    Often    Occasionally    Seldom    Almost never    Don't know or N/A

3. How frequently do you encounter/use HEAT TRANSFER?

Almost always    Often    Occasionally    Seldom    Almost never    Don't know or N/A

a. How frequently do you encounter/use conduction heat transfer?

Almost always    Often    Occasionally    Seldom    Almost never    Don't know or N/A

b. How frequently do you encounter/use convection heat transfer?

Almost always    Often    Occasionally    Seldom    Almost never    Don't know or N/A

c. How frequently do you encounter/use radiation heat transfer?

Almost always    Often    Occasionally    Seldom    Almost never    Don't know or N/A

**Figure 2. Survey questions to determine frequency of participant’s work in specific topics.**

The hierarchy described previously can be seen clearly in Figure 2, with a question about thermal systems overall first, followed by one question about thermodynamics as a complete discipline, and then several questions on specific topics that are typically taught within thermodynamics. Heat transfer is next, following the same structure as the thermodynamics questions. It was hoped that this part of the survey would indicate if additional heat transfer content was necessary in the introductory course for course coverage to be proportional to industry usage.

The next part of the survey addressed specific industrial applications of thermal systems. It was hoped that the responses from this part could guide course development by focusing new course materials on applications that are most frequently seen in industry. Figure 3 below shows the second part of the survey, in the form of one question in a “select all that apply” format.

4. **THERMAL SYSTEMS: which of the following do you encounter/use?** (select all that apply)  
 [These are some typical systems that require use of multiple types of thermal analysis covered above.]

- Power Generation: Fossil Fuel-Fired Steam
- Power Generation: Nuclear
- Power Generation: Diesel
- Power Generation: Gas Turbine
- Renewable Energy (Solar, Wind, Hydroelectric, etc.)
- IC Engines
- Heat Exchangers
- HVAC
- Refrigeration
- Electronics Cooling
- Manufacturing Thermal Management
- Manufacturing Process Heat
- Thermal Diagnostics
- Energy Conservation/Efficiency
- Energy Audits
- OTHER (please specify.)

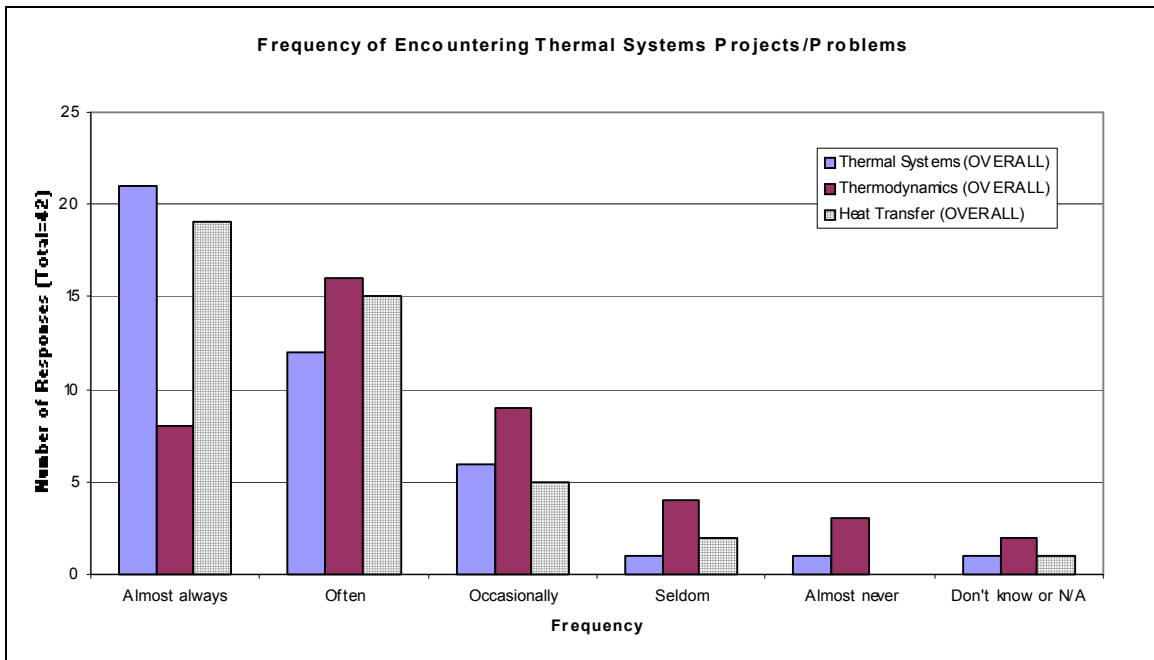
**Figure 3. Survey question to determine thermal systems applications seen in industry.**

**Survey Results**

Two main resources were used for distribution of the survey. The first resource was internal departmental industry contacts in engineering and management positions. This included the MET Industrial Advisory Committee as well as other employers of the program graduates. This pool included approximately 45 contacts, all of which were made via e-mail, and resulted in eight returns.

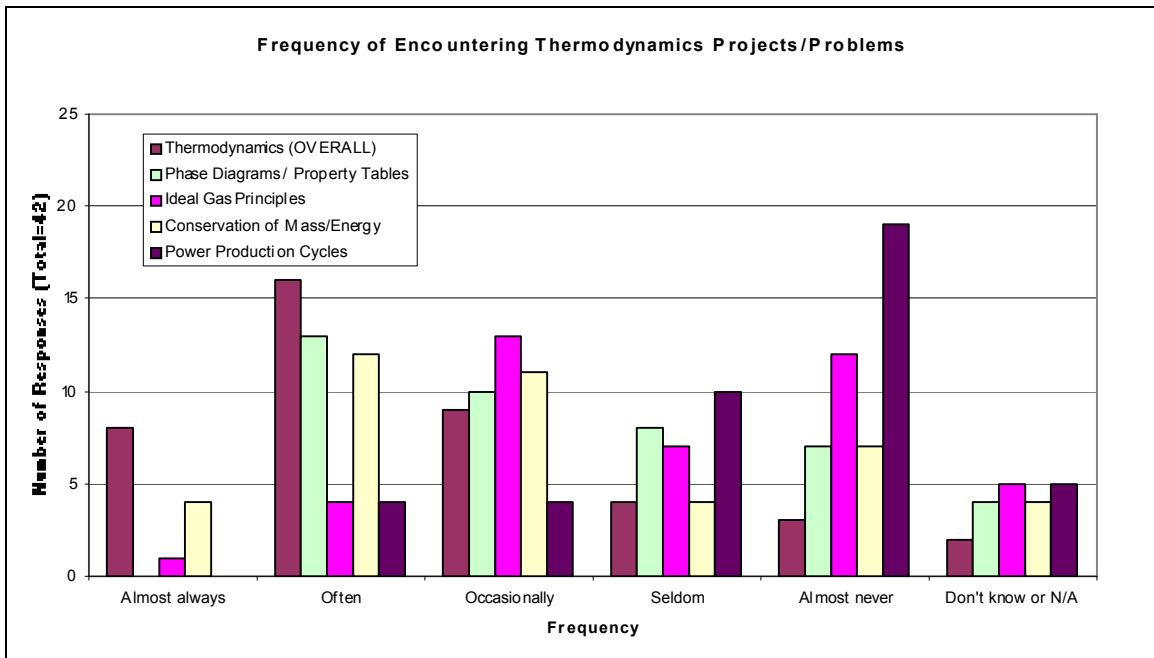
The second resource was professional societies. Two societies, the American Society of Mechanical Engineers (ASME) and the American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) were targeted for the survey. The central Indiana chapters of each society were contacted. The ASHRAE distribution was made via e-mail sent to members, while ASME distributed the survey information in a paper newsletter. Of the remaining 34 returns (total returns = 42), it is estimated that 90 percent were from ASHRAE. It was not possible to determine exactly how many returns came from each society since not all respondents provided contact information.

Of the 42 survey returns, 50 percent indicated that they “almost always” encounter projects in thermal systems, while 93 percent indicated they encounter projects in thermal systems at least “occasionally”. This alone confirms that the response to the survey was limited to participants with the appropriate background in thermal systems as was desired. For thermodynamics as an overall discipline, 17 percent “almost always” and 76 percent at least “occasionally” encounter thermodynamics. For heat transfer as an overall discipline, 45 percent said they encounter heat transfer “almost always” and 76 percent said at least “occasionally”. Figure 4 below depicts these results graphically. The larger percentage using heat transfer “almost always” indicates a potential for increasing the amount of heat transfer content in thermal science courses, but the equal number of responses showing at least occasional usage of both thermodynamics and heat transfer means that emphasis on thermodynamics should not be lost in the process.

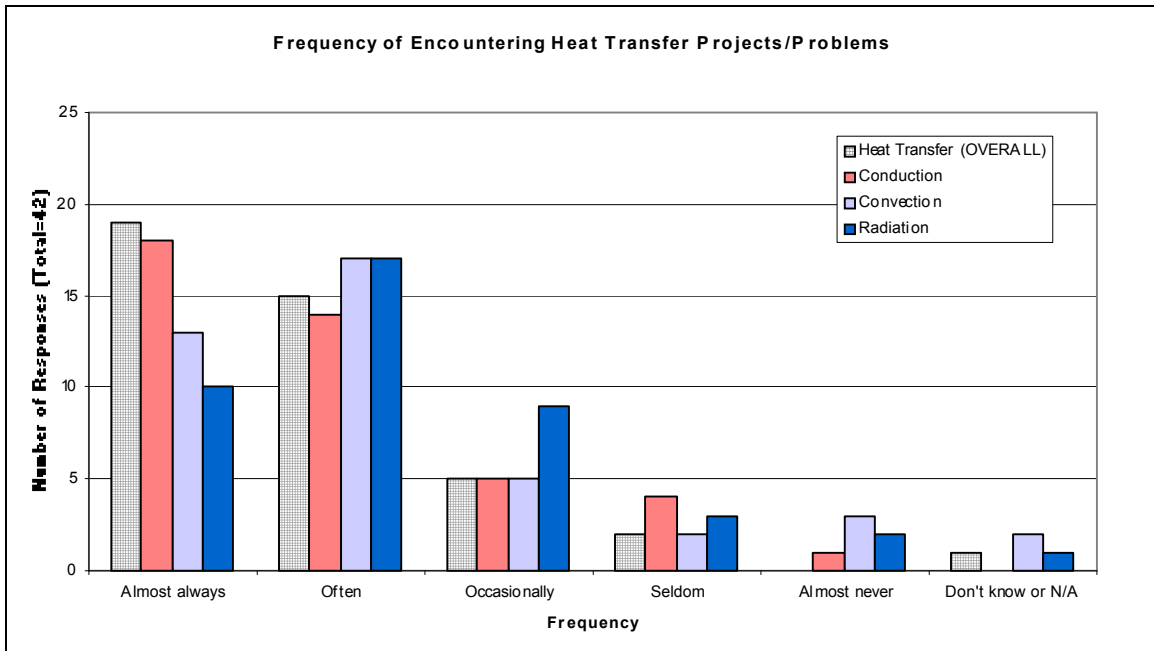


**Figure 4. Frequency of survey participants' work in overall disciplines.**

Figures 5 and 6 below show the survey results for more specific topics within thermodynamics and heat transfer, respectively. An initial review of these graphs indicates that no single thermodynamics topic is used most often in industry, and that heat transfer topics seem to find approximately equal distribution or usage in industry.

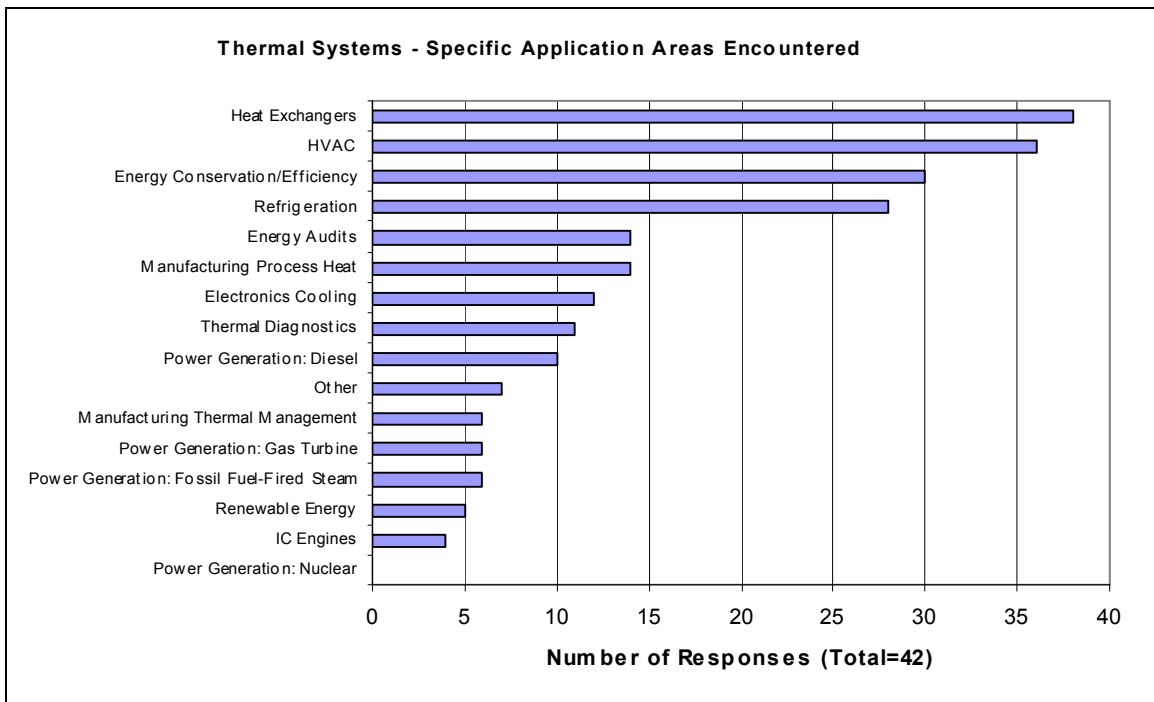


**Figure 5. Frequency of survey participants' work in thermodynamics topics.**



**Figure 6. Frequency of survey participants' work in heat transfer topics.**

The top four industrial application areas identified as being used the most frequently were: heat exchangers, HVAC, energy conservation/efficiency, and refrigeration. These results are shown in Figure 7 below.



**Figure 7. Thermal systems application areas encountered by survey participants.**

## Course Materials

Based on the survey results showing significant industry usage of both thermodynamics and heat transfer, the introductory thermal science course was modified to include more heat transfer coverage in the Fall 2002 semester. Table 1 below outlines the previous and Fall 2002 course structures, to highlight the increased heat transfer coverage. The new course structure devoted approximately equal time to thermodynamics and heat transfer topics. Also, a section on thermal systems was added, to provide an introduction to practical applications where more than one discipline may be involved. It is believed that the reduction in thermodynamics coverage did not significantly impact the overall curriculum for three reasons: (1) the essential introductory elements were retained, (2) the thermal systems portion of the course allowed further exposure to thermodynamics problems in industrial applications, and (3) any eliminated topics are still covered in the junior-level thermal science course or in elective courses.

**Table 1. Modifications to course outline based on survey results.**

<b>COURSE TOPICS</b>	<b>Previous Semesters COVERAGE</b>	<b>Fall 2002 Semester COVERAGE</b>
<b>Basic Concepts &amp; Properties</b>	<b>2 weeks</b>	<b>2 weeks</b>
<b>Thermodynamics</b>	<b>9 weeks</b>	<b>5 weeks</b>
<b>Heat Transfer</b>	<b>4 weeks</b>	<b>6 weeks</b>
<ul style="list-style-type: none"> <li>• Steady Conduction</li> <li>• Transient Conduction</li> <li>• Convection</li> <li>• Radiation</li> <li>• Heat Exchangers</li> </ul>	1 week ½ week 1 week ½ week 1 week	2 weeks ½ week 1 week 1 week 1 ½ weeks
<b>Thermal Systems</b> <i>(combined topics &amp; applications)</i>	<b>NONE</b>	<b>2 weeks</b>

In addition to the changes described above, the specific application area with the most responses, heat exchangers, was the focus of an additional guest lecture and assignment on diesel engine radiator design in the Fall 2002 semester. The lecture provided an introduction to diesel engine cooling systems and typical measurement and analysis techniques used for the systems. The assignment required students to use a spreadsheet-type simulation of an engine and cooling system to evaluate design tradeoffs. They then had to prepare a technical and cost analysis of the design options evaluated. Student response to the lecture and assignment was very positive, with the majority indicating the experience was relevant to the course and to their futures in industry.

## Future Development

Unfortunately, the majority of the survey returns came from one source, the central Indiana chapter of ASHRAE. This is most likely due to the fact that the survey was delivered to ASHRAE members within the context of an e-mail newsletter, as opposed to inclusion of the web address in a paper newsletter for ASME members. Future surveys of this type should ensure inclusion of a broader audience, and should ensure delivery of the survey to the entire target

audience through e-mail so that participants can easily link to the survey page.

Additional work is planned to use the results of this survey in the development of new laboratory experiments for the introductory thermal science course. It is also hoped that the industry exposure to Purdue's MET program through the survey and follow-up will provide an opportunity for additional collaboration with industry respondents through tours, guest lectures, or student projects.

### **Conclusions**

A web-based survey was implemented successfully to aid in thermal science course development in the mechanical engineering technology curriculum. The survey results indicated that heat transfer topics are encountered in Indiana industry at least as frequently as the traditionally covered thermodynamics topics, so course development in heat transfer was warranted. Some modifications to the introductory thermal science course were implemented, with initially favorable results. In keeping with continuous improvement goals in education, this type of survey project can be easily implemented in a variety of disciplines to help evaluate and maintain technical currency in various engineering and engineering technology curricula.

### **References**

1. Accreditation Board for Engineering and Technology, Inc. website (2003), <http://www.abet.org/>
2. Creative Research Systems website (2002), *The Survey System: Your Complete Software Solution for Survey Research*, <http://www.surveysystem.com/sdesign.htm>
3. Writing Survey Items (n.d.), Retrieved June 4, 2002, from Purdue University Student Services website: [http://vwave-01.adpc.purdue.edu/ssinfo/help/Writing\\_Survey\\_Items.html](http://vwave-01.adpc.purdue.edu/ssinfo/help/Writing_Survey_Items.html)

### **Biography**

HEATHER L. COOPER, P.E.

Heather L. Cooper is an Assistant Professor of Mechanical Engineering Technology at Purdue University. She has seven years of product engineering experience at General Motors Corporation, including extensive work in noise and vibration. Professor Cooper is currently the lead instructor for the introductory thermal science course at the West Lafayette campus.