Transferable Integrated Design Engineering Education

FINAL REPORT

January 1999

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ACKNOWLEDGMENTS

The Transferable Integrated Design Engineering Education (TIDEE) project is supported with funding from the National Science Foundation, Division of Undergraduate Education programs in Course and Curriculum Development and in Undergraduate Faculty Enhancement, under grant number DUE 9455158. Additional support for pre-college summer camps and student support are provided by The Boeing Company.

DEDICATION

This report is dedicated to Richard W. Crain, Jr., a TIDEE project leader who passed away in August 1997. Dick's untiring energy, his dedication and deep understanding of engineering education, and his inspirational perspectives contributed much to the success of the TIDEE project. Many of the concepts and materials developed through this project are directly attributable to our colleague Dick Crain.

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INTRODUCTION

TIDEE is the acronym for "Transferable Integrated Design Engineering Education." This project began in February 1995 with funding from the National Science Foundation (NSF), Division of Undergraduate Education (DUE), jointly supported by Course and Curriculum Development (CCD) and Undergraduate Faculty Enhancement (UFE) programs.

Planning and leadership for the TIDEE project have come from Washington State University (WSU), University of Washington (UW), and Tacoma Community College (TCC). Through the Washington Council for Engineering and Related Technical Education (WCERTE), faculty at other colleges and universities in the state of Washington have been engaged extensively in this project's activities. Project leaders have been Denny Davis and Richard Crain[*] (WSU), Dale Calkins (UW) and Kenneth Gentili (TCC). Michael Trevisan (WSU) has provided educational assessment expertise while Charlena Grimes (WSU) and Janet Hannan (TCC) have coordinated summer camp activities for the project. Faculty at numerous institutions and engineers from a number of companies have participated in multi-disciplinary teams for definition of design concepts and development of curricular materials.

This report describes achievements for the full project period, February 1995 through January 1999. For details on achievements during previous years of the project, readers are referred to numerous reports and presentations referenced in this document Additional information about the TIDEE project may be found on the project's worldwide web site at: http://www.cea.wsu.edu/TIDEE/.

PROJECT GOAL AND OBJECTIVES

GOAL

The overall goal of the TIDEE project is to develop flexible yet consistent foundational (first-two-year) engineering design education for a diverse pool of students who follow a variety of paths toward their engineering baccalaureate degrees. Native and transfer students at an institution will be offered comparable paths to achieve the same "integrated" engineering design competencies and to experience equally high success in degree completion through programs at their respective institutions. Project activities are concentrated in the state of Washington but also extend across the nation through workshop offerings that support dissemination and widespread adoption of project outcomes.

OBJECTIVES

Four primary objectives for the TIDEE project are:

1. Establish a curricular structure for achieving well-defined, transferable introductory engineering design education in an environment of diverse institutions, curricula, and students.
2. Produce exemplary transportable introductory engineering design curricular materials and instructional methods that support effective "integrated" design education in transfer environments.
3. Enable faculty at a variety of institutions to adopt, implement, and evaluate exemplary introductory design curricular materials and instructional methods suitable for their programs and students.
4. Achieve increased enrollment and retention of students, especially women, minorities, and disabled, in early engineering design courses.

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[*] Deceased

PROJECT IMPLEMENTATION THRUSTS

The TIDEE project addresses engineering design education during the first two years of an engineering curriculum, the period during which students are retained or lost from engineering programs and during which a foundation for engineering design must be developed. Faculty teaching design during this period face many challenges, including students with little or widely-varied technical preparation, labor-intensive student design projects, ill-defined design content, and minimal personal history in teaching design. Another challenge is providing students definable design preparation that will effectively transfer to other institutions and to other degree programs, a necessity faced by many engineering students who begin in two-year colleges or change engineering majors. Definable design education outcomes for the first two years of a curriculum also support documentation of achievement and improvement of design education, most notably for transfer among programs, as required for engineering program accreditation by the Engineering Accreditation Council (EAC) of the Accreditation Board for Engineering and Technology (ABET).

In the light of these conditions, the TIDEE project has used three major thrusts to achieve its objectives. These are:

Curricular Development

The curricular development thrust focuses on defining engineering design competencies (or educational outcomes) in the first two years, development of instructional materials and methods to achieve the desired competence, and assessing student achievement of design competencies.

Faculty Enhancement

The faculty enhancement thrust employs workshops to enhance engineering faculty’s understanding of design competencies and to guide them in development of curriculum materials and assessments to ensure that they achieve these competencies in their students.

Student Recruitment and Retention

A multi-institution summer camp has been used to reach prospective students underrepresented in engineering, engage them in the engineering design process, introduce them to a variety of educational institutions, and test project-developed materials and methods with these students.

CURRICULAR DEVELOPMENT

Curricular development has been achieved primarily by the TIDEE project leaders and participants in TIDEE workshops. Faculty participants in workshops and the TIDEE Advisory Panel have helped to define and/or validate, expand, and model concepts.

FRAMEWORK FOR OUTCOMES

Defining educational outcomes requires a framework to clarify concepts for others to understand and to provide a basis for measuring increased levels of achievement over time. The TIDEE project establishes this framework for engineering design educational outcomes.

Design Competencies

Defining engineering design competencies is central to formulating and assessing outcomes-based engineering curricula. Historically, engineering educators have not looked at engineering design as a topic for which specific competencies were required. Recent action by the Accreditation Board for Engineering and Technology (ABET) has adopted outcomes-based accreditation requirements for engineering curricula. This reveals the need for definable competencies in engineering design.

Students’ competencies must prepare them to participate productively in the engineering design process, typically as part of design teams. Three major categories of competencies are required for team-based engineering design: (1) design process, (2) teamwork, and (3) design communication.

Design Process

The engineering design process is defined as six distinguishable elements, as illustrated in Figure 1. This process includes gathering information relevant to a need or opportunity, establishing product requirements, creating alternative solution concepts to address the requirements, analyzing options and selecting the ones best meeting requirements, and converting these decisions into deliverable products. These elements are used frequently and iteratively in steps employed during design. The iterative use of these elements results in a design process that is continually being reviewed and refined.

The six elements of the engineering design process are defined below.

- Information Gathering— Accessing, acquiring, and evaluating information relevant to design issues
- Problem Definition— Preparing statements of project goals and specific technical and non-technical design requirements that must be satisfied for a successful design product
- Idea Generation— Selecting, employing, and improving methods for generating innovative yet relevant ideas as possible approaches to satisfy stated requirements
- Evaluation and Decision Making— Selecting, utilizing, and judging viability of results from methods for analyzing concepts and making design decisions based on established requirements
- Implementation— Interpreting and synthesizing information and decisions and taking action to produce useful deliverables for prospective clients
- Process Development— Managing, evaluating, and improving design activity to use information and resources to achieve design objectives optimally

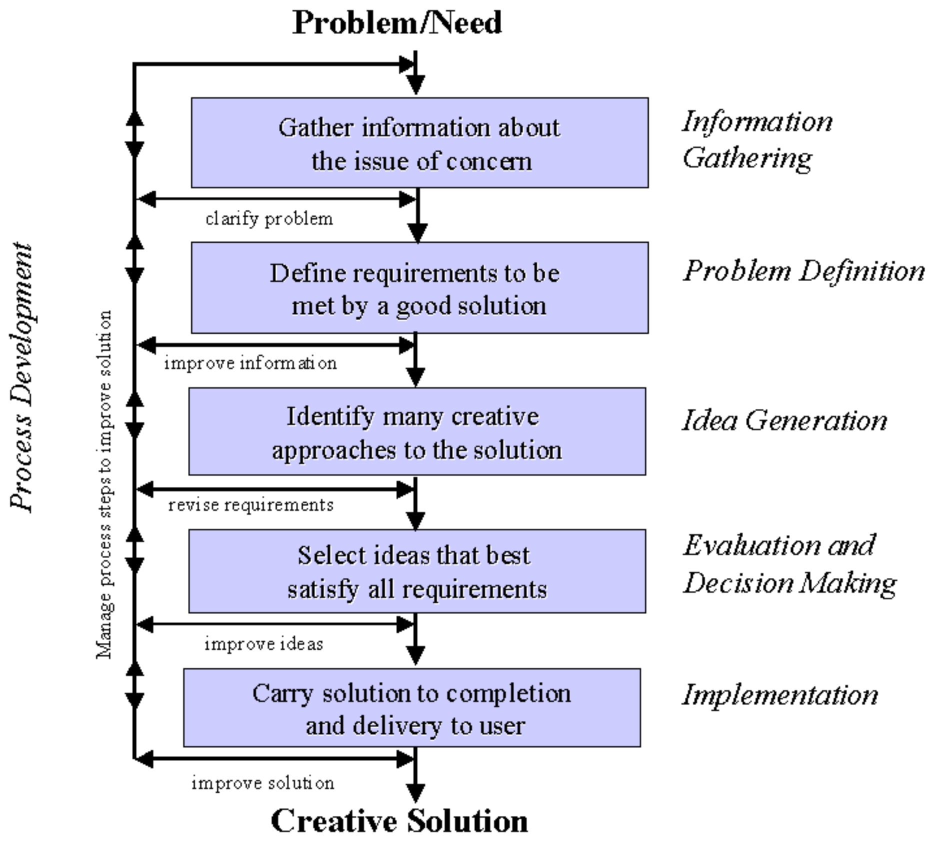

Figure 1. Illustration of the Engineering Design Process

Teamwork

Teamwork is the second category of competencies required for effective performance of team-based engineering design. This encompasses capabilities associated with managing the personnel involved in a project to achieve the performance expected from effective teams. Elements of effective teamwork include:

- Purpose and Goals— Defining and being motivated by common team purpose and goals
- Roles and Responsibilities— Understanding and performing responsibilities as required for effective team function
- Team Attitude— Interacting with other team members in ways that support team cohesiveness, member contribution, and enjoyment
- Planning— Identifying schedules and monitoring progress toward team goals
- Resource Management— Utilizing team member skills, information, and other resources effectively
- Operating Procedures— Understanding and using procedures that support team goals
- Rewards— Using rewards and recognition to encourage team success

Communication

Design-related communication comprises the third category of competencies for team-based engineering design. This category addresses capabilities associated with managing the information and its transfer during completion of a design project. Elements of design communication include:

- Structure— Organizing information to make it understandable in its parts and whole
- Content— Presenting information with completeness and accuracy that establish confidence about its correctness and usefulness under stated conditions
- Relevance to Audience— Including attributes in communication that make information attractive to an audience
- Listening— Achieving receptiveness and attentiveness of recipient that make information understood
- Value— Containing information that adds value to internal and/or external clients
- Availability— Making information convenient and adaptable to other appropriate uses

Levels of Competencies

Designation of student design achievement requires a basis for distinguishing levels of knowledge or skill associated with competencies in a category. Table 1 presents four levels of achievement for engineering design competencies defined by the TIDEE project. These delineate progressive sophistication of knowledge, its use, and its development. Typically, students need some capability at the lowest level (basic knowledge) before they can properly apply this knowledge (application of knowledge level). Then, they need both basic knowledge and some experience in its application before being able to judge and critique the knowledge (critical analysis level). The highest level (extension of knowledge) requires ability to critique in order to discern valid extensions.

Table 1. Definitions for Levels of Achievement for Engineering Design Competencies.

Level	*Description*
Basic Knowledge	Recognition and understanding of facts, terms, definitions, descriptions, relationships
Application of Knowledge	Use of knowledge in ways that demonstrate understanding of concepts or terms, their proper use, and limitations of their applicability
Critical Analysis	Examination and evaluation of information as required to judge its value to a design solution and to make decisions
Extension of Knowledge	Extending knowledge beyond what was received, creating new knowledge, making inferences, transferring knowledge to usefulness in new areas of application

The combination of competency categories and levels offers a framework for distinguishing among a set of design competencies. Using a matrix construction, with a category-vs-level arrangement as shown in Figure 2, enables one to characterize specific competencies and to decide a suitable order for their inclusion in design education.

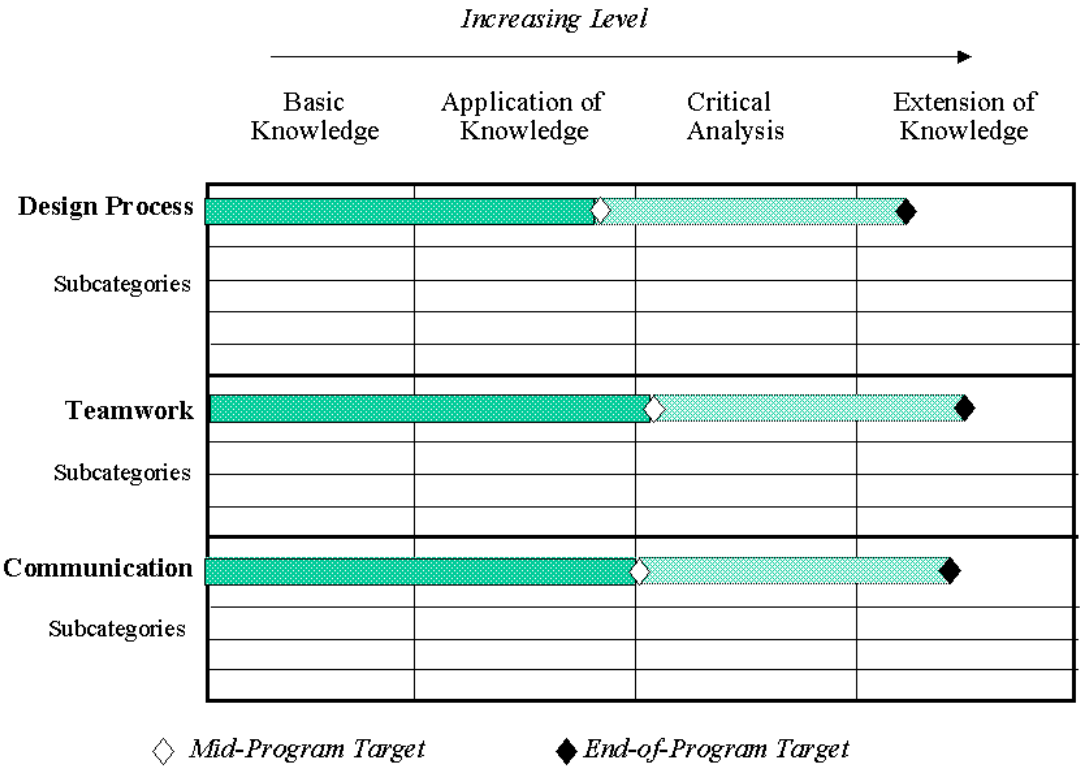

Figure 2. Category-Level Framework for Engineering Design Competencies

The horizontal bars and diamond symbols in Figure 2 illustrate hypothetical levels of targeted competencies for the three design categories, both at the mid-program point and the end-of-program (graduation) point. These bars suggest that students achieve "application of knowledge" to "critical analysis" levels by the end of the first two years of their curriculum and higher levels by graduation. To date, faculty participating in TIDEE workshops in the state of Washington have defined selected target levels for entering-junior engineering students. Their targets are defined for subcategories of the design process category, but for the teamwork and communication categories, they defined only one target level for each category. These engineering design achievement target levels are summarized in Table 2.

Table 2. Target Levels for Engineering Design Competencies at the Mid-Program Point

Category	***Subcategory***	***Target Level***
Design Process	Information Gathering	Critical Analysis
	Problem Definition	Application of Knowledge
	Idea Generation	Critical Analysis
	Evaluation and Decision Making	Application of Knowledge
	Implementation	Application of Knowledge
	Process Development	Application of Knowledge
Teamwork	Overall Teamwork	Critical Analysis
Communication	Overall Design Communication	Critical Analysis

Based on this table, engineering students in the state of Washington should have a significant foundation in engineering design by the end of their first two years of engineering curricula. Entering juniors should demonstrate basic knowledge and an ability to apply this knowledge in each design category. In some categories or subcategories of engineering design competencies, students should be able to judge their own knowledge and skills in engineering design.

In the light of these definitions of targeted levels of competencies for entering juniors, the Washington Council for Engineering and Related Technical Education (WCERTE) adopted a statement which endorses the need for foundational design education in the first two years. This statement, adopted October 25, 1996, is:

> ***“The foundations for design education must be incorporated into the first two years of engineering and engineering technology curricula.***
> ***This includes development of competence in communication, teamwork, and the creative problem solving or engineering design process.”***

The WCERTE endorsement does not specify categories and levels of competencies expected in the entering-junior engineering student. It does, however, imply achievement in the TIDEE categories of design process, teamwork, and communication. An example set of specific competencies that lie within the preparation indicated in the WCERTE statement is given in Table 3. These or similar competencies can be identified and assessed as learning outcomes for students completing the second year of their engineering or engineering technology curriculum.

Table 3. Example Competencies Fitting the WCERTE Endorsement Statement.

Category	*Level*	*Examples of Specific Competencies at Designated Levels*
Design Process	Basic Knowledge	• Students are able to define elements or activities that constitute a generic engineering design process.
	Application of Knowledge	• Students can perform steps of the design process to create a design product satisfying client needs.
Teamwork	Basic Knowledge	• Students are able to define a team structure that functionally supports completion of a given engineering design project.
	Application of Knowledge	• Students can perform satisfactorily each of the identified functional team roles when working on a team project.
Communication	Basic Knowledge	• Students are able to define audience interests and a format to communicate information to this audience.
	Application of Knowledge	• Students can prepare a report that exchanges design-related information intelligibly, neatly, and accurately.

ASSESSMENT OF LEARNING

Types of Learning Outcomes

The TIDEE project identified three types of educational outcomes that are observable, measurable, and relevant to engineering design competencies: student knowledge, student process skills, and design products resulting from students’ efforts. (See Table 4.) Some of these are attributable to individuals, some are distinctly associated with the competencies of a team, and some may be either individual or team outcomes.

Table 4. Types of Observable Outcomes.

Type	*Definition of Outcome Type*
Knowledge	Cognitive information or understanding, as indicated by correctness of answers or explanations of concepts
Process Skills	Steps defined and performed to accomplish tasks or to create requested products, as indicated by proper definition and execution of appropriate steps
Products	Objects or deliverables created upon request, as indicated by extent to which deliverables meet clients’ requirements

Consideration of these outcome types is useful when planning students' educational development and when assigning grades to student work. Figure 3 is a plot showing the relative attention that should be given to the three different types of outcomes at stages during a student's baccalaureate degree program. The student needs to establish a foundation of fundamental knowledge and rudimentary process skills before focusing on the quality of products coming from a design effort. Thus, design education should begin with instruction in design concepts and processes. With the passing of time, and the corresponding increase in students' design proficiency, attention shifts toward the quality of the students' design products. Thus, by the time students graduate, significant attention (and correspondingly, significant weight for grading) should be given to the quality of the final design product. This prepares students for their professions, where the quality of their products is vital to their success.

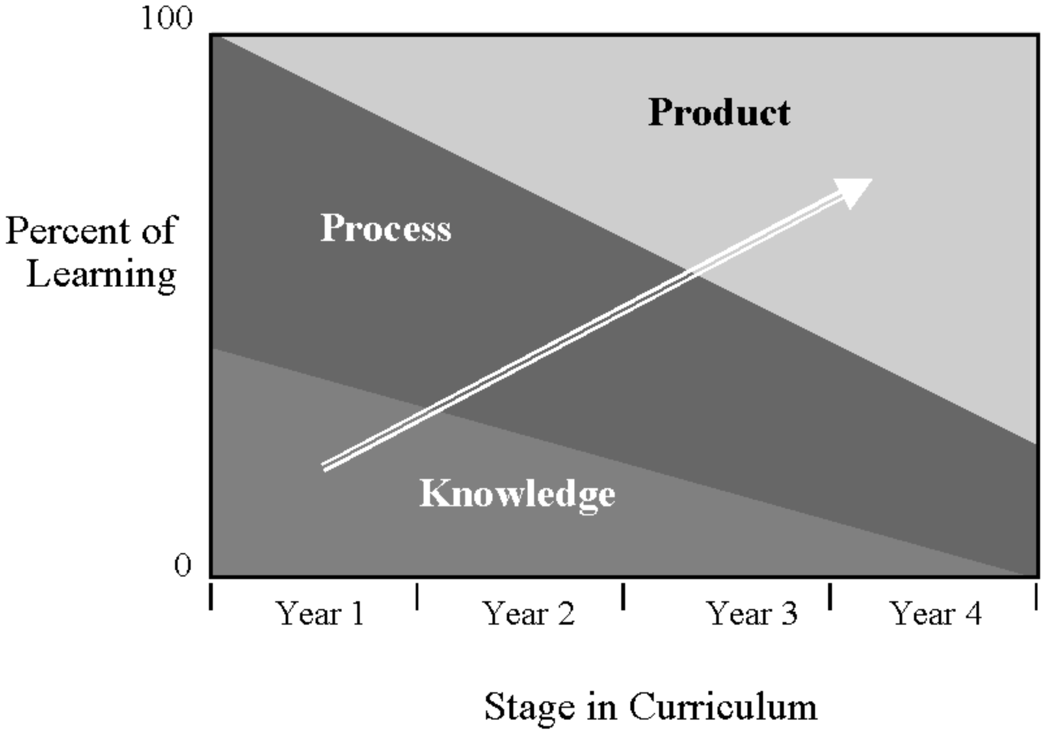

Figure 3. Attention Given to Outcome Types at Different Stages in the Curriculum

Defining Achievement Targets

The purpose of the TIDEE project's engineering design assessment effort is to develop tools by which student achievement of design competencies is measured. These measurements form the basis by which one determines if targeted outcomes have been achieved, and they provide feedback for improvement of student learning of design competencies. (Note: The assessment tools developed in the TIDEE project are not intended for assigning grades to students or rankings to instructors or institutions.)

Conditions for Quality Assessment

The quality of assessment results depends upon the quality of the assessment instrument and assessment process. Quality assessments must meet five conditions:

- The assessments arise from a clearly articulated achievement target.
- The purpose of the assessments is known.
- Appropriate methods are used to obtain assessment data.
- Proper sampling methods are used to represent the student population.
- Assessments are controlled to avoid bias and distortion.

Scales for Design Achievement Targets

The basis for determining student achievement is a set of established educational outcome achievement targets. In the TIDEE project, workshops and other forums were used to determine industry and academic expectations of student achievement in the design process, teamwork, and communication. This information was used to establish a set of scoring scales defining anticipated ranges of engineering student achievement prior to completion of their baccalaureate degrees. These scales are structured around the three categories and corresponding subcategories of competencies defined earlier.

The TIDEE scoring scales for team-based engineering design provide performance descriptions on a scale from 1 to 7. Performance descriptions are defined for scores of 1, 3, 5, and 7, while intermediate definitions may be interpolated from the ones presented. Baccalaureate engineers are expected to achieve a score of approximately 5 in each category. Engineering design achievement targets for entering-juniors lie around a score of 3 on each category scale. The score definitions for overall categories allow students to achieve scores below 3 on selected subcategories (for which development occurs later in the engineering curriculum) and yet achieve an overall category score of 3. Tables 5, 6, and 7 present scoring scales established for design process, teamwork, and communication categories, respectively. These scales continue to undergo revision as their use identifies needed improvement.

Table 5. Scoring Scale for Team-Based Design Category: DESIGN PROCESS

Subcategory: Information Gathering						
1	2	3	4	5	6	7
No information gathered specifically to support design.		Information gathered primarily once or from single source; aware that information varies in quality.		Varied sources used to obtain information; some judgment of information quality; information gathered multiple times.		State-of-the-art and customers fully understood; many, varied information sources used; quality of information determined; information processed, synthesized to improve value.
Subcategory: Problem Definition						
1	2	3	4	5	6	7
No design requirements stated, or few but ambiguous at best.		General design goal stated; design requirements of both technical and non-technical nature defined.		Goal and requirements defined fully, revised over time, address technical and non-technical issues such as performance, cost, reliability, manufacturability, and safety.		Design goal defined; internal and external customer requirements fully defined, refined over time; targets set for technical and non-technical criteria (safety, manufacturability, reliability); life-cycle costs and potential failure causes addressed.
Subcategory: Idea Generation						
1	2	3	4	5	6	7
Need for creativity not addressed or inept at being creative.		Idea generation used to add creativity to design products; used once; only one method used.		Creative ideas sought to improve design products; used more than once; multiple methods used; creative environment sustained.		Creative ideas and approaches sought multiple times throughout design to improve both products and processes; internal and external stimuli used; creative environment sustained.
Subcategory: Evaluation						
1	2	3	4	5	6	7
Only cursory analysis of ideas.		Analysis limited in methods used; quantitative analysis of uncertain reliability; results not checked.		Quantitative and qualitative issues analyzed; appropriate analytical and experimental methods, tools, and information used.		Quantitative and qualitative issues analyzed; proper analytical and experimental methods, tools, and information used; results checked for uncertainty, reviewed by second party.
Subcategory: Decision Making						
1	2	3	4	5	6	7
Decisions made passively or arbitrarily.		Basic decision matrix used to consider requirements in making decisions; team input limited.		Decision matrix used to apply requirements in making decisions; appropriate scoring methods used at different points in decision making; team input used in decision making.		Effective decision making tools and processes used at each design stage; technical and non-technical criteria prioritized and applied; decisions made with broad team input.
Subcategory: Implementation						
1	2	3	4	5	6	7
No deliverables produced or they fail to meet requirements.		Design decisions converted to deliverables; design products meet primary requirements.		Decisions integrated to yield design products that satisfy most system requirements; products delivered on time and within allowed resources.		Decisions fully satisfy or exceed customer requirements at system and component levels; products delivered on time, within budget; continuous improvement practiced.
Subcategory: Process Development						
1	2	3	4	5	6	7
Several design elements not used; no effort to improve.		All design process elements evident; some iteration to improve the desired product.		Process elements used, repeated to improve results; design process planned, recorded, and reviewed for improvement.		Process elements used iteratively to improve results; design process planned, recorded, and reviewed regularly for improvement of both process and product.
OVERALL CATEGORY: DESIGN PROCESS						
1	2	3	4	5	6	7
Most design elements not evidenced; no effort to manage process.		Most design elements evidenced; few show depth of understanding; need for iteration recognized.		All design elements evidenced, some repeated to improve results; depth of understanding seen for several elements; good process management.		All process elements used skillfully and iteratively; design process planned, recorded, and reviewed regularly to improve both process and product; all design criteria met or exceeded; creativity, thorough analysis, customer understanding evident; continuous quality improvement concepts practiced.

Table 6. Scoring Scale for Team-Based Design Category: TEAMWORK

Subcategory: Purpose and Goals

1	2	3	4	5	6	7
Team goals nonexistent or poorly defined; members clueless about team goals.		Team has stated goals; members marginally knowledgeable, moderately committed to goals.		Team driven by clear goals; members know goals and how will be assessed; members committed to common purpose.		Team driven by clear, challenging, dynamic goals; members able to describe goals and explain how achievement is assessed; members regularly review goals and renew commitment.

Subcategory: Roles and Responsibilities

1	2	3	4	5	6	7
Team members have no clear role assignments or role ownership; important roles not performed.		Most members have roles, at least manager and recorder identified; moderately effective in roles.		Members understand responsibilities, own and fulfill their roles to support team; all important roles covered well.		Team defines, facilitates, enforces role expectations; members understand, refine, skillfully fulfill their roles to support team; team reviews and revises roles periodically.

Subcategory: Team Attitude

1	2	3	4	5	6	7
Team members are disrespectful and critical in spirit		Team members share polite acceptance of one another; no team cohesiveness or team pride.		Members foster respect, encourage contributions, show pride in team, are confident and motivated for team success.		Members foster respect in one another, share pride and satisfaction in team and its accomplishments; members confident, highly motivated for team and member success.

Subcategory: Planning

1	2	3	4	5	6	7
Team has no plan to guide efforts toward timely completion of goals.		Team has plan to complete team goals on time; major milestones identified in plan.		Team has schedule to accomplish individual and team goals; milestones identified, monitored to ensure completion on time.		Team has short and long-term plans useful to meet goals; milestones identified and monitored; schedules for team and members reviewed and updated regularly.

Subcategory: Resource Management

1	2	3	4	5	6	7
Team without adequate skills or resources to complete project; no effort to obtain needed resources.		Team has primary skills needed; member capabilities used ineffectively; other resources not accessed or used well.		Team has proper mix, levels of skills needed for project; team uses talents, knowledge, skills of all members; other resources accessed and used effectively.		Team has proper mix and levels of skills; team effectively uses and enhances all members' talents, knowledge, skills; members empowered to make decisions and access resources; resources shared, used effectively.

Subcategory: Operating Procedures

1	2	3	4	5	6	7
Team does not have defined procedures for working together.		Operating procedures in team defined & understood; members generally support them.		Operating procedures defined, understood, supported by members; support effective interaction, decision making, and productivity.		Operating procedures defined, creative, consistent with organization's policies, support team objectives; meetings efficient and add value; members share team maintenance.

Subcategory: Rewards

1	2	3	4	5	6	7
Disincentives for team success; other recognition for achievement rare.		Occasional reward or recognition; team success not given adequate recognition.		Team success clearly recognized and rewarded; members acknowledge individual and team achievements.		Team members & leader frequently, creatively acknowledge individual & team achievements; rewards and recognition contribute to team motivation and success.

OVERALL CATEGORY: TEAMWORK

1	2	3	4	5	6	7
Most of teamwork subcategories missing; no roles assigned.		Team exhibits half of the subcategories; roles assigned; some effort to encourage cooperation.		Team organizes and makes assignments, allocates time and resources; procedures and climate allow team success; members buy-in and work for team success.		Team structured for responsibility and performance; members empowered for team success; clear team focus; strong member commitment; member interactions highly refined; team and member successes rewarded.

Table 7. Scoring Scales for Team-Based Design Category: COMMUNICATION

Subcategory: Structure						
1	2	3	4	5	6	7
Information in random or illogical order; meaning confused by disorder.		Organization makes information understandable; some improvement needed.		Information organized to delineate details and relationships, flow of thoughts, major themes, and key points; highly understandable.		Information organized for rapid understanding at desired depth; clear relationships among parts; logical ordering; structure supports understanding for different learning styles.
Subcategory: Content						
1	2	3	4	5	6	7
Information incomplete or has obvious errors; overall reliability questioned.		Contains essential information; content appears accurate, but validity not documented.		Information stated clearly, completely, and accurately; measures of reliability stated and justified.		Information stated clearly, completely, and accurately; measures of reliability stated and justified; content reviewed and updated as new information becomes available.
Subcategory: Relevance to Audience						
1	2	3	4	5	6	7
Information not relevant to audience as presented.		Information in form understandable to audience, details of appearance or language not effective.		Information in form, appearance, language, and level attractive and understandable to intended audience; understanding communicated well.		Information in form, appearance, language, and level attractive and understandable to intended audience; achieves desired impact on audience's understanding and response.
Subcategory: Listening						
1	2	3	4	5	6	7
Members not attentive, not interested in information.		Members watch and listen when information received or being presented.		Members actively seek to read, listen, and understand; questions asked to clarify; notes made of key points.		Members aggressively read, listen, ask questions, seek application; outlines developed, relationships sketched to enhance understanding and test validity.
Subcategory: Value						
1	2	3	4	5	6	7
Information recorded or communicated has little value to design team or others.		Information is useful to team for making design decisions; communication adds some value to products.		Information is timely and of value to team and to others; supports quality design decisions and value-added actions by others.		Information is of great value to team and to external clients; enhances team knowledge; supports quality design decisions, patent applications, production and delivery of improved products and processes.
Subcategory: Availability						
1	2	3	4	5	6	7
Information not shared with others who could benefit.		Information made available to others on semi-regular basis; untimeliness and irrelevance limit value.		Information made available to others continuously; processes for transfer clearly defined and effective to support team and others needing access.		Information made available to others continuously and conveniently; processes for transfer clearly defined and effective to support team and others needing access; processes ensure security and long-term retrieval.
OVERALL CATEGORY: COMMUNICATION						
1	2	3	4	5	6	7
Information basically not reliable, understandable, or useful.		Information is of value but not as complete and useful as desired; half of subcategories show weaknesses.		Information of quality and usefulness; exhibits positive attributes in most subcategories, some score quite high.		Professional quality recording, transfer, presentation of information; information supports design excellence; reliability and security ensured; scores 5 or above for all subcategories.

Mid-Program Design Assessment Instrument

The TIDEE Mid-Program Assessment for Team-Based Engineering Design was developed as an assessment instrument for students' design achievement at the entering-junior point in their degree programs. This instrument facilitates stand-alone measurement of design capabilities, not requiring a specific course or course content around which it is administered. The assessment can be administered effectively at the start of a junior-level course, at the end of a sophomore-level course, or independent of any course. Sampling of design concepts is accomplished by using a three-component assessment to broaden sources of evidence obtained. Sampling of students may include, for example, the entire set of entering-junior students in a degree program or one or more sections of an entering-junior class. Bias and distortion are controlled through input from numerous faculty, engineers, and students during definition and revision of the assessment instrument.

The three-component assessment collectively addresses the three different types of outcomes being assessed. Some of the targeted entering-junior outcomes relate to knowledge, while others relate to process skills. At early stages of the development of this assessment, faculty encouraged inclusion of questions to determine students' preparation in math and basic sciences as well as in design. However, to provide better focus and relevance to the goals of the TIDEE project, the Mid-Program Assessment of Team-Based Engineering Design includes assessment items related to design that is appropriate for entering-junior students in engineering degree programs.

Component 1: Individual Short-Answer Questions

A short-answer quiz is used to determine students' abilities to provide basic definitions of what constitutes the engineering design process, effective teamwork, and effective communication in support of design. They are given 15 minutes and space between questions on a one-sided quiz page to show their knowledge. These questions seek evidence about students' preparation at the basic knowledge level.

Scoring of this assessment component yields three separate scores— one each for design process, teamwork, and communication. Scores of 1 to 7 are assigned based on the scoring scales in Tables 5, 6, and 7.

Component 2: Group Activity

Students are divided into groups of approximately four students each. All groups are assigned the same design-related activity. Groups are instructed to organize themselves into a team, perform the activity per written instructions (using the design process and teamwork in this effort), and maintain records of their activities and achievements. They are provided worksheets for recording specific information needed as evidence of their performance. This evidence is used to judge especially their process skills in use of the design process, teamwork, and communication. They have approximately 45 minutes to complete and document their work.

Each team member receives a common score for their team's performance in each of the three categories: design process, teamwork, and communication. Using the documentation of their process and the results they achieved, they receive scores from 1 to 7 per definitions in Tables 5, 6, and 7.

Component 3: Individual Essay

Students are asked to write a reflective essay on their team design experience, describing their use of the design process, teamwork, and communication. They are asked to describe incidents of different types and indicate how their approaches worked. This gives evidence about their understanding of concepts (basic knowledge), their actual performance and understanding in a specific situation (application of knowledge), and their ability to discern how well they performed (critical analysis). The essay is normally assigned as homework and targeted at two pages in length.

Students are scored individually based on their understanding and performance of the design process, teamwork, and communication. Their ability to articulate concepts and terms relevant to design is considered as part of their communication score. Each person receives separate scores for design process, teamwork, and communication referenced to scales in Tables 5, 6, and 7.

The Mid-Program Assessment of Team-Based Engineering Design is prepared for distribution in both hardcopy and electronic format. This 37-page document (including appendices) provides an explanation of design education concepts, assessment concepts relevant to design, sample design education outcomes, sample achievement targets, and actual assessment instruments. Hard copies may be obtained from the TIDEE project director, but the entire document is downloadable from the TIDEE web site. Interested parties are encouraged to download, use, and share the instrument. The TIDEE web site URL is: http://www.cea.wsu.edu/TIDEE/.

Assessment Results

The Mid-Program Assessment of Team-Based Engineering Design has been developed and tested with faculty and industry persons at a number of workshops in 1997 and 1998. Participants in these workshops performed the group activity component of the assessment, then they provided suggestions for revising this and other components of the assessment. Their feedback led to changing component 1 from multiple-choice questions to short-answer questions, and to add questions related to design communication. They also suggested using direct-observation scoring of the group activity to replace or supplement the present scoring based on team worksheets. This latter suggestion has been tested with one workshop, but is not refined adequately for inclusion at this time.

The Mid-Program Assessment of Team-Based Design has been pilot tested at the start of junior-level engineering classes at Washington State University and the University of Washington and in freshman engineering classes at Tacoma Community College. Use of this assessment in these classes contributed positively to the climate of the classes and to student learning that followed. Students generally showed interest in participating in the assessment. Faculty administering the assessment identified two benefits to their classes: (a) it demonstrated to students the importance of understanding design concepts in the course and (b) it increased student attention given processes they used later in design activities in the class. Example results obtained from administration of the mid-program assessment are presented in Tables 8 and 9.

Table 8 shows scores obtained for an assessment administration to junior-level engineering students. These values are average scores for members of each team in each of the design categories and for each component of the assessment. Note that for this administration of the assessment, a score for communication was given for only the essay component of the assessment, as occurred before design communication questions were added to the quiz (component 1). Although individual member scores (not shown) varied from 1 to 5, mean team scores for a category and component of the assessment appear relatively consistent. This class overall performed at a score of 3.1 in the design process category, 2.7 in the teamwork category, and 2.8 in the communication category. These scores are near but slightly below the target score of 3 for entering-junior engineering students in Washington. This suggests that students in classes prior to their junior year need additional instruction in teamwork and writing so they achieve statewide targets for engineering design educational outcomes.

Table 8. Sample Summary of Entering-Junior Performance on Mid-Program Design Assessment.

	Design Process			***Teamwork***			***Communication***	
	Quiz	*Group*	*Essay*	*Quiz*	*Group*	*Essay*	*Essay*	*Row Mean*
Team A Mean	2.75	3.00	2.13	3.63	2.50	2.50	2.63	2.73
Team B Mean	2.75	3.00	2.13	2.50	2.00	2.38	2.38	2.45
Team C Mean	3.90	4.00	3.60	3.00	2.00	3.40	3.20	3.30
Column Mean	**3.19**	**3.38**	**2.69**	**3.04**	**2.15**	**2.81**	**2.77**	**2.86**
Category Mean	**3.09**			**2.67**			**2.77**	

Table 9 shows comparable scores for teams of students in a freshman engineering class. In this (somewhat larger) class, individual student scores ranged from 0 to 4 (not shown), as would be expected for students with widely varied backgrounds and no formal instruction in engineering design yet in this class. Overall class scores for the design process, teamwork, and communication categories are 2.6, 2.0, and 2.1, respectively. This indicates that instruction is required to raise the scores of the entire class, and some students significantly more than others, to achieve scores of 3 before they reach their junior year. Based on the scores shown for the design category, these students need to learn concepts of the engineering design process and learn how to articulate them. Teamwork scores suggest that students know some concepts of teamwork, but they are not able to implement them effectively in practice. Communication scores indicate that some students need help in written communication.

Table 9. Sample Summary of Freshman Performance on Mid-Program Design Assessment.

	Design Process			***Teamwork***			***Communication***	
	Quiz	*Group*	*Essay*	*Quiz*	*Group*	*Essay*	*Essay*	*Row Mean*
Team A Mean	2.88	3.50	2.25	0.50	3.00	1.50	2.00	2.32
Team B Mean	2.25	4.00	1.67	1.25	2.50	1.83	2.17	2.28
Team C Mean	1.88	3.50	2.17	2.00	3.00	2.00	2.00	2.40
Team D Mean	2.50	2.00	2.30	1.80	1.00	1.90	2.00	1.93
Team E Mean	1.75	3.00	2.38	2.75	2.00	2.38	2.13	2.34
Column Mean	**2.26**	**3.14**	**2.18**	**1.67**	**2.24**	**1.97**	**2.06**	**2.23**
Category Mean	**2.55**			**1.96**			**2.06**	

These two class examples illustrate the usefulness of the Mid-Program Assessment for Team-Based Engineering Design for improving engineering design education. Results of the assessment provide useful feedback to (1) identify students' overall achievement levels relative to established targets, (2) identify categories within engineering design where individual or class strengths and weaknesses occur, and (3) distinguish between capabilities in knowledge and skill capabilities. These kinds of information help guide revisions to instructional materials and instructional methods to improve student preparation for team-based engineering design.

Faculty are positioned to be the primary users of this assessment and the implementers of change. They need to be prepared to administer the assessment, interpret results, and create effective learning situations focused to develop needed student competencies. The faculty enhancement thrust of the TIDEE project addresses these issues.

FACULTY ENHANCEMENT

The TIDEE project's faculty enhancement efforts have created and used an integrated learning model to achieve its goals. The integrated learning model defines a structure for effective teams and uses well-structured learning activities to achieve both conceptual understanding and practical skills. Through TIDEE workshops, faculty, practicing engineers, and others have collaborated to define engineering design concepts, define structure for engineering design education, and create effective design education teaching materials and corresponding assessments.

WORKSHOPS CONDUCTED

Table 10 lists the workshops conducted as part of the TIDEE project during the four-year duration of this project. These workshops addressed the definition of design competencies, creation of learning activities to achieve design competencies, definition of design assessment concepts, and development of assessments for design outcomes. The TIDEE project leaders also found this workshop model useful with K-12 students, teachers, and administrators as well as faculty from non-engineering disciplines and practicing engineers.

Table 10. TIDEE Workshops Conducted for Faculty and Others

Dates	***Length***	***Workshop Title***	***Workshop Audience***	***No.****
1-9-95	7 hr	Process Education	WSU-CEA** faculty	20
1-30-95	7 hr	Process Education and Engineering Design	WSU-CEA faculty	18
4-27-95	7 hr	Design Engineering Education	WCERTE***	20
6-19-95 to 6-21-95	3 dy	TIDEE Faculty Workshop	WA state engineering faculty	10
8-17-95 to 8-18-95	2 dy	Enhancing Development of Design Competencies	WSU faculty	14
10-26-95	7 hr	Engineering Education to Achieve Competence in Design	WCERTE	18
11-9-95 & 11-16-95	4 hr	Walla Walla College TIDEE Workshop	Walla Walla College engineering faculty	13
1-8-96	4 hr	Design Competency Workshop	WSU-CEA faculty	10
1-9-96	8 hr	Creating and Assessing Design Projects	WSU-CEA faculty	9
5-2-96	2 hr	Introduction to Competency-Based Design Education	WCERTE	12
5-2-96	2 hr	Assessment in Engineering Design Education	WCERTE	11
6-17-96	7 hr	Fundamentals of Engineering Design Education	WA engineering faculty	7
6-18-96 to 6-19-96	7 hr	Creation and Assessment of Design Projects	WA state engineering faculty	8
7-14-96	7 hr	Outcomes-Based Engineering Education	ASAE annual conference	15
10-19-96	4 hr	Getting Started: Collaborative and Active Learning in Science and Technology Classes	North Seattle Community College	20
1-7-97	7 hr	Creative Problem Solving Approach to Enhanced Student Learning	WSU faculty	27
3-24-97	3 hr	Team-Based Creative Problem Solving: A Model for Learning and Doing	Cascade Christian School administrators	13
4-11-97	1.5 hr	The Importance of High-Quality Assessment	National Assessment Conference	40
5-1-97	7 hr	Foundation for Outcomes-Based Engineering Education: Structure, Practice & Assessment	PNW-ASEE conference	22
6-15-97	7 hr	Foundation for Outcomes-Based Engineering Education: Structure, Practice & Assessment	Annual ASEE conference	12
6-30-97 to 7-2-97	3 dy	Creating and Assessing Outcomes-Based Design Projects	National engineering faculty	14
8-10-97	7 hr	Outcomes-Based Engineering Education	ASAE annual conference	15
8-14-97 to 8-15-97	2 dy	Outcomes-Based Engineering Programs	University of Idaho engineering faculty	20
10-23-97	7 hr	Entering-Junior Engineering Design Assessment	WCERTE	16
11-5-97	3 hr	Outcomes-Based Engineering Education	FIE annual conference	13
2-28-98		Using Continuous Assessment to Create High Expectations in Student Learning	TYC-21 Region 3 Conference	23
3-98 to 5-98		Developing and Adapting TIDEE Material for Elementary School Physical Science Classes	Tacoma 5th grade teacher, aids, students	25
4-24-98	3 hr	Assessment of Entering-Junior Design Capabilities	PN-ASEE conference	16
4-30-98	4 hr	Developing and Assessing Teamwork in Engineering Design	WCERTE	5
4-30-98	4 hr	Assessment of Entering-Junior Engineering Design Capabilities	WCERTE	15
7-14-98	4 hr	Developing and Assessing Teamwork in Engineering Design	ASAE annual conference	17
8-98	2 hr	Developing Teams for Effective Collaborative Learning	TYC-21 National Conference	55
10-16-98 to 10-17-98	1 hr + 1 hr	The Meaning and Importance of High-Quality Assessment	National Assessment Conference	25
10-17-98	1.5 hr	Multi-Component Assessment for Engineering Design Competencies	National Assessment Conference	19
			TOTAL	597

* Attendees **College of Engineering and Architecture ***Washington Council for Engineering and Related Technical Education

Workshop participants over the duration of the TIDEE project total approximately 600. Participant information was obtained for 267 different workshop participants. Of these 163 (61% were from the state of Washington). Ten (4%) of these were industry representatives. Eighty six (32%) were from outside Washington, and 8 (3%) were from outside the US. One hundred eighty one (68%) of Washington participants were faculty. Of these, 58% represented 4-year public institutions, 23% represented 2-year public institutions, and the remainder represented from private institutions. This identifiable participant population provided diverse perspectives for development of TIDEE materials. The unidentified participants were equally as diverse—some representing disciplines outside engineering, many outside of Washington, some practicing engineers, and some engineering students.

WORKSHOP IMPACT

Impact of the TIDEE workshops is evidenced by the number of workshops repeated or offered in response to invitations. The 1998 ASAE national workshop was invited (and another workshop invitation has been accepted for July 1999). Workshops conducted for the American Physics Teachers were invited, as were the workshop at Ohio State University and the one for the University of Idaho. The ECSEL* Coalition requested a workshop for their Articulation 2000 partners, although as planning progressed for this workshop, it became an interactive presentation instead of a typical workshop. The popularity of the TIDEE workshops has demonstrated that TIDEE concepts and methods are applicable to a broad audience interested in effective active and collaborative learning strategies and outcomes-based engineering design education.

Survey Questions

A more direct measure of the impact of TIDEE workshops was obtained from surveys of workshop participants conducted in December 1995 and December 1996. This survey was designed to determine the impacts of workshops on faculty teaching of engineering topics (design and engineering science). In 1996, a total of 26 responses were received from surveys sent to over 150 participants. Respondents represented 2-year community colleges and 4-year private and public institutions in the state of Washington and 4-year public institutions outside the state. They also represented a wide range of disciplines and attendees of workshops presented as early as January 1995. Thus, results appear to represent the broad population of workshop attendees.

Results obtained from the two survey administrations were similar, so only 1996 results are presented in Table 11. Respondents participated in a variety of workshops, so their experiences were different. The highest mean score (3.5 out of 5) showed significant impact of workshops on faculty members' teaching of design; over half of them indicated strong (score of 4 or 5) impact on their teaching of design. Responses indicated that workshops also impacted faculty members' teaching of engineering science (84% indicating significant impact). Another area of high impact is faculty use of student teams to enhance learning (96% indicating significant impact and 85% indicating strong impact). In each area queried, over 75% of the respondents acknowledged significant impact from the workshops.

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* Engineering Coalition of Schools for Excellence in Engineering Education and Leadership

Table 11. Impact of Workshops on Participants

Area of Impact	***Survey Question and Response Choices***	***Mean Score***	***Significant (2 to 5)***	***Strong (4 to 5)***
Teaching Engineering Design	How would you rate the impact of the workshop(s) you attended on your teaching of engineering design? (0 = none to 5 = major)	3.5	96%	57%
Teaching Engineering Science	How would you rate the impact of the workshop(s) you attended on your teaching of engineering science? (0 = none to 5 = major)	2.8	84%	32%
Understanding Design Process	Amount the workshop(s) contributed to your understanding the engineering design process: (0 = none to 5 = very much)	2.3	85%	42%
Understanding Design Competencies	Amount the workshop(s) contributed to your understanding competencies required in design: (0 = none to 5 = very much)	2.7	96%	54%
Understanding Competency Levels	Amount the workshop(s) contributed to your understanding levels of student achievement in design: (0 = none to 5 = very much)	2.3	96%	28%
Planning Learning Exercises	Amount the workshop(s) contributed to your planning exercises to achieve specific learning outcomes: (0 = none to 5 = very much)	2.5	92%	50%
Enhance Student Learning	Amount the workshop(s) contributed to your enhancing student learning of engineering topics: (0 = none to 5 = very much)	2.3	81%	38%
Scoring Student Achievement	Amount the workshop(s) contributed to your scoring student achievement in design: (0 = none to 5 = very much)	2.1	81%	27%
Using Teams in Student Learning	Amount the workshop(s) contributed to your using student groups/teams to enhance their learning: (0 = none to 5 = very much)	3.0	96%	81%
Developing Team Skills in Students	Amount the workshop(s) contributed to your development of effective team skills in students: (0 = none to 5 = very much)	2.9	96%	73%
Understanding Outcomes-Based Education	Amount the workshop(s) contributed to your understanding what outcomes-based education is: (0 = none to 5 = very much)	2.5	92%	44%
Assessing Student Outcomes	Amount the workshop(s) contributed to your assessing outcomes from engineering education: (0 = none to 5 = very much)	2.1	76%	28%

Teaching Changes Made

The surveys asked faculty to identify teaching changes they made due to their participation in one or more of the TIDEE workshops. Twenty-one of 26 respondents listed changes they had made. Table 12 shows their responses categorized as those relating to use of teams (T), use of design projects (D), addressing competencies (C), or assessment of outcomes (A). Because all the workshops have addressed teamwork and the design process, it is not surprising to see that these areas were affected most, according to reported changes.

Table 12. Teaching Changes Made by Workshop Survey Respondents.

Reported Change in Teaching	**T***	**D**	**C**	**A**
• Focused classes towards groups/teams activities to greater extent. Planning exercises to achieve specific learning outcomes and assessing these.	X		X	X
• Suggested more team-design to our senior projects students.	X	X		
• More teamwork in junior classes.	X			
• Assigning students in small groups to analyze information presented in drawings and team drafting.	X			
• Added a design project to a required junior-level course in EM fields and waves. Students work in teams, write up a "professional" report, & present their results in front of the class.	X	X		
• Student design teams are organized now, as per the workshop methods.	X			
• Factored what I learned into the 7-week team project assignment I give my students.	X	X		
• More team structure in group projects.	X			
• Impacts both teaching and research strategies for everything I do.				
• Incorporated/emphasized leadership and task assigning to design projects.	X			
• Perhaps the most important benefits have been: how to structure practical design problem, improve quality of understanding of the design process for the students through self discovery and teamwork. These were fundamental issues both for MEEP and TIDEE.		X		
• I have generated criteria & method for group selection and communication.	X			
• Using small group interaction for learning.	X			
• Increased use of brainstorming (exploring) associated with classroom work.		X		
• Now use roles for student team members. Now use design problems in junior-level courses. Developed group design projects for new freshman-level sci./tech. course.	X	X		
• In senior Ag processing (non Engr.) class, I do group work differently, now assigning tasks and grading on process as well as final product.	X			X
• I can't say I've made any specific changes at this time. I am, however, more tuned in to assessment issues.				X
• Using learning base outcomes when planning design projects. Use of reflectors. Learning to separate process from product when learning design.	X	X	X	
• Used student involvement methods to increase class participation on engineering ethics.	X			
• I now make more use of brief team exercises to build teamwork and skills in the different team roles. I am currently trying an exercise developed in one of the workshops (Handout attached).	X	X		
• More group involvement; specify expected outcomes for students.	X		X	

* T = teamwork, D = design, C = competencies, A = assessment

TEACHING/LEARNING MATERIALS

A number of teaching and learning materials have been developed for classes associated with the TIDEE project, for use in TIDEE workshops, or as products of TIDEE workshops. Most of these are team activities that require 10 to 45 minutes and focus participants on concepts specifically related to team-based engineering design education. Table 13 summarizes the major groupings of activities developed. Additional detail on teaching/learning activity topics is found in the Appendix.

Table 13. Summary of Developed Teaching/Learning Activity Variations

Activity Major Group	***Activity Sub-Group***	***Activities***
Team Process	Team Member Differences	2
	Team Roles	4
	Fostering Teamwork	2
	Team Assessment	3
Communication	Oral Report	1
	Communication within Group	2
The Design Process	Steps or Activities	2
	Steps or Activities to Categories	6
	Interrelationship of Design Process Categories	1
	Assigning Competencies to Categories	1
	Competencies Scaled to Year	2
	Competencies to Categories and Learning Levels	1
Desired Design Competency Levels of Students	Mid-Program or Entering-Junior	1
	End-of-Program	1
Assessment of Students	Quality Assessment Defined	1
	Steps to Assessment	4
	Types of Assessment	3
	Pilot Assessment: “Entering-Junior Design Assessment”	6
	Uses of Assessment	1

The engineering design concepts encompassed in the TIDEE teaching/learning model link the engineering design process to structured team-based learning activities. These concepts, methods, and materials are being described in a text under development by the project authors.[1]

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[1] Teaching, Learning, and Assessing Engineering Practice and Design

STUDENT RECRUITMENT AND RETENTION

The primary focus of the TIDEE project's student recruitment and retention efforts was to increase the diversity of engineering enrollment. This was approached through a summer camp developed around TIDEE design concepts and learning methods. A secondary function of the summer camp was to provide a forum for testing the appropriateness of TIDEE methods and materials for high school students and for students normally under-represented in engineering.

The summer camp was developed to address the following conditions:

- High school students have limited exposure to engineering as a profession, and engineering enrollments for female, African American, Native American, and Hispanic/Latino American students remain especially low.
- Attributes desired in new engineering graduates include experience in engineering design, flexible problem solving skills, and teamwork.
- Engineering design is fundamental to all areas of engineering education and it embodies the elements of engineering of greatest interest to new learners.

The introductory engineering design curriculum developed from the statewide TIDEE project was used for the summer camp. Most camp activities were presented at the college freshman level. The camp presented engineering in a lively, interactive way to encourage continued study in math and science in high school. The high school campers participated in hands-on, team-based, collaborative and active learning activities. Camper teams worked with university engineering faculty on small research projects, which resulted in a technical poster presentation at the camp's conclusion. However, since this was a summer camp and not a regular class, the camp schedule included more physical activities, more breaks, more teaming exercises, and less homework.

Leadership for the high school summer camp was provided by Tacoma Community College, with aid from Washington State University and University of Washington. Camp leaders included Janet Hannan and Ken Gentili at TCC, Dale Calkins at UW, and Charlena Grimes at WSU. Richard Crain at WSU contributed to the camp in 1995 through 1997. In addition to its funding from the NSF, the TIDEE summer science camp received funding intended to increase underrepresented enrollment in engineering from The Boeing Company.

Twenty to twenty five outstanding entering-sophomore and entering-junior students participated each of the four years of the camp. With the help of the Tacoma MESA (Mathematics, Engineering, Science Achievement) office, diverse groups of applicants were obtained each year. Participant selection was based on a personal essay written by the prospective camper, a recommendation by a teacher, and the student's interest in science.

SUMMER CAMP STRUCTURE

Goals for the TIDEE camp were threefold:

- Build skills in engineering design, including developing teamwork skills
- Increase career awareness in engineering and other sciences
- Increase camper confidence in creative problem solving

Five components of the camp were developed to achieve these goals. Student campers were:

- Introduced to various engineering fields and shown the preparation needed for them
- Engaged in a small group research project with university engineering faculty
- Guided through a tour of an engineering firm
- Engaged in activities structured to ensure that everyone experiences some success
- Provided substantial time-on-task, with journal writing and preparing team poster presentations.

Campers were organized into teams for their learning experiences. For the first week, each team consisted of four or five high school students, plus a teaching assistant (TA). The TAs were college students representing a diversity of underrepresented groups, having been selected based on their experiences in engineering design, teamwork, and leadership. Each TA supported a specific camper team, facilitated large group discussions, and led team-building activities. Students were assigned to a new 3- to 5-person team during their second week.

Each year, the TIDEE summer camp was held during two consecutive weeks in July. The first week was a day camp at Tacoma Community College (TCC) with a day trip to the University of Washington (UW), and the second week was a residential camp at Washington State University (WSU). The closing activity of the camp was a technical poster presentation and awards banquet for campers and their families back at TCC.

The first week introduced students to the entire process of engineering design several times, increasing camper skills in team building, communication, and process development through a series of activities. Students worked on design projects including a T-shirt design, camera dissection (reverse design), reverse engineering of a bicycle, and planning a bike trip based on their problem definitions for the trip. They also analyzed human-powered vehicle designs. These design projects addressed several engineering design competencies including communication skills, team building, decision making, the iterative nature of engineering design, and cost constraints.

To start the second week of the TIDEE camp, campers were driven 300 miles in school vans to Washington State University in Eastern Washington. They lived on campus in residence halls for five days. They toured a local engineering firm that manufactures fault-detection devices for power companies, and they visited a pulp mill to see engineering applications to this industry. At WSU campers experienced the breadth of engineering fields available to them as they explored various engineering and science departments. Campers learned about academic research and how to design and prepare posters for effective poster presentations. WSU faculty led camper teams in small group research projects, in which students performed varied technical activities. Students recorded data and learned concepts that provided the basis for a technical poster, which they presented to their families at the closing awards banquet.

CAMP ACHIEVEMENTS

At the conclusion of the camp, students completed camp evaluations to self-assess their learning in engineering design and to report the impact of the camp on possible career choices in engineering. Based on this feedback, the TIDEE summer camp clearly met its goals. Evaluation results showed a great increase in students' design competencies, especially team building. Campers were enthusiastic about their camp experiences. Many campers wanted to return again, or to help in another capacity.

Observations by the TIDEE personnel and feedback from campers identified a number of camp successes. The team-based, cooperative, hands-on activities appealed to the campers. Camp activities were planned for student success, and they provided a safe and supportive environment. Teaching assistants, graduate students, instructors, and professors were good engineering role models. Tours expanded campers' career horizons. Campers believed they had acquired competencies in all areas of engineering design addressed. Campers' experiences away from home built their confidence and expanded their career aspirations. Minority and women TAs developed enhanced leadership capabilities that produced unanticipated results: subsequent promotion of the camp and recruitment of students, new teaching materials, and a new program at TCC to recruit and mentor women and minorities.

The awards banquet was a striking success as it brought campers and their families together around engineering topics—enabling all to increase their understanding and collective commitment to engineering careers. This sets the stage for successful participation in engineering education programs that will open engineering careers to these students.

ADVISORY PANEL

A TIDEE Advisory Panel was appointed to provide external perspectives to the project. This panel has met annually with the TIDEE project leaders to review accomplishments, provide recommendations for project focus, and assist the TIDEE project implementation in other ways. Members have contributed significantly to the review and definition of engineering educational outcomes that are appropriate preparation for engineering practice and are relevant to students with diverse backgrounds and interests. Contributions of Mr. Selby and Mr. Dewey were especially helpful to TIDEE leaders in establishing categories and subcategories for competencies and in defining scoring scales for student achievement of engineering design competencies.

Membership on the TIDEE Advisory Panel is presented in Table 14. Members include representatives from institutions of higher education in the state of Washington, organizations that support diversity in engineering, and employers of engineering graduates.

Table 14. Membership on the TIDEE Advisory Panel.

Name	***Title***	***Affiliation***
Mr. Steve Mason	Supervisor, Chemical Technology	Boeing Commercial Airplane Group
Mr. Fred Ives	Project Manager	Hewlett-Packard Company
Mr. John Selby	Engineering Specialist	Weyerhaeuser Company
Mr. John McIntyre	Manager, Sumner Office	Parametrix Consulting Engineers
Mr. Gerald Walls	Director, Engineering Services	Puget Sound Power & Light Co.
Ms. Suzanne Hahn	Supervisor, Process Engineering Department	Texaco
Mr. Donald Dewey	Director of Technical Education	Boeing Commercial Airplane Group
Dr. Patricia Daniels	Associate Dean, Science and Engineering	Seattle University
Dr. Gretchen Kalonji	Associate Professor, Materials Science, Campus Director ECSEL[a]	University of Washington
Dr. Greg Miller	Associate Professor, Civil Engineering	University of Washington
Dr. Jens Jorgensen	MEEP[b] PI, Professor, Mechanical Engineering	University of Washington
Dr. Howard Copp / Dr. David McLean	Assistant Chair, Civil and Environmental Engineering	Washington State University
Mr. Jeff Burnett	Assistant Professor, Architecture	Washington State University
Ms. Elinor Christenson	Engineering Instructor	Shoreline Community College
Mr. Robert Christianson	Engineering Instructor	Green River Community College
Ms. Donna Odom	Director, Minority Engineering and Technology Program	Tacoma Community College
Ms. Susan Starbuck	Director, Women in Science & Engineering	North Seattle Community College
Ms. Brenda Walker	Director, Tacoma MESA	Pacific Lutheran University
Mr. Gene Magallenes	Director, Minority Science & Engineering Program	University of Washington

[a] Engineering Coalition of Schools for Excellence in Engineering Education and Leadership, NSF engineering education coalition
[b] Manufacturing Engineering Education Partnership, DoD-TRP and NSF-DMI university-industry educational partnership

Significant contributions of the TIDEE Advisory Panel to the project include:

- Provided recommendations for collaboration with appropriate individuals, organizations, coalitions
- Defined engineering design competencies utilized in industry
- Described evaluation systems used in industry for team contributions
- Provided guidance and encouragement to gain statewide endorsement of design education in first two years
- Defined focus of engineering design education during the first two years of curricula
- Expressed need for extending TIDEE concepts and models to second half of the curriculum
- Assisted in developing a plan for extending TIDEE to a regional project (needing new funding)
- Provided diverse perspectives to the TIDEE project
- Endorsed and revised annual priorities to guide project efforts

SUMMARY OF PROJECT ACHIEVEMENTS

The TIDEE project grew in faculty participation and gained energy far exceeding the expectations of the projects' leaders. Aware that outcomes-based education would be required for accreditation under ABET EC 2000, many faculty and engineering professionals saw the importance of establishing design education outcomes and assessing their achievement. This need for outcomes-based engineering design education added fuel to the TIDEE project.

The TIDEE project's workshops provided structured forums for addressing engineering design education concerns. These engendered understanding and statewide consensus on engineering design education competencies at a time when faculty teaching engineering design needed this assistance. From the contributions of hundreds of educators and practicing engineers, key engineering design concepts, methods, and materials were synthesized. These products offer a useful framework and practical methods for teaching engineering design. They also present user-friendly tools for measuring student achievement of engineering design competencies.

The most significant achievements of the TIDEE project are listed below.

- A framework has been developed for definition of engineering design competencies at different points in a curriculum. This framework establishes a set of engineering design competency categories and subcategories and four levels of achievement within categories and subcategories. Specific competencies defined in this framework identify targeted design education outcomes of three possible types—student knowledge, process skills, and products of their efforts—which are observable for assessment.
- An assessment system has been developed to enable measurement of mid-program (end of first two years of a degree program) design outcomes achievement. The assessment uses open-ended questions, a group activity, and a self-reflective essay to produce products to be assessed. This assessment has been used in pilot test situations at cooperating universities and colleges.
- Significant partnering relationships have been established among two-year colleges, four-year universities, and industry. Successful collaboration on an issue important to all parties has produced results responsive to everyone's needs and has increased levels of trust for future cooperation on educational issues.
- An integrated learning model, which engages functionally-defined teams in structured outcomes-based activities, has proven effective in achieving specific learning objectives. This model has been used effectively in classes, workshops, and in other gatherings of undergraduate students, high school students, faculty, and engineering professionals.
- Approximately 600 faculty and engineering practitioners have participated in 34 TIDEE workshops, in which they practiced team-based learning and developed curricular materials. They have validated definitions of design competencies, created new student learning activities, defined assessment materials, and targeted outcomes for specific points in engineering degree programs.
- Statewide agreement has been obtained from two-year and four-year institutions, endorsing the concept that a foundation for engineering design be established for students in the first two years of their engineering and engineering technology degree programs. This endorsement was based on faculty's understanding of engineering design competencies appropriate for the first two years, achieved through TIDEE workshops.
- Representatives from engineering programs in the state of Washington have agreed in principle to use the TIDEE Mid-Program Assessment of Team-Based Engineering Design to gather data on students' engineering design achievement to improve engineering design education during the first two years of their curriculum. This step may lead to a more formal process for exchanging information about student achievement to support adoption of best practices and more effective student transfer.
- A two-week multi-institution summer camp for high school students from underrepresented population groups has effectively engaged them in engineering activities and introduced them to community college and research institution campuses. The integrated learning model proved effective in capturing their excitement and teaching them the methods of engineering design.
- Project members have disseminated TIDEE results regionally and nationally through numerous papers and presentations, faculty workshops, a quarterly TIDEE newsletter, and a TIDEE worldwide web site. A text to assist faculty in their understanding and utilization of TIDEE concepts and methods is in preparation.
- An advisory panel has met annually to review and provide input to the TIDEE project. Panel members represent a variety of academic institutions, industries, and programs that reflect a diverse student population.

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APPENDIX: LIST OF TIDEE ACTIVITIES DEVELOPED

TEAM PROCESS

Team Member Differences

Activity for observing strengths of members

Preferred learning style / thinking preferences

- **Evaluate for self and group**
- **Evaluate for self and group; relate to roles, design categories**

Team Roles

Thinking up roles

Roles defined

- **Four defined - Leader, Recorder, Reflector, Tech Specialist**
- **Four defined - Leader, Recorder, Reflector, Explorer**
- **Four defined - Manager, Recorder, Reflector, Reporter**
- **Five defined - Manager, Recorder, Reflector, Reporter, Explorer**

Choosing roles

Revising team roles

Fostering Teamwork

Team identity

- **Team Name (or logo or motto)— No roles assigned**
- **Logo— Roles assigned**
- **T - shirt design— Roles, criteria, decision matrix**

Miscellaneous

- **Unique commonalities**
- **Identify when their students need to solve problems**
- **New teams formed for effectiveness -members familiar with roles**

Team Assessment

Benefits and drawbacks of teams

- **Learning scenarios and impacts on 1) learning, 2) product, and 3) process**
- **Problems and benefits of teams**
- **Purposes for teams**

How to assess team performance

- **Talk outline: Purposes for assessment of group work**
- **Plan for assessment or 1) learning, 2) product, or 3) process**
- **Scoring criteria for 1) knowledge, 2) product, or 3) process**

Team self-assessment

COMMUNICATION

Oral Report

Communication within the Group

Non-verbal

Positive vs. negative statements

- **Positive and negative**
- **Killer and igniter**

THE DESIGN PROCESS

Steps or Activities

List activities in design process

List steps in design process

Steps or Activities to Categories

Categories defined (presentation)

Generic categories for steps/activities in design process

Catapult project

Catapult project

Homeless shelter

Product dissection - general

Product dissection - vegetable peeler

Interrelationship of Design Process Categories

Assigning Competencies to Categories

Competencies Scaled

Basic, intermediate, advanced

First two years, any of four, last four years

Competencies to Categories and Learning Levels (Basic Knowledge, Application of Knowledge, Critical Analysis, Extension of Knowledge)

DESIRED DESIGN COMPETENCY LEVELS OF STUDENTS

Mid-Program or Entering Junior

End of Program

ASSESSMENT OF STUDENTS

Quality Assessment Defined

Steps to Assessment

Goals and target levels for program outcomes

Educational objectives for target levels

Performance elements for educational objectives

Scoring criteria for educational objectives

Types of Assessment

Self assessment

Direct observation

Choosing best method of assessment

Pilot Assessment: "Entering-Junior Design Assessment"

Steps in pilot assessment

Listing observables

Perform group exercise component

Analysis of pilot assessment

Revising group activity component

Revising essay component

Uses of Assessment