Assessment of Student Cognitive Development in the Energy Systems Laboratory

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I. Introduction

Kettering University is a fully cooperative school where students alternate between eleven-week work terms and eleven-week academic terms. The core engineering courses in the Mechanical Engineering Department are divided into four threads, one of which is the Energy Systems thread. Students progress through the Energy Systems thread by taking courses in thermodynamics and fluid mechanics at the junior level, and heat transfer and energy systems at the senior level. The Energy Systems Laboratory course is an integrated laboratory experience where students apply fundamental concepts learned in previous courses. There is also an aspect of design incorporated into the laboratory and additional topics in modern computational and experimental techniques are also addressed. All mechanical engineering students are required to take the four of the Energy Systems thread courses. Because the laboratory course is a senior level integrated experience with a broad range of student learning outcomes and multiple instructors are involved during all course offerings, it is necessary to develop an effective and efficient assessment process that can be applied uniformly by all instructors. The assessment process must also improve cognitive learning as well as meet accreditation requirements. This paper addresses an assessment plan that has been implemented for the Energy Systems Laboratory course.

Assessment is often driven by the need to obtain accreditation from organizations such as North Central Association of Colleges and Schools (NCA) and Accreditation Board of Engineering and Technology (ABET). However, assessment should be driven by a desire to improve cognitive learning while meeting accreditation requirements. The Energy Systems thread, when considered as a whole, is a complete model of cognitive learning at all domain levels[1]. In the thermodynamics, fluid mechanics, and heat transfer courses, students acquire knowledge and comprehension as well as develop an ability to apply and analyze engineering problems. Synthesis and evaluation occurs in the Energy Systems Laboratory. An assessment process should be chosen to be consistent with the cognitive learning domain supported by the course.

An assessment process involves setting common course objectives and student learning outcomes, developing a set of strategies to deliver knowledge to the students, developing a set of evaluation tools to monitor progress toward learning outcomes, and devising a feedback mechanism to improve the process[2,3,4,5]. Strategies are activities that will enable the accomplishment of course objectives. Student learning outcomes state the knowledge and skills each student must acquire at the end of the course. The assessment tools are the instruments that will be used to measure progress toward student learning objectives. Feedback schemes are used to modify any portion of the process and are developed from the results of the assessment tool evaluation process.

The assessment process should involve the entire process[4], and therefore, should involve the entire Energy Systems Thread as well as the entire institute. However, as instructors, it is often necessary to assess only the course without involving any other portion of the process. To make the assessment process effective at the course level, methods should be devised to assess the input to the system (student knowledge coming into the laboratory course) and feedback mechanisms should be implemented to improve the input to the system.

Standard assessment models use lessons, prepared course material, homework, reports, student teams, as well as student-professor interaction for course strategies. Assessment tools include forced-choice tests, essay-problem tests, checklists, surveys, student diaries, and student portfolios[5,6]. When the course is aimed at higher levels of cognitive learning, such as occurs at the synthesis and evaluation levels, non-traditional assessment tools or methods may be more effective in evaluating progress toward student learning outcomes[7].

The assessment process for the Energy Systems Laboratory is explained in the following sections. Section II describes the components of the assessment process including strategies, student learning objectives, assessment tools, criteria for success, feedback methods, and accreditation considerations. A discussion of the assessment process and implementation is contained in Section III.

II. Structuring an efficient and effective assessment process

A. Structure of the Energy Systems Thread

The Energy Systems Laboratory course builds upon previously learned material. To do this effectively and efficiently, it is necessary to provide students with prerequisite course experiences that maximize student learning. By introducing topics at appropriate stages in the learning process or cognitive development, faculty can maximize the amount of knowledge a student can absorb as well as comprehend. The course sequence in the Energy Systems Thread gives students the opportunity to apply and analyze fundamental concepts in three consecutive eleven-week academic terms. During the first semester of the junior year, students (who have successfully met prerequisite requirements in mathematics and physics) are introduced to fundamental concepts in thermodynamics. During the second term of the junior year, students take a course in fluid mechanics. They are introduced to fundamental concepts in heat transfer during the first semester of the senior year. Some students choose to take Energy Systems Laboratory at this time. However, most students take the laboratory during the second term of the senior year. The course, therefore, also serves as an excellent review opportunity for the EIT/FE exam. Strategies used in the thermodynamics, fluid mechanics, and heat transfer courses include homework problems, reports, presentations, and design projects. These strategies allow students to apply and analyze fundamental concepts in energy systems. In the prerequisite courses, student progress toward learning outcomes is assessed with traditional tools such as forced-choice tests, essay problem tests, and student surveys.

Students in the Energy Systems Laboratory course are expected to go beyond their ability to apply and analyze fundamental concepts and are expected to develop skills that will promote cognitive growth allowing students to synthesize and evaluate presented material. The course requires students to conduct experiments, write formal and informal reports, and present and discuss results throughout the term. Some of the experiments conducted in the course include road-load simulation of an automobile, lift and drag experiments using NACA airflow sections, performance of fans and centrifugal pumps, compressible flow through a convergent-divergent nozzle, and an energy balance on a turbojet engine. New engineering tools and technologies such as computational fluid dynamics and particle image velocimetry are introduced in the course. The students also apply knowledge gained throughout the course to design experiments for the purpose of analyzing engineering components or systems.

There are a few challenges encountered when designing an effective assessment plan for the Energy Systems Laboratory course. The course is a somewhat non-traditional course and, therefore, a mixture of traditional and non-traditional assessment tools should be used to effectively evaluate student progress toward educational learning outcomes. The implementation of the course also presents challenges. There are at least three, and often four, instructors involved in the course at any time and often different instructors are assigned to the course each term. Because a large and diverse number of instructors are involved in the process, the assessment plan must be one that is easy to follow, easy to apply, applied uniformly, and applied efficiently.

When developing the assessment plan addressed in the next section, all instructors were involved in the process from the beginning. It was necessary to develop a common understanding of course objectives and instructor expectations. It was also necessary to identify available tools.

B. The assessment plan

The intent of the Energy Systems Laboratory course is to provide students with an integrated energy systems experience and to provide students with opportunities to develop effective communication skills. Simply acquiring data and performing calculations is not enough. The students must understand, apply, and communicate results. With this in mind, the course learning objectives were divided into four objectives dealing with the application of fundamental concepts and engineering tools, and two objectives dealing with communication skills and effective team working skills. Mastering all of these objectives prepares the students for work experiences during the cooperative component of their education and after graduation.

The course learning objectives are shown in Table 1. The table also includes course strategies, student learning outcomes, assessment tools, criteria for success, feedback methods, targeted ABET Engineering Criteria (ABET a-s), and Mechanical Engineering Program Educational Outcomes (ME PEO's). A detailed description of each element in the assessment process is contained in the following sections.

Course Objective 1: Provide students with opportunities to apply fundamental principles of thermodynamics, fluid mechanics, and heat transfer.					
Strategies	**Student Outcomes**	**Assessment Methods**	**Criteria for Success**	**Feedback**	**ABET (a-s) ME PEO**
Each student will review lecture material, take quizzes, and conduct laboratory experiments.	(1.1) Students will apply the principles of momentum, energy and continuity to energy systems.	Evaluate performance on 3 worked out problems on both the mid-term exam and the final exam.	(1) For each exam, an average score of no less than 75% of the total points allotted for the 3 problems. (2) An average score of at least 50% of the total points allotted for each problem.	Instructors will review calculations on reports and provide feedback to students. Electronic feedback on quizzes will be given throughout term.	A, E 3
Each student will review lecture material, take quizzes, and conduct laboratory experiments.	(1.2) Student will apply dimensional analysis to experiments.	Evaluate performance on one forced choice question on the mid-term exam.	An average score of no less than 75% of the total points allotted.	Instructors will review calculations on reports and provide feedback to students.	A, E 3
Each student will review lecture material, take quizzes, and conduct laboratory experiments.	(1.3) Students will apply concepts of convection.	Evaluate performance on one worked out problem on the final exam.	An average score of no less than 75% of the total points allotted.	Instructors will review calculations on reports and provide feedback to students.	A, E 3

Course Objective 2: Provide students with opportunities to apply modern measurement techniques and experimental methods to energy systems.					
Strategies	**Student Outcomes**	**Assessment Methods**	**Criteria for Success**	**Feedback**	**ABET (a-s) ME PEO**
Each student will conduct experiments.	(2.1) Students will apply fundamental error analysis concepts.	Evaluate performance on one worked out problem on the final exam.	An average score of no less than 75% of the total points allotted.	Instructors will review error analysis calculations on laboratory reports and provide feedback to students.	B, N 3
Each student will use laboratory equipment in laboratory experiments.	(2.2) Students will apply basic measurement techniques.	Evaluate participation in laboratory experiments using Class Participation Evaluation form.	An average score of no less than 8 on question one of the form.	Instructors will review participation expectations with students throughout term.	B, N 3
Establish lectures on modern measurement techniques. Each student will take quizzes and conduct experiments.	(2.3) Students will apply principles used in modern velocimetry techniques.	Evaluate performance on two forced-choice questions on the final exam.	An average score of at least 75% of the total points allotted for each question.	Students will be given electronic quizzes. Feedback will be provided to the students.	B, N 3
Course Objective 3: Provide students with opportunities to apply computational techniques to energy systems.					
Each student will analyze systems using computational fluid dynamics software and experimental techniques.	(3.1) Students will identify the process followed when applying computational fluid dynamics tools to energy systems.	Evaluate performance on second computational fluid dynamics laboratory report using the Computational Skills Report Evaluation form (50 % sample).	(1) An average score of at least 7. (2) An average of at least 5 on each question.	Instructors will provide feedback on reports.	K 3
Establish lectures on finite difference techniques.	(3.2) Students will develop finite difference approximations of differential equations.	Evaluate performance on one worked out problem on the mid-term exam.	An average score of at least 75 % of the total points allotted.	Electronic feedback will be provided for one quiz.	A 3

Course Objective 4: Provide students with opportunities to design experiments and evaluate experimental results.					
Strategies	**Student Learning Outcomes**	**Assessment Methods**	**Criteria for Success**	**Feedback**	**ABET (a-s) ME PEO**
Each student will work on a team to complete a design project.	(4.1) Students will design appropriate experiments to analyze energy systems.	Evaluate performance using the Design Project Evaluation form (50% sample).	(1) An average score of at least 7. (2) An average of at least 5 on each question.	Instructors will hold class discussions and provide feedback on progress toward completion of design project.	N 1
Each student will work on a team to analyze energy systems through laboratory experiments.	(4.2) Students will properly evaluate and explain experimental results.	Evaluate performance on one informal laboratory report using the Experimental Analysis Evaluation form (50 % sample).	(1) An average score of at least 7. (2) An average of at least 5 on each question.	Instructors will provide feedback on laboratory reports.	B 3
Course Objectives 5: Provide students with opportunities to communicate effectively.					
Each student will contribute to written laboratory reports.	(5.1) Students will produce effective written laboratory reports.	Evaluate performance on third laboratory report using Formal Report Evaluation form.	(1) An average score of at least 7. (2) An average of at least 5 on each question.	Instructors will provide feedback on all written reports.	G 3
Each student will participate in oral presentations.	(5.2) Students will deliver effective oral presentations.	Evaluate performance on final oral presentation using Oral Presentation Evaluation form.	(1) An average score of at least 7. (2) An average of at least 5 on each question.	Instructors and class members will provide feedback to presenters after all oral presentations.	G 3
Course Objective 6: Provide students with opportunities to apply team-working skills.					
Each student will work on a team to conduct experiments and perform a design project.	(6.1) Students will set and work toward team goals.	Evaluate performance through peer evaluation process using Team Skills Evaluation form.	(1) An average score of at least 7. (2) An average score of at least 5 on each question.	Instructors will provide feedback on class discussions.	R 3, 7
Each student will contribute to class and team discussions.	(6.2) Students will contribute to team discussions.	Evaluate performance using Class Participation Evaluation form.	(1) An average score of at least 7. (2) An average of at least 5 on each question.	Instructors will provide feedback on class discussions.	R 3, 7

Table 1. Course evaluation information for Energy Systems Laboratory course.

B.1 Course strategies

When selecting course strategies, the most effective methods for meeting the course objectives as well as the tool available were considered. The available tools include everything from available experimental equipment and software packages, to the knowledge, background, and time-commitment of the instructors. The strategies for the course include a student manual, lectures, laboratory experiments, team work-groups, laboratory reports, oral presentations, and a design project. Although these appear to be traditional methods, some of the delivery strategies are implemented in a non-traditional manner.

The student manual is prepared by the instructors and published by Kettering University each term. The manual includes not only the laboratory experiments, but also a review of fundamental concepts, basic information about experimental methods, and a specific guideline for writing engineering reports. The manual is upgraded every one or two terms to address feedback supplied by students and instructors. The student manual is used as a strategy for course objectives 1, 2, and 5 in Table 1.

Two-hour common lectures covering fundamental energy system concepts, weekly laboratory experiments, necessary information about measurement techniques, and engineering tools necessary for the completion of the weekly laboratory experiment are given each week. Some of the lectures are video taped to provide consistent delivery of the course material by the most qualified instructor despite the fact that different instructors may be involved in the course each term. Lectures are used as strategies for course objectives 1, 2, and 3. As indicated in Table 1, videotaped lectures are used for the computational portion of the course.

Students participate in laboratory experiments each week in two two-hour laboratory sessions. The experiments allow students to apply concepts discussed in the common-lecture and develop team skills. Laboratory experiments are used as strategies for course learning objectives 1, 2, and 3.

Each student team writes a laboratory report for every experiment. Three of the reports are formal engineering reports and the remaining (informal) reports include only sample calculations, results, and a discussion. The intent of the formal laboratory reports is to provide an opportunity for the students to effectively communicate ideas and information in a written format. The informal laboratory reports are intended to focus on the application of fundamental concepts as well as the ability of the students to evaluate and discuss results. After the completion of each report, the laboratory instructors review the reports and provide feedback to each student team. The student teams are then expected to apply the suggested improvements to the following report. Through this process, feedback is continuously provided to the students throughout the term. Laboratory reports are used as strategies for course objectives 1, 3, and 6.

Upon completion of each laboratory report, one student team presents the results for the experiments. All students in the laboratory class are expected to engage in a discussion with the presenting group and compare and contrast experimental results. After the oral presentation is complete, the students and the instructor discuss the strengths and the weaknesses of the presentation allowing for feedback to the presenting group as well as feedback for future presenters. Oral presentations are used as strategies for course objective 5.

All of the students in each laboratory section of the course contribute to a single design project. The projects involve some element of experimentation and the students are required to choose appropriate experiments and instrumentation to achieve desired results. The team must consider the types of measurements that must be made as well as accuracy, precision, and sensitivity of measurements. Upon completion of the project, the students write a formal report and present the design to students in the common lecture class. The design project is used for course objective 4.

B.2 Assessment methods

The assessment tools used in the course include evaluation of student performance on exams, reports, oral presentations, and a design project. Assessment tools also include evaluation of team skills by other team members and evaluation of student class participation by instructors.

Mid-term and final examinations are given to assess individual student progress toward student learning outcomes 1.1, 1.2, 1.3, 2.1, 2.3, and 3.2. All other activities in the class are conducted as a group. The exams are a combination of forced-choice questions and worked out problems. The exam format was chosen for two reasons: worked out problems more effectively measure learning in the synthesis and evaluation cognitive learning domains, and forced-choice problems better reflect the testing environment encountered on the FE/EIT exam. Although preparation for the FE/EIT exam was not a specific objective of the course, students in the course are preparing for this exam and the course serves as a review for questions related to energy systems.

Report development is one of the most effective methods for allowing students to participate in the entire engineering process, thus allowing for synthesis and evaluation including the acquisition of data, the analysis of data, the formulation of results, the evaluation of the system, and the process of effectively communicating ideas, results, and conclusions. Since a large number of instructors are involved in the course throughout the year, it is necessary to adopt an assessment method or tool that can be applied easily, efficiently, and systematically by all instructors. The most effective approach is to develop an evaluation form that measures specific attributes of the report and to identify an evaluation team that does not change throughout the year. It is also necessary to implement an evaluation form that measures attributes considered important by all instructors. Since the instructors are providing feedback to the students throughout the term, everyone involved in the process must have the same expectations. The student laboratory manual is upgraded every two terms to reflect any changes in instructor expectations.

A team of instructors evaluates the final formal laboratory report each term. By the time students have written the final formal report, the instructors have provided feedback to the student work groups on two other formal laboratory reports so it is expected that the students will clearly understand instructor expectations. To expedite the evaluation process, only a random sample of 50 % of all submitted reports is used in the evaluation process.

The evaluation team consists of the three instructors routinely involved in the course throughout the year. The main focus of the evaluation process is to assess the ability of the students to effectively communicate ideas, fundamental concepts, results, and conclusions in a written format. The evaluation forms are used to assess student progress toward student learning outcome 5.1.

One informal laboratory report is evaluated to determine the ability of the students to effectively apply engineering tools and fundamental concepts to energy systems. The report chosen for evaluation involves the application of computational fluid dynamics and experimental results to the analysis of an energy system. The students are given sufficient feedback from instructors on other laboratory reports before the computational fluid dynamics laboratory is completed and assessed. Evaluation forms are completed by the evaluation team and are used to assess student progress toward student learning outcomes 3.1 and 4.2. A random sample of 50 % of the submitted reports is used in the evaluation process. The Computational Skills Evaluation and Experimental Analysis Evaluation forms shown in Table 2 are used in the assessment process.

Student design project reports are evaluated at the end of the term by the assessment team to evaluate student progress toward student learning outcome 4.1. The instructors work closely with the students throughout the term to allow for sufficient feedback before completion of the project. The Design Project Evaluation form used in the assessment process in shown in Table 2.

Oral presentation skills are evaluated near the end of the term by a team of instructors. Students routinely conduct presentations throughout the term in the laboratory class and are provided feedback from the instructor and other students in the class during class discussions. At the end of the term, students present their design projects to the lecture class and a team of instructors evaluate the presentations for each group using the Oral Presentation Evaluation form shown in Table 2.

Progress toward student learning outcomes 2.1 and 6.2 is evaluated using the Class Participation Evaluation form shown in Table 2. The instructors encourage student participation and class discussions throughout the course and provide feedback to the students.

Progress toward student learning outcome 6.1 is evaluated using the Team Skills Evaluation form shown in Table 2. All members of the team complete the form for each member of the team.

To improve the efficiency of the assessment process, assessment forms are evaluated through the software package, Blackboard. The software package allows for data entry and rapid data analysis.

Class Participation Evaluation
1. Students applied basic measurement techniques in laboratory experiments.
2. Students used automatic data acquisition systems.
3. Students completed all laboratory experiments.
Computation Skills Report Evaluation
1. An appropriate computational grid was generated.
2. The appropriate information was used in the pre-processing program.
3. The numerical results were interpreted properly.
4. The numerical results were validated properly.
Team Skills Evaluation (Peer Evaluation)
1. Attended group meetings.
2. Participated in team brainstorming.
3. Assumed responsibilities.
4. Participated in team discussions.
5. Communicated clearly with other team members.
6. Completed assigned team tasks.
Formal Written Report Evaluation
1. The report was organized in a clear and logical manner.
2. The apparatus and experimental technique sections of the report were easy to follow and understand.
3. The sample calculations were easy to follow and understand.
4. Plots and figures presented the subject matter clearly.
5. The report contained a sufficient discussion of the experimental results.
6. A clear and concise conclusion was presented.
Oral Presentation Evaluation
1. The presentation was organized in a clear and logical manner.
2. The presentation included sufficient computer graphics and computer generated presentation material.
3. The topic was explained in sufficient detail.
Experimental Analysis Evaluation
1. Ability to apply fundamental concepts.
2. Ability to apply error analysis to results.
3. Ability to comprehend and discuss results.
Design Project Evaluation
1. The report included a sufficient discussion of published papers and other resources.
2. The report was organized in a clear and logical manner.
3. The component or system was described sufficiently using well-designed experiments.
4. The appropriate analysis tools were applied in the design.
5. The results were interpreted correctly.

Table 2. Evaluation forms used in the assessment process. Each question is assigned a points out of a scale of 1 – 10, with one indicating expectations were not met and 10 indicating that all expectations were met.

B.3 Feedback

Feedback is an important part of the assessment process and is one of the assessment tools applied at the course level. Although accreditation often drives the assessment process, thus leading to feedback after completion of the course or program, the purpose of feedback is to improve the learning process. If feedback only occurs after course or program completion, there are a large number of students that will not benefit from the process. Feedback can be divided into at least four levels: feedback to the students throughout the course by course instructors, feedback to course coordinators and instructors teaching the course upon course completion, feedback to instructors teaching pre-requisite courses upon course completion, and feedback to all instructors involved in the educational process after a segment of students have completed the program. Although the last type of feedback may perhaps be the most important type of feedback for accreditation purposes, all levels of feedback are important for improved learning and should be incorporated into the assessment process. Feedback other than at the course level is beyond the scope of this paper.

Feedback to the students throughout the course on reports, oral presentations, and the design project is the responsibility of the laboratory instructors and is accomplished through the methods outlined in Sections B.1 and B.2. Feedback methods used by the instructors are discussed at an assessment meeting held at the beginning of each term and are part of the assessment report completed and distributed biannually by the course coordinators.

It was discovered early in the development of the course that students did not perform well on the mid-term and final exams. Because of this, common quizzes were implemented throughout the course and offered electronically through Blackboard. This method of quiz delivery proved to be quite efficient and allowed for consistency throughout the course despite changes in laboratory instructors. The software package also allows students to view quiz results and solutions.

Feedback for the course instructors and course coordinators each term is accomplished through assessment meetings and assessment reports. Results from the assessment evaluation upon completion of the previous term are presented and all instructors are involved in devising course improvements or assessment plan changes. Improvements to the student laboratory manual, class lectures, and laboratory experiments are instituted the following term.

It was discovered in the early offerings of the course that the students were not retaining necessary fundamental information from previous courses. Because of this, a pre-test will be given to students at the beginning of the Energy Systems Laboratory course. The fundamental topics students must understand before entering the course will be given to the instructors and students in the thermodynamics, fluid mechanics, and heat transfer courses. The pre-test will be administered electronically through Blackboard to allow students to obtain feedback immediately upon completion of the test. The students will be required to review necessary material to meet course expectations. The purpose of pre-testing is to provide feedback to the instructors and students in the prerequisite courses and to make students aware of instructor expectations prior to entering the Energy Systems Laboratory.

C. ABET Engineering Criteria and Mechanical Engineering Program Educational Objectives

The final step in the assessment process is ensuring that the ABET Engineering Criteria (ABET (a-s)) and Mechanical Engineering Program Educational Objectives (ME PEO's) are met. The correlation between student learning outcomes for the course, ABET a-s, and ME PEO's is shown in the last column of Table 1. Tables 4 and 5 contain a description of the ABET criteria and the ME PEO's. The progress toward meeting these criteria by the entire Mechanical Engineering program is evaluated at the program level and is beyond the scope of this paper.

1	Are knowledgeable in the effective use of modern problem solving and design methodologies.
2	Understand the implications of design decisions in the global engineering marketplace.
3	Are effective engineers, i.e. ones who are able to formulate and analyze problems, to think creatively, communicate effectively, synthesize information, and work collaboratively.
4	Have an appreciation and an enthusiasm for life-long learning.
5	Actively engage in the science of improvement through quality driven processes.
6	Practice professionally and ethically in the field of Mechanical Engineering.
7	Are prepared for positions of leadership in business and industry.

Table 4. Mechanical Engineering Program Educational Outcomes.

III. Assessment obstacles and preliminary results

A few obstacles were encountered while developing and implementing the assessment plan. The obstacles involved both human factors and the need to effectively and efficiently collect data and use the data to improve the student learning process.

Assessment planning and implementation is time-consuming and requires cooperation on the part of the faculty members involved. It is important to remember that the purpose of assessment is to enhance the student learning experience. The belief that assessment is only for the purpose of satisfying ABET makes it difficult to implement an assessment plan that all faculty actively support. During the initial stages of assessment planning, the faculty involved in the course saw assessment as something that was forced on the instructors only for the purpose of satisfying accreditation requirements. Because of this, it was difficult to develop or implement any plan.

Faculty began to see some use for assessment when small portions of the plan were implemented effectively. Data were collected and used to improve the course. Implementing familiar tools, such as exams, is the best place to begin the process. Common midterm and final exams were implemented and student test results were used to evaluate student progress toward learning outcomes. Since the student test scores were low during the first few terms the course was offered, electronic quizzes were implemented and student test scores immediately improved by 5%. This allowed the faculty to understand the importance of collecting and

a.	An ability to apply knowledge of mathematics, science, and engineering.
b.	An ability to design and conduct experiments, as well as, to analyze and interpret data.
c.	An ability to design a system, component, or process to meet desired needs.
d.	An ability to function on multi-disciplinary teams.
e.	An ability to identify, formulate, and solve engineering problems.
f.	An understanding of professional and ethical responsibility.
g.	An ability to communicate effectively.
h.	The broad education necessary to understand the impact of engineering solutions in a global and societal environment.
i.	A recognition of the need for an ability to engage in life-long learning.
j.	A knowledge of contemporary issues.
k.	An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.
Kettering University - Additional ABET Engineering Criteria (l-s) 2002-2003:	
l.	An ability to work professionally in both thermal and mechanical systems areas including the design and realization of such systems.
m.	A competence in the use of computational mathematics and the systems analysis tools germane to the world of engineering.
n.	A competence in experimental design, automatic data acquisition, data analysis, data reduction, and data presentation, both orally and in the written form.
o.	A competence in the use of computer graphics for design communication and visualization.
p.	A knowledge of chemistry and calculus based physics with a depth in at least one of them.
q.	An ability to manage engineering projects including the analysis of economic factors and their impact on the design.
r.	An ability to understand the dynamics of people both in a singular and group setting.
s.	A competence in the analysis of inter-disciplinary mechanical/electrical/hydraulic systems.

Table 5. ABET Engineering Criteria.

evaluating assessment data, then using the data to improve student learning. As the process became more familiar to everyone involved, the faculty began to be more aware of the need to tie the exam questions to the student learning outcomes.

The next part of the assessment process implemented in the course was the evaluation and improvement process used for formal student laboratory reports. It became necessary for everyone teaching the course to become involved in developing a common format for the reports and a common understanding of expected student performance. This was another step toward involving everyone in the assessment process including the students. The students were made aware of the feedback process and clearly understood that the final formal report would be used for ABET assessment purposes. Once the students understood the process, their performance on the formal written reports improved. Course evaluation forms completed by students at the end of the class indicated that the students perceived the written requirements in the course to be a beneficial tool for improving student technical writing skills.

Another obstacle encountered in the development of the assessment plan was the need to overcome the idea that any information that could not be taught in other energy systems courses would be taught in the Energy Systems Laboratory course. As new software tools were implemented in the prerequisite and corequisite courses, fewer topics could be covered in these classes and the Energy Systems Laboratory course was used to compensate for all deficiencies in the Energy Systems thread. A point was reached where it was necessary to reevaluate the objectives of the course and reduce the course content. Meetings were held with all faculty involved in the Energy Systems thread to provide feedback at all stages of the process. The meetings resulted in revisions of the objectives for all prerequisite courses, corequisite courses, and the Energy Systems Laboratory course.

IV. Conclusions

When developing an assessment plan for a somewhat non-traditional course like the Energy Systems Laboratory course, the instructors must share a common vision and common expectations for the assessment plan to be effective. Participation by all instructors during the development stage of the process is essential. The assessment process is more effective when instructors understand and support all aspects of the plan.

The assessment plan should draw on the strengths of the faculty involved in the course and the tools available at the institute. To overcome obstacles, such as continuous changes in laboratory and lecture instructors, strategies that result in consistent delivery of the course material, such as videotaped lectures or student laboratory manuals, should be devised. Selecting assessment tools that can be applied easily and uniformly and implementing available resources, such as software packages, will enhance the efficiency of the assessment process. Assessment meetings aimed at discussing effective feedback techniques and results of the evaluation process should be held regularly. These meetings serve to ensure that all instructors have a common understanding of, and are effective participants in, the assessment process.

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