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Deriving Design Course Learning Outcomes from a Professional Profile*

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National calls for enhanced preparation of engineering graduates have spawned and elevated efforts toward assessment-driven improvement of engineering education. Adoption of outcomes-based accreditation criteria by the Accreditation Board for Engineering and Technology (ABET) provided incentive for this change. A necessary first step is embedding attributes of engineering professionals in the program and course objectives of specific baccalaureate degrees. This paper presents a 'profile of an engineer' that encapsulates important roles performed by engineers and key observable behaviors associated with effective performance of these roles. The profile is then utilized to derive sample learning outcomes for a client-driven capstone design course. This involves identifying key roles in support of the course as well as the type of learning outcome best aligned with each of these roles. Outcomes derived in this manner provide rich definitions of desired student achievement that will aid in engineering design education and assessment.

Keywords: engineering design; learning outcomes; professional profile.

INTRODUCTION

FOR DECADES, the public has called for improved preparation of engineering graduates to meet the broad and ever-changing challenges found in engineering practice [1–3]. In many cases engineering graduates were seen as lacking important professional skills, such as ability to communicate effectively, work in multidisciplinary teams, and demonstrate self-initiated professional growth [4]. These perceived deficiencies have driven the creation of new, outcomes-based accreditation criteria for engineering programs and increased attention given to design in engineering education [5]. The combination of these two changes produced a third challenge: defining, assessing, and documenting achievement of outcomes for engineering design and professional development [6–8].

Engineering educators across the world have sought to develop educational outcomes consistent with the requirements for accreditation of their programs by the Accreditation Board for Engineering and Technology [9, 10]. Many have expanded ABET engineering Criterion 3 outcomes or developed their own definitions of the attributes of an engineer as a basis for developing their program outcomes [11, 12]. Recently, the National Academy of Engineering proposed attributes of the engineer that go beyond the ABET criterion 3a-k outcomes [13]. The challenge remains to compile attributes of an engineering professional that are applicable across disciplines and work functions and that are presented in a compact format useful for engineering educators [14].

The Transferable Integrated Design Engineering Education (TIDEE) consortium of colleges in the Pacific Northwest conducted a survey of capstone design course instructors in 2002 that showed that many struggle with assessing design adequately [15]. This has led TIDEE collaborators to shift their focus from articulation between 2-year and 4-year programs to capstone course assessment [16, 17]. In 2004 TIDEE received a National Science Foundation grant to develop transferable assessments for capstone engineering design courses. This project revealed a need for a deeper, richer definition of the knowledge, behaviors, and attitudes important to engineering practice.

Profiles of professional practitioners are valuable to students, faculty, and employers. Students can use engineering profiles to form accurate perceptions, dispel misconceptions, and generate motivation to pursue a field of study. Faculty can use profiles to clarify practices in their disciplines, design appropriate educational materials and instruction, and link other disciplines to their own. Employers can use these profiles to communicate their expectations to educators and to guide professional development of employees.

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The research question explored by this paper is how to anchor capstone design course learning outcomes in behaviors typical of engineering professionals. It is hypothesized that using key roles to organize a professional profile provides insight about the type of learning outcomes that are best aligned with course intentions. Furthermore, it is hypothesized that identifying a small set of general actions associated with each role in the profile serves as an effective prompt for writing profession-focused learning outcomes for a specific course.

PROFESSIONAL PROFILE DEVELOPMENT

The process for developing an expert profile is discussed by Davis *et al.* [18, 19]. Several criteria were introduced for judging the quality of a professional profile:

- *Comprehensive*—statements address all key areas important to the professional or discipline.
- *Concise*—statements provide a snapshot of key behaviors or characteristics.
- *Distinct*—statements are non-overlapping.
- *Organized*—statements are ordered or grouped for deeper meaning.
- *Action-oriented*—statements identify observable actions.
- *Compelling*—elements inspire development and respect.

The TIDEE engineer profile work began in late 2002 by compiling accreditation criteria, codes of ethics, attributes valued by employers, and core competencies valued by professional societies. Synthesis of these traits produced a set of ten holistic behaviors of an engineer [19]. Feedback from capstone course instructors, industry representatives, and members of the American Society for Engineering Education (ASEE) Corporate Member Council provided valuable perspectives used in refinements that led to role descriptions. Holistic descriptions of each role are given in Table 1. These ten roles can be grouped in three categories:

- Technical (including analyst, problem solver, designer, and researcher).
- Interpersonal (including communicator, collaborator, and leader).
- Professional (including self-grower, achiever, and practitioner).

It should be noted that over half of these roles may be seen as non-technical. Holistic descriptions of these roles are given within a workplace context that helps to visualize the dimensions of each role. Some roles are more critical than others in performing a particular job assignment.

Five observable behaviors supporting each role are given in Table 2. Each statement begins with an action verb and includes detail that aids in visualizing the behavior. These statements are intended to be high-level manifestations of each behavior, extending beyond normal baccalaureate degree preparation. The behaviors given in Table 2 encompass all aspects of ABET engineering criteria 3a–k, however with less overlap and clearer performance expectations. Because the profile is

Table 1. Roles and holistic behaviors of an engineer

Technical roles	Holistic technical behaviors
Analyst	When conducting engineering analysis, the engineer adeptly applies principles and tools of mathematics and science to develop understanding, explore possibilities and produce credible conclusions.
Problem-solver	When facing an engineering problem, the engineer produces solutions that properly address critical issues and assumptions and that are conceptually and contextually valid.
Designer	When facing an engineering design challenge, the engineer develops designs that satisfy stakeholder needs while complying with important implementation, societal, and other constraints.
Researcher	When conducting applied research, the engineer designs and conducts studies that yield defensible results and answer important applicable research questions.
Interpersonal roles	**Holistic interpersonal behaviors**
Communicator	When exchanging information with others, the engineer prepares, delivers, and receives messages that achieve desired outcomes.
Collaborator	When working with others in joint efforts, the engineer supports a diverse, capable team and contributes toward achievement of its collective and individual goals.
Leader	When providing needed leadership, the engineer promotes shared vision to individuals, teams, and organizations and empowers them to achieve their individual and collective goals.
Professional roles	**Holistic professional behaviors**
Self-Grower	Motivated for lifelong success, the engineer plans, self-assesses, and achieves necessary personal growth in knowledge, skills, and attitudes.
Achiever	When given an assignment, the engineer demonstrates initiative, focus, and flexibility to deliver quality results in a timely manner.
Practitioner	Driven by personal and professional values, the engineer demonstrates integrity and responsibility in engineering practice and contributes engineering perspectives in addressing societal issues.

written to represent diverse engineering environments, not all stated behaviors are evident or necessary in a single job description.

CAPSTONE PROJECT CHARACTERIZATION

Capstone courses exist in all engineering programs throughout the country. The ABET engineering Criterion 4 requirement of a major design experience that draws on previous knowledge is usually addressed in these courses [5]. There are many similarities among engineering capstone courses [20]:

- Students work in teams (some are interdisciplinary).
- Projects are of extended lengths (often yearlong).
- Projects have external sponsorship (i.e., the instructor is not the customer).

Table 2. Behavior-based profile of an engineer

Role	Behaviors or observable actions
Analyst	a. Searches strategically to identify all conditions, phenomena, and assumptions influencing the situation b. Identifies applicable governing principles of mathematics, natural sciences, and engineering sciences c. Selects analysis tools consistent with governing principles, desired results, assumptions, and efficiency d. Produces and validates results through skillful use of contemporary engineering tools and models e. Extracts desired understanding and conclusions consistent with objectives and limitations of the analysis
Problem-solver	a. Examines problem setting to understand critical issues, assumptions, limitations, and solution requirements b. Considers all relevant perspectives, solution models, and alternative solution paths c. Selects models for obtaining solutions consistent with problem type, assumptions, and solution quality d. Uses selected models, methods, and data to produce desired solution e. Validates results, interprets and extends the solution for wider application
Designer	a. Searches widely to determine stakeholder needs, existing solutions, and constraints on solutions b. Formulates clear design goals, solution specifications (including cost, performance, manufacturability, sustainability, social impact), and constraints that must be satisfied to yield a valuable design solution c. Thinks independently, cooperatively, and creatively to identify relevant existing ideas and generate original solution ideas d. Synthesizes, evaluates, selects, and defends alternatives that result in products (components, systems, processes, or plans) that satisfy established design criteria and constraints to meet stakeholder needs e. Reviews and refines design processes for improved efficiency and product (solution) quality
Researcher	a. Formulates research questions that identify relevant hypotheses or other new knowledge sought b. Plans experiments or other data gathering strategies to address questions posed and to control error c. Conducts experiments or other procedures carefully to obtain reliable data for answering questions d. Uses accepted data analysis procedures to infer trends, parameters, and data error e. Interprets and validates results to offer answers to posed questions and to make useful application
Communicator	a. Listens, observes, and questions to assess audience background and information needs b. Documents and mines available information and differing perspectives for understanding and application c. Prepares a message with the content, organization, format, and quality fitting the audience and purpose d. Delivers a message with timeliness, credibility, and engagement that achieve desired outcomes efficiently e. Assesses the communication process and responds in real-time to advance its effectiveness
Collaborator	a. Respects individuals with diverse backgrounds, perspectives, and skills important to the effort b. Values roles, accepts role assignments, and supports others in their roles c. Contributes to development of consensus goals and procedures for effective cooperation d. Resolves conflicts toward enhanced buy-in, creativity, trust, and enjoyment by all e. Contributes to and accepts feedback and change that support continuous improvement
Leader	a. Facilitates and articulates a shared vision valued by targeted individuals, groups, or organizations b. Motivates others to action by crafting a compelling yet credible case for achieving individual and organizational goals c. Provides authority and resources and removes barriers to aid others' success d. Supports risk-taking and growth by creating trust, providing counsel, and modeling desired attributes e. Encourages achievement by recognizing and rewarding individual and group successes
Self-grower	a. Takes ownership for one's own personal and professional status and growth b. Defines personal professional goals that support lifelong productivity and satisfaction c. Regularly self-assesses personal growth and challenges to achieving personal goals d. Achieves development planned to reach personal goals e. Seeks out mentors to support and challenge future growth and development
Achiever	a. Accepts responsibility and takes ownership in assignments b. Maintains focus to complete tasks on time amidst multiple demands c. Takes appropriate actions and risks to overcome obstacles and achieve objectives d. Monitors and adapts to changing conditions to ensure success e. Seeks help when the challenge exceeds current capability in the given time constraints
Practitioner	a. Displays integrity, consistency, ethical, and professional demeanor in engineering practice and relationships b. Embraces and employs appropriate professional codes, standards, and regulations c. Engages with engineering professionals and organizations to support excellence in engineering practice d. Demonstrates citizenship through service to society on local, national and/or global scales e. Brings responsible engineering perspectives to global and societal issues

- Projects stem from ill-defined problems for which there is no single solution.
- Quality of products is improved through iteration (facilitated by design reviews).
- Projects require management for on-time, under-budget, high-quality results.
- Instructors hold high expectations for oral and written reports.
- Most work products are team-generated, as opposed to individual-generated.

Capstone course learning outcomes commonly focus on the engineering design process, integrating the design process with teamwork and communication to produce results, addressing business and societal issues, operating as a professional, and making rational decisions [15]. In this regard, many capstone courses seek development of [8]:

- skills and knowledge;
- processes to create a product on time;
- metacognition to manage decisions and activities;
- product quality and its comprehension.

Capstone course evaluation, therefore, needs to consider both the processes used by designers and the products they deliver to clients. Client satisfaction with the design products they receive often plays a major role in determining course grades. Qualities that are considered in client evaluation are the degree to which design requirements are met, feasibility of implementation, demonstration of creativity, added value through simplicity, and a positive overall impression [21].

Significant differences between capstone engineering design courses stem from project types included in the course [22]. For example, many mechanical and electrical engineering capstone courses yield prototypes for industry clients. Oftentimes, chemical engineering projects seek to define processes developed as far as bench-scale implementation. Many materials engineering and bioengineering projects are more individualized and research-focused. Inter-disciplinary projects between business and engineering are expected to produce both marketable products and business plans. Design competitions engage larger teams and emphasize performance optimization within narrow requirements and constraints. Distinguishing characteristics of each project type include: end product created, recipient of project work, product attributes, constraints, team composition, and collaborators involved. Table 3 compares three common project types, one of which is explored further in subsequent sections of the paper.

TYPES OF LEARNING OUTCOMES

Five different types of learning outcomes are common in higher education: competencies, movement, accomplishments, experiences, and integrated performance [23]. These are mapped to different dimensions of social learning as described by Wenger *et al.* [24]. Each type is best suited to distinct educational methods and requires collecting different evidence to demonstrate that the outcome has been achieved [25]. A competency is a collection of knowledge, skills, and attitudes needed to perform a specific task effectively and efficiently at a defined level of performance. Movement is documented growth in a skill that can be transferred across disciplines. Accomplishments are significant work products or performances that transcend normal class requirements and are externally affirmed by an outside expert. Experiences are interactions, emotions, responsibilities, and shared memories that clarify one's position in relation to oneself, a community, or discipline. Integrated performance is the synthesis and application of prior knowledge skills, processes, and attitudes with new learning to address a difficult challenge within a strict time frame.

Competency outcomes focus on the level of mastery of specific skills and knowledge across a wide range of contexts. These outcomes are content-laden but depend on appropriate knowledge construction and deconstruction. Performance levels are often referenced to disciplinary standards and/or accreditation criteria. Competency outcomes are snapshots of what learners can do at a specific time, and they are relatively easy to measure [26]. Special attention should be given to exact levels of knowledge expected for these outcomes to reach the appropriate level in Bloom's Taxonomy [11].

Movement outcomes focus on continuous

Table 3. Comparison of project types in capstone design courses

	Client-driven	Market-driven	Service-driven
End product	*Tested implementation of concept*	*Marketable concept*	*Workable solution*
Recipient	*Sponsor*	*Investor*	*End user*
Product attributes	*Novel, adds value, documented, meets requirements*	*Competitive, adaptable, attractive*	*Usable, maintainable, user-sensitive*
Constraints	*Fixed budget, defined context, defined customer*	*Competitors, time to market, market size*	*Life cycle, user skills, cultural values*
Team composition	*Diverse technical skill set*	*Technical & business skill set*	*Technical & social skill set*
Collaborators	*Technical expert, senior manager*	*User focus group, production & marketing experts*	*Policy expert, manufacturing expert, users*

improvement of life skills and learning processes in different situations over a period of time. They prescribe a desired direction and magnitude of growth that extends beyond the present capabilities of all learners in the course. Movement outcomes require multiple samplings over time to document whether and to what extent real growth has occurred [27, 28].

Experience outcomes are often shared among groups of people, and they frequently serve to clarify goals, roles, and responsibilities within an organization and within oneself. They should reveal awareness and critical analysis of the causes and impacts of personal changes in the learner. Processing of the experience should produce new understanding that can be shared with others through purposeful reflection and self-assessment [29, 30].

Accomplishment outcomes are significant additions to the practice of a discipline and have value to a wider audience. These can be innovations in knowledge, practice, or creative work, but they must have value beyond the classroom [21]. They usually represent a clear endpoint and can often be archived for future reference or study. Outside affirmation by other faculty, alumni, or practitioners in a field can be used to eliminate instructor bias. Often these outcomes can be evaluated and celebrated at the same time in a public display.

Integrated performance outcomes stress how well expertise can be drawn together in response to a complex challenge. They require extension and transfer of knowledge, skills, and perspectives in a professional environment. This type of outcome must be measured in a situation that ensures peak performance on the part of the learner in a relatively short period of time [31].

Learning outcomes for a course share some common characteristics that contribute to an effective learning experience. They must be stated concisely to facilitate understanding and must capture major performance expectations [26]. They must be specific enough to support measurement and be achievable within the time frame available, considering the developmental level of the learners [32, 33]. They should be aligned with long-term behaviors expected within a program and be motivating to learners [34]. Finally, learning outcomes are most compelling if they are defined within a specific application or setting that is sensitive to student background [35].

Table 4. Key professional roles for different capstone project types

	Client-driven	Market-driven	Service-driven
Analyst	H	M	M
Problem-solver	M	M	H
Designer	H	H	H
Researcher	M	H	L
Communicator	M	H	M
Collaborator	M	H	H
Leader	L	M	L
Self-Grower	M	M	M
Achiever	H	H	H
Practitioner	M	M	H

PROCESS FOR WRITING LEARNING OUTCOMES

For a given type of project, the professional profile can be used to define course learning outcomes by using the following methodology.

- Prioritize professional roles emphasized by types of projects in a course.
- Select most relevant type(s) of learning outcome for each role.
- Define role-driven learning outcomes using behavioral prompts from the profile.

The first step in crafting learning outcomes involves identifying roles emphasized in a particular design experience. These depend on project type. Table 4 investigates three common project types used in capstone courses. To illustrate differences, the authors have ranked the importance of the ten roles in the engineering profile for the three project types. Client-driven projects, needing to produce new solution concepts worthy of further development by clients, stress roles of the analyst, designer, and achiever. Market-driven projects, needing to appeal to broad audiences and challenge competing products, emphasize roles of designer, researcher, communicator, collaborator, and achiever. Service-driven projects, needing to create a finished product that is long-lived and socially acceptable, require roles of problem solver, designer, collaborator, achiever, and practitioner.

The second step in crafting learning outcomes from a professional profile is identifying the type of outcome most closely aligned with each role in the professional profile. Table 5 identifies a more prominent type of outcome suggested by each role. It should be noted that other outcome types are often appropriate for these roles. As shown in Table 5, the full set of roles in the engineer profile can invoke all five types of learning outcomes. Competency outcomes describe performances of the analyst who needs to use engineering tools at an acceptable level to produce credible conclusions. Movement outcomes are described by interpersonal and professional growth that occurs over time. Accomplishment outcomes are highly valued work products of a designer. Experience outcomes entail reflective thinking about interactions, impacts, and environments associated with engineering practice. Integrated performance outcomes require synthesis of prior knowledge, integration of new knowledge, and transfer of problem solving as well as research skill in real-time. As can be seen, the following outcome types truly support the roles, but additional outcome types would be necessary to obtain the richness of each role as described in the profile.

Table 5. Mapping outcome types to professional roles

Role	Preferred outcome type
Analyst	Competency *(use of tools)*
Problem-solver	Integrated performance *(solution process)*
Designer	Accomplishment *(design product)*
Researcher	Integrated performance *(synthesis of resources)*
Communicator	Movement *(growth in skills)*
Collaborator	Movement *(growth in skills)*
Leader	Movement *(growth in skills)*
Self-grower	Movement *(growth in skills)*
Achiever	Movement *(growth in skills)*
Practitioner	Experience *(valuing design environment)*

The third step in crafting learning outcomes involves projecting role behaviors given in the professional profile back into a specific course context. Table 2 provides a comprehensive and mutually exclusive set of professional behaviors for each role. Writing outcome statements begins by noting which role behaviors given in Table 2 are relevant to the course context. Next, it is useful to formulate common questions about student performance associated with each of the key roles underlying a course. These questions are intended to remind the writer of important course intentions related to specified roles. Finally, learning outcomes are written in response to the course intentions and questions about student performance, keeping in mind the type of learning outcome emphasized for each role.

The worksheet shown in Table 6 is intended to facilitate outcome definition in any engineering course. The outcomes shown are written for one possible implementation of a client-driven design project course while addressing only one type of outcome per role. This example is useful in appreciating how learning outcomes are written for different outcome types.

The analyst outcomes are competencies that can be translated into checklists that describe minimum acceptable levels of achievement in a well-defined situation. The examples target student understanding of principles and assumptions, tools, and

Table 6. Example questions and learning outcomes for a client-driven project course

Role: Analyst	Outcome Type: *Competency*	Profile Behaviors: *a,b,c,d,e*
Question: *What analysis is essential in project work?*		
Outcome: *Can use science and engineering principles to put meaning to a set of design requirements.*		
Question: *What methods and tools are most appropriate for completing the required analysis?*		
Outcome: *Can effectively use the governing equations and associated engineering tools to perform required engineering analysis.*		
Question: *Were calculations done competently and interpreted correctly?*		
Outcome: *Can produce results from analysis that are correct and valid for the project.*		
Role: *Designer*	Outcome Type: *Accomplishment*	Profile Behaviors: *a,b,c,d*
Question: *Does the proposed product meet all customer needs?*		
Outcome: *Produces a customer sign-off that states that the project proposal meets all functional, financial, societal, and ethical considerations crucial to a successful design solution.*		
Question: *Was the product implemented in a way that the client can easily develop it further?*		
Outcome: *Produces acceptable design solution and documentation that support future development of the product to the next level of implementation.*		
Question: *Was the client impressed by the creativity and quality of the product?*		
Outcome: *The client endorses the design product for its significant value in addressing the problem at hand.*		
Role: *Achiever*	Outcome Type: *Movement*	Profile Behaviors: *a,b,c,d,e*
Question: *Does the student recognize his or her responsibility to the client and to other team members toward achieving project success?*		
Outcome: *Is increasingly responsive and accountable to needs of the client by supporting other team members throughout the project.*		
Question: *How strong is the student's commitment to taking actions necessary for project success?*		
Outcome: *Recognizes needs more thoroughly and takes initiative more quickly to achieve individual and team goals as the project progresses.*		
Question: *Does the student expand his or her performance by seeking out resources and help in ways that support timely, quality performance?*		
Outcome: *Has developed better self-esteem and confidence to be resourceful in identifying and acquiring information, tools, and expert advice to meet project milestones.*		

application of analysis done as part of a design project. The designer outcomes are accomplishments that focus on work products and stakeholder endorsement. Unlike the other examples given in Table 6, note that only four of the five designer role behaviors (a, b, c, d) from the professional profile were selected for inclusion. Especially in applying the worksheet to lower-division courses, it is likely that different subsets of role behaviors are the proper focus for any individual course. The achiever outcomes are movements that require data collection and interpretation at regular intervals. Some of these achiever outcomes touch on important aspects of communication, collaboration, and self-growth that are allied with professional roles rated as having only moderate importance for a client-driven project.

Once course-specific learning outcomes are assembled, they can be synthesized to prescribe criteria for analyzing performance, tasks for collecting relevant performance data, and measurement instruments for scoring and interpreting these data [25, 32, 33]. These elements are the subject of future work planned as part of the ongoing TIDEE capstone engineering design assessment grant.

CONCLUSIONS

This paper introduces a profile of an engineering professional that is broadly applicable to all engineering disciplines. It has been developed in recent years with input from an interdisciplinary audience of capstone design instructors and industry representatives. The results of this collaboration have produced a profile consisting of ten holistic role definitions, each supported by five professional behaviors. One of the most significant uses of the profile is alignment of course-specific learning outcomes with long-term professional expectations. A three-step procedure is presented for using the profile to craft role-related learning outcomes. A worksheet has been created to assist others in implementing this procedure for other courses or course focuses. Use of the worksheet is demonstrated for a capstone design course that features client-driven projects.

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REFERENCES

1. Secretary's Commission on Achieving Necessary Skills, *What Work Requires of Schools: A SCANS Report for America*, US Department of Labor, Washington, DC (1991).
2. National Science Foundation, Shaping the future of undergraduate education in science, mathematics, engineering, and technology, *Synergy*, Directorate for Education and Human Resources, Washington DC (1996).
3. National Science Foundation, *Women, Minorities and Persons with Disabilities in Science and Engineering*, Report number NSF 04-317, Arlington, VA (2004).
4. L. J. Shuman, M. Besterfield-Sacre and J. McGourty. The ABET professional skills. Can they be taught? Can they be assessed? *J. Eng. Educ.*, **94**(1), 2005, pp. 41–56.
5. Accreditation Board for Engineering and Technology, Engineering criteria, Baltimore, MD, 2005. http://www.abet.org
6. J. F. Volkwein, L. R. Lattuca, P. T. Terenzini, L. C. Strauss and J. Sukhbaatar, Engineering change: A study of the impact of EC 2000, *Int. J. Eng. Educ.*, **20**(3), 2004, pp. 318–328.
7. M. Weiss and M. D. Aldridge, Assessing the effects of the ABET/NSF/industry regional faculty workshops, *Int. J. Eng. Educ.*, **18**(2), 2002, pp. 245–253.
8. D. C. Davis, S. W. Beyerlein, L. J. McKenzie, M. S. Trevisan and K. L. Gentili, Innovations in design education catalyzed by outcomes-based accreditation, *Proc. Accreditation Board for Engineering and Technology Annual Meeting,* Pittsburgh, PA, October 30–November 1, 2002.
9. J. Prados, Can ABET really make a difference? *Int. J. Eng. Educ.*, **20**(3), 2004, pp. 315–317.
10. J. W. Prados, G. D. Peterson and L. R. Lattuca. Quality assurance of engineering education through accreditation: the impact of Engineering Criteria 2000 and its global influence, *J. Eng. Educ.*, **94**(1), 2005, pp. 165–184.
11. M. E. Besterfield-Sacre, L. J. Shuman, H. Wolfe, C. J. Atman, J. McGourty, R. L. Miller and B. M. Olds, EC2000 outcome attributes: Definition and use, *Proc. American Society for Engineering Education Conf.,* Charlotte, NC, June, 1999.
12. L. Hanneman, S. Mickelson, L. Pringnitz and M. Lehman. Constituent-created, competency-based, ABET-aligned tools for the engineering experiential education workplace, *Proc. Accreditation Board for Engineering and Technology Annual Meeting*, Pittsburgh, PA, October 31–November 1, 2002.
13. National Academy of Engineering, *The Engineer of 2020: Visions of Engineering in the New Century*, The National Academies Press, Washington, DC (2004).
14. P. Brackin, Assessing engineering education: An industrial analogy, *Int. J. Eng. Educ.*, **18**(2), 2001, pp. 151–156.
15. L. J. McKenzie, M. S. Trevisan, D. C. Davis and S. W. Beyerlein, Capstone design courses and assessment: a national survey, *Proc. American Society for Engineering Education Conf.*, Salt Lake City, UT, June 2004.
16. D. C. Davis, K. L. Gentili, M. S. Trevisan and D. E. Calkins, Engineering design assessment processes and scoring scales for program improvement and accountability, *J. Eng. Educ.*, **91**(2), 2002, pp. 211–221.

17. Transferable Integrated Design Engineering Education (TIDEE), NSF projects EEC 9973034 and EEC 0003291, 2005. http://www.tidee.wsu.edu
18. D. C. Davis and S. W. Beyerlein, Development and use of an expert profile, module in *Faculty Guidebook*, Pacific Crest, Lisle, IL (2005).
19. D. C. Davis, S. W. Beyerlein and I. T. Davis, Development and use of an engineer profile, *Proc. American Society for Engineering Education Conf.*, Portland, OR, June 2005.
20. R. H. Todd, S. P. Magleby, C. D. Sorensen, B. R. Swan and D. K. Anthony, A survey of capstone engineering courses in North America, *J. Eng. Educ.*, **84**(2), 1995, pp. 165–174.
21. D. K. Sobek and V. K. Jain. Two instruments for assessing design outcomes for capstone projects, *Proc. American Society for Engineering Education Conf.*, Salt Lake City, June 2004.
22. A. J. Dutson, R. H. Todd, S. P. Magleby and C. D. Sorenson, A review of literature on teaching design through project-oriented capstone courses, *J. Eng. Educ.*, **76**(1), 1997, pp. 17–28.
23. S. Beyerlein, D. Davis and D. Apple, Learning outcomes, *Faculty Guidebook*, Pacific Crest, Lisle, IL (2004).
24. E. Wenger, R. McDermott and W. Snyder, *Cultivating Communities of Practice: A Guide to Managing Knowledge*, Harvard Business School Press, Boston, MA (2002).
25. D. K. Apple, *Assessment Institute Handbook*, Pacific Crest, Lisle, IL (2002).
26. R. Mager, *Preparing Instructional Objectives: A Critical Tool in the Development of Effective Instruction*, 3rd edition, Center for Effective Performance, Atlanta, GA (1997).
27. K. Gentili, J. Lyons, E. Davishahl, D. Davis and S. Beyerlein, Measuring added value using a team design skills growth survey, *Proc. American Society for Engineering Education Conf.*, Portland, OR, June 2005.
28. D. K. Sobek, Use of journals to evaluate student design processes, *Proc. American Society for Engineering Education Conf.*, Montreal, QE, June 2002.
29. J. Turns, Learning essays and the reflective learner: supporting assessment in engineering design education, *Proc. Frontiers in Education Conf.*, Session F1H, Pittsburg, PA, November 1997.
30. R. S. Adams, J. Turns and C. J. Atman, Educating effective engineering designers: the role of reflective practice, *Design Studies,* **24**, 2003, Elsevier Science, pp. 275–294.
31. W. Dick, L. Carey and J. Carey, *The Systematic Design of Instruction,* 6th Edn, Allyn and Bacon, Boston, MA (2001).
32. A. M. Olds, B. M. Moskal and R. L. Miller, *J. Eng. Educ.*, **94**(1), 2005, pp. 27–40.
33. J. McGourty, L. Shuman, M. Besterfield-Sacre, C. Atman, R. Miller, B. Olds *et al.*, Preparing for ABET EC2000: research-based assessment methods and processes, *Int. J. Eng. Educ.*, **18**(2), 2002, pp. 157–167.
34. G. Wiggins, and J. McTighe, *Understanding by Design*, Association for Supervision and Curriculum Development, Alexandria, VA (1998).
35. K. A. Smith, S. D. Sheppard, D. W. Johnson and R. T. Johnson, Pedagogies of engagement: classroom-based practices, *J. Eng. Educ.*, **94**(1), 2005, pp. 87–102.