Technological Literacy of Undergraduates:
Developing Standard Models

National Academy of Engineering, Washington D.C.

Mon-Tues March 26-27, 2007

Workshop Background
and
Supporting Information for Participants

3/8/07

Organizing Committee:

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ASEE Technological Literacy Constituent Committee Chair.

David Ollis, Distinguished Professor, North Carolina State University, ollis@eos.ncsu.edu

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Greg Pearson, Program Officer, National Academy of Engineering.

Contents

1. Workshop Charge

A group will be convened which will:

- Identify, explore, and develop a few models of technological literacy courses that could be further developed with instructional and instructor materials for widespread use.

- Define learning outcomes, course outlines, and lists of resource material.

- Evolve in core groups to continue to work.

- Lead to development of CCLI proposals.

Technical literacy is not likely to gain wide acceptance until the scholarly community develops standard courses that are supported by textbooks and other course materials. In 2005, a workshop sponsored by the National Science Foundation identified the research issues in the technological literacy of undergraduates. In addition, an array of successful courses was presented as evidence that engineering faculty can develop and teach courses that advance the understanding of technology by all Americans. For widespread impact however, standard classes must be taught at many institutions around the country. To accomplish this, standard easily adopted technological literacy courses must be developed.

A workshop will be conducted to bring educators and related professionals together to facilitate collaboration and focus future efforts. The goal of the workshop will be to bring these efforts close to an implementation resulting in collaborations and future course development. At the workshop, groups will define and discuss several models of technological literacy courses. These models will then become candidates for further development. The objective will be to create materials for both students and instructors with the intention of easy adoption and widespread use. The primary outcomes will be materials describing several models for technological literacy courses, a community focused on developing these models, and dissemination of these results to a broader audience.

2. Defining and Assessing Technological Literacy

Technically Speaking (2002)

To minimize the problems caused by local definitions of technological literacy it is suggested that the workshop should adopt the NAE's *Technically Speaking* as a common reference for this concept. William Wulf, Taft Broome and Greg Pearson, members of the Technically Speaking Committee will be at the workshop.

In *Technically Speaking*, the NAE describes three dimensions of technological literacy:

1. Knowledge
2. Capabilities
3. Ways of Thinking and Acting

Tech Tally (2006)

Tech Tally (2006) follows *Technically Speaking* (2002) with an emphasis on assessment. *Tech Tally* editors Elsa Garmire and Greg Pearson will be at the workshop.

In *Tech Tally* the three dimensions described in *Technically Speaking* are considered to be three cognitive levels relevant for assessment. The "Ways of Thinking and Acting," has been rephrased to "Critical Thinking and Decision Making." In addition, four content areas are defined: technology and society; design; products and systems; and characteristics, concepts, and connections. This is summarized in Figure 1, adapted from Figure ES-2 from *Tech Tally*.

COGNITIVE DIMENSIONS

CONTENT AREAS

	Knowledge	Capabilities	Critical Thinking & Decision Making
Technology & Society			
Design			
Products & Systems			
Characteristics, Core Concepts, & Connections			

Figure 1: Proposed assessment matrix for technological literacy in *Tech Tally*.

This assessment matrix from *Tech Tally* may serve as a way to classify and organize pre-existing courses or to help define the scope of new courses.

ITEA Standards for Technological Literacy

The International Technology Education Association has developed a set of standards (ITEA 2000) *Standards for Technological Literacy: Content for the Study of Technology*,http://www.iteaconnect.org/TAA/Publications/TAA_Publications.html. This consists of five areas that are subdivided into 20 standards. The five main areas are:

1. Understanding the Nature of Technology
2. Understanding of Technology and Society
3. Understanding of Design
4. Abilities for a Technological World
5. Understanding of the Designed World.

Workshop participants Mary Annette Rose, Mark Sanders, Elsa Garmire, and William Wulf were involved in developing these standards.

Table 1: Listing of the ITEA Technological Literacy Standards.

	The Nature of Technology
1	The characteristics and scope of technology.
2	The core concepts of technology.
3	The relationships among technologies and the connections between technology and other fields.
	Technology and Society
4	The cultural, social, economics, and political effects of technology.
5	The effects of technology on the environment.
6	The role of society in the development and use of technology.
7	The influence of technology on history.
	Design
8	The attributes of design.
9	Engineering design.
10	The role of troubleshooting, research and development, invention and innovation, and experimentation and problem solving.
	Abilities for a Technological World
11	Apply the design process.
12	Use and maintain technological products and systems.
13	Assess the impact of products and systems.
	The Designed World
14	Medical technologies
15	Agricultural and related biotechnologies.
16	Energy and power technologies.
17	Information and communication technologies.
18	Transportation technologies.
19	Manufacturing technologies.
20	Construction technologies.

While the ITEA standards address K-12 students, the detail of these standards may be helpful in categorizing or classifying the content areas that appear in courses for undergraduates.

3. Candidates Models for Standardized Technological Literacy Courses.

Based on the published descriptions, most of the existing courses can be organized into four categories. There are a few existing courses that appear in more than one category. The four candidate standard models are:

1. The Technology Survey Course.
2. The Technology Focus or Topics Course.
3. The Technology Creation Course (Engineering Design Course).
4. The Technology Critique, Assess, Reflect, or Connect Course.

The technology survey courses offer a broad overview of a number of areas of engineering and technology. The technology or topics or focus course is narrower in scope and develops one well-defined area. The engineering design course (or technology creation) places an emphasis on the engineering design process in developing technological solutions to problems. The last model to emerge from existing courses is concerned with assessing technological impacts, connecting technological developments to other areas of society, history and culture, or reflecting on engineering in a broader context. This last course model was tentatively called technology: critique, assess, connect, or reflect.

<u>1. Technology Survey Courses.</u>
Address a range of technologies.
May include social and historical dimensions.
May include lectures, demonstrations, laboratories.
Scientific principles usually a major component.
Includes "How Things Work" courses
Includes Physics courses that emphasize everyday technology.
Could include some introduction to engineering courses.

Examples:

Bloomfield[+] et. al. ....How Things Work: Physics of Everyday Life
DeGoode* ....How Things Work
Disney[+,]* ....Science at Work: Technology in the Modern World
Hammack[+]..............................The Hidden World of Engineering
Kim ....Introduction to Electro-Technology
Krupczak[+,]* ....Science and Technology of Everyday Life
Lienhard[+]................................Engines of our Ingenuity
Oakley* ....Everyday Engineering
Ollis[+,]*...................................How Things Work
Vedula[+] ....Technology and the Human-Build World.

* = 2007 workshop participant
\+ = 2005 workshop participant

2. Technology Focus or Topics Courses

These courses tend to address a single technological topic or issue.
Subject matter is intentionally focused rather than intentionally broad.
May have a substantial technical or quantitative component.
May include laboratories or projects.
May include some social and historical aspects of the topic.

Examples:

Klein* and Balmer+: ....Converging Technologies at Union
Billington, Littman+ et. al ....Civil Infrastructure.
George+,* ....Fuel Cells
Mechtel+,* Korzeniowksi et al. ....Electrical Engineering for Non-Engineers
Kuc+: ....Information Technology
Norton,* and Bahr ....Materials
Orr, Cyganski, and Vaz: ....Information Technology
Pisupati, Mathews, and Scaroni ....Energy Conservation
Walsh, Demmons, and Gibbs.............Materials
Shraibati* ....Intro to Computer Graphics Tools.

* = 2007 workshop participant
\+ = 2005 workshop participant

In developing and teaching these courses, instructors are often working from their area of research expertise. Topical courses focused on one area of technology were characteristic of many of the courses developed under the Sloan Foundation New Liberal Arts Program (Steen 1999).

3. Engineering Design for Everyone (Technology Creation or Application Courses)

These courses focus on the engineering design process.
May include engineering majors along with non-engineering majors
Also includes some of the work being done with K-12 teachers.
Includes some introduction to engineering courses.

Examples:

Baish+ ....Designing People, Form and Function
DeGoode* ....How Things Work
Mahajan. and McDonald....................Exploring Technology
Mikic and Voss ....Engineering for Everyone
Nocito-Gobel*....................................Project-based Introduction to Engineering
Whitman+,* ....Engineering for Non-Engineers
J. Young* ....Introduction to Engineering.

* = 2007 workshop participant
\+ = 2005 workshop participant

4. Technological Impacts, Assessment, and History Courses.
(Critique, Assess, Reflect, and Connect Courses)
These courses emphasize the relation between technology and culture, society, history. May include technological policy assessment or analysis.
Probably well-represented in STS programs but not many examples offered by engineers or jointly taught.

Examples:
- Carlson[+,*] and Gorman: ....Invention and Innovation
- Cutcliffe[+,*] ....Technology and Human Values
- Herkert ....Engineering Disasters
- Klein* and Balmer[+,] ....Converging Technologies Courses at Union.
- Neeley[+,*] ....Engineering in Context.
- Rosa[+,] ....Technology 21

* = 2007 workshop participant
\+ = 2005 workshop participant

Comparison to of Course Formats Across Disciplines.

All of the existing courses on technology for non-engineers were developed in the absence of any formal organizational scheme. However, the four standard models appear to be in a consistent format that can be applied to other disciplines. A comparison of the technology course models with a sampling of other disciplines is given in Table 2. Also included in the table are some example courses names in each category.

Table 2: Comparison of Technology Literacy Courses to Other Disciplines Including Example Course Names.

Activity	**Engineering for Everyone (Technology Literacy)**	**English**	**Psychology**	**Music**
Survey	Technology Survey Courses	English 101: *Intro to Literature*	Psychology 101: *Intro to Psych*	Music 101: *Intro to Music*
Focus	Technology Focus Courses *Fuel Cell Systems* *Materials: Foundation of Soc.*	Focus or Topics Courses *British Literature* *American Literature*	Focus or Topics Courses *Developmental Psych* *Organizational Psych*	Focus or Topics Courses *Jazz Styles and Analysis* *Music of 18th Century*
Create Apply	Technology Creation Courses (Engineering Design) *Intro. to Engineering Design* *Designing People*	Writing Courses *Creative Writing: Nonfiction* *Creative Writing: Poetry*	Creation or Application Courses *Research Methods in Psych* *Clinical Assessment*	Music Performance Music Composition
Critique Assess ***Reflect Connect***	Technology Critique Courses *Converging Technologies* *Engineering in Context*	Critique Course Examples: *Literature and Cultural Difference* *Literary Forms and Reformulations*	Critique, Assess, History Ex: *History of Modern Psychology* *The Psychology of Everyday Things*	Critique, Assess, History Ex: *History of Music Theory* *Aesthetic Theory and Modernism*

Basic similarity in course models exists across disciplines. All disciplines have survey courses that are open to all undergraduate students with limited or no prerequisites. Theses courses help to define the scope and breadth of the discipline. All areas also have a focus or topics course model. Courses of this model are of narrower scope but greater in depth than survey courses. The third category of engineering design courses are analogous to English courses focusing on writing or Music courses in composition or performance.

The fourth category is the broadest in scope and possibly the most difficult to define. However all disciplines have a course model that examines activity in some type of context external to itself. This model includes discipline-specific history courses and courses focusing on critique or assessment.

One notable difference between the engineering for everyone courses and the other disciplines listed in Table 2, is that courses in each of the other disciplines are mostly located in on one department. The technology courses can be dispersed through a range of departments including: chemical engineering, civil engineering, electrical engineering, physics, history, or STS departments.

While the boundaries between categories are by no means rigid, these four standard models appear to approximate the organization of courses that has persisted in other disciplines. This provides some confidence that these models of technology courses could endure into later eras of course development.

4. Cross Cutting Issues Of Course Formats And Pedagogy.

There are curricular elements and methods of pedagogy that different instructors use to cut across the different content areas. Methods of instruction could be considered as a third dimension to the Content Areas and Cognitive Dimensions given in the *Tech Tally* assessment matrix. This third dimension of curriculum and pedagogy may be a direction along which standard materials can be developed.

Mechanical Dissection
    Ollis[+,]*, Sheppard et al., T. Simpson*

Design Projects
    Baish[+], DeGoede*, J. Young*

Lego Mind Storms
    L. Whitman[+,]*, C. Rogers, J. Young*,

Make-and-take
    DeGoode,* Krupczak[+,]*, George[+,]*

Investigative Labs
    Disney[+,]*, M. Littman[+], Weiss

Course Formats
    Format 1: Lecture/Demonstration
        Example: Bloomfield[+] et al.

    Format 2: Lecture/Lab
        Example: DeGoode*

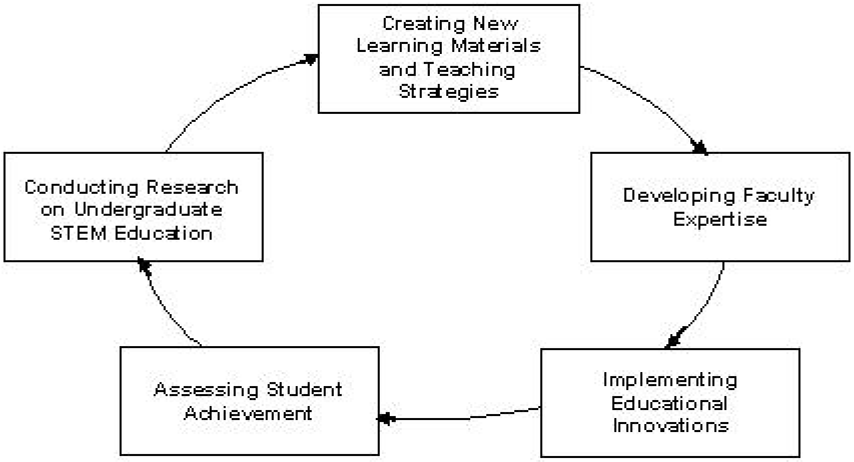
    Format 3: Integrative: Multidisciplinary Engineering + Other Disciplines,
        May include laboratories or projects.
        Example: Ollis[+,]*

* = 2007 workshop participant
+ = 2005 workshop participant

5. NSF Course Curriculum and Laboratory Improvement (CCLI) Program.

The NSF CCLI Program was substantially revised in 2005. Proposal should address one or more components of this cycle. Details can be found in Program Solicitation NSF 07-543 http://www.nsf.gov/pubs/2007/nsf07543/nsf07543.pdf. The general structure of the CCLI program is summarized below.

(Taken from NSF 07-543)



A. Project Components

All proposals must contribute to the development of exemplary undergraduate STEM education. Proposals may focus on one or more of the components of this cycle.

- **Creating Learning Materials and Teaching Strategies.** Guided by research on teaching and learning, by evaluations of previous efforts, and by advances within the disciplines, projects should develop new learning materials and tools, or create new and innovative teaching methods and strategies. Projects may also revise or enhance existing educational materials and teaching strategies, based on prior results. All projects should lead to exemplary models that address the varied needs of the Nation's diverse undergraduate student population. They may include activities that help faculty develop expertise in adapting these innovations and incorporating them effectively into their courses, the next step in the cycle.
- **Developing Faculty Expertise**. Using new learning materials and teaching strategies often requires faculty to acquire new knowledge and skills and to revise their curricula and teaching practices. Projects should design and implement methods that enable faculty to gain such expertise. These can range from short-term workshops to sustained activities that foster new communities or networks of practicing educators. Successful projects should provide professional development for a diverse group of faculty so that new materials and teaching strategies can be widely implemented.
- **Implementing Educational Innovations**. To ensure their broad based adoption, successful educational innovations (such as learning materials, teaching strategies, faculty development materials, assessment and evaluation tools) and the research relating to them should be widely disseminated. These innovations may come from CCLI projects or from other sources in the STEM community. Funds may be requested for local adaptation and implementation projects, including instrumentation to support such projects. Results from implementation projects should illuminate the challenges to and opportunities for adapting innovations in diverse educational settings, and may provide a foundation for the development of new tools and processes for dissemination. They also may provide a foundation for assessments of learning and teaching.

- **Assessing Student Achievement**. Implementing educational innovations will create new needs to assess student learning. Projects for designing tools to measure the effectiveness of new materials and instructional methods are appropriate. Some projects may develop and share valid and reliable tests of STEM knowledge; other projects may collect, synthesize, and interpret information about student reasoning, practical skills, interests, or other valued outcomes. Projects that apply new and existing tools to conduct broad-based evaluations of educational programs or practices are appropriate if they span multiple institutions and are of general interest. Projects should carefully document population characteristics and context for abstracting what can be generalized. Results obtained using these tools and processes should provide a foundation that leads to new questions for conducting research on teaching and learning. Assessment projects likely to have only a local impact are discouraged.
- **Conducting Research on Undergraduate STEM Education.** Results from assessments of learning and teaching as well as from projects emphasizing other components in the cyclic model provide a foundation for developing new and revised models of how undergraduate STEM students learn. Research to explore how effective teaching strategies and curricula enhance learning is appropriate. Some research results may compel faculty to rethink STEM education for the future. Other projects will have a practical focus. All projects should lead to testable new ideas for creating learning materials and teaching strategies that have the potential for a direct impact on STEM educational practices.

6. Standards for Evaluating Scholarly Work

Charles E. Glassick, Mary Taylor Huber, and Gene I. Maeroff
Scholarship Assessed: Evaluation of the Professoriate.

Exhibit 2.1. Summary of Standards

Clear Goals

Does the scholar state the basic purposes of his or her work clearly? Does the scholar define objectives that are realistic and achievable? Does the scholar identify important questions in the field?

Adequate Preparation

Does the scholar show an understanding of existing scholarship in the field? Does the scholar bring the necessary skills to his or her work? Does the scholar bring together the resources necessary to move the project forward?

Appropriate Methods

Does the scholar use methods appropriate to the goals? Does the scholar apply effectively the methods selected? Does the scholar modify procedures in response to changing circumstances?

Significant Results

Does the scholar achieve the goals? Does the scholar's work add consequentially to the field? Does the scholar's work open additional areas for further exploration?

Effective Presentation

Does the scholar use a suitable style and effective organization to present his or her work? Does the scholar use appropriate forums for communicating work to its intended audiences? Does the scholar present his or her message with clarity and integrity?

Reflective Critique

Does the scholar critically evaluate his or her own work? Does the scholar bring an appropriate breadth of evidence to his or her critique? Does the scholar use evaluation to improve the quality of future work?

Source: *Glassick,* C.*E., Huber, M.T., and Maeroff, G.I.*
Exhibit 2.1 in Scholarship Assessed: Evaluation of the Professoriate.
San Francisco: Jossey-Bass, 1997, p.36.

7. Review of Recommendations of 2005 Workshop and Actions Taken

2005 WORKSHOP RECOMMENDATIONS

1. Definitions and dimensions of technological literacy.

Create a Different Terminology for Technological Literacy
The term “technological literacy” has a negative, remedial connotation. A definition is required in language that is broad enough to resonate with a multiplicity of expert, undergraduate, and lay audiences is needed.

Actions:
Neeley, Kathryn, “From "How Stuff Works" to "How STUFF Works": A Systems Approach to The Relationship Of STS and "Technological Literacy".” Proceedings of the 2006 American Society for Engineering Education Annual Conference (2006).

Develop an Underlying Theory
Develop a theoretical core or theory-base for technological literacy.

Actions:
Technically Speaking is a reasonable starting point which was not explored in much detail during the first workshop.

Emphasize Engineering Design as a Creative Process
Creativity and design are themes found in many disciplines and could form the basis of collaborations between engineering and other disciplines for teaching technological literacy.

Actions:
Ollis, David, “Cross-College Collaboration of Engineering with Industrial Design.” *Proceedings of the 2005 American Society for Engineering Education Annual Conference* (2005).

Teach Engineering Thinking as a Fundamental Outcome
This can occur through any of several contexts such as understanding how things work, analyzing history of technological developments, or study of contemporary issues.

Actions:
Design process and quantitative thinking included in *Technically Speaking* and ITEA Standards.

Connect Technological Literacy to Humanities and Social Sciences and to STS
The history of technology and historical context of technological developments are important elements in understanding technology. These topics are not exclusively the domain of any college or discipline; cross-college collaborations are needed.

Actions:

1. Technology and Society identified as content areas in *Tech Tally* and ITEA Standards
2. Carlson, W. Bernard, “Technological Literacy and Empowerment: Exemplars from the History of Technology,” *Proceedings of the 2006 American Society for Engineering Education Annual Conference* (2006).

<u>Develop Links to Other Competency Criteria</u>
Concepts of technological literacy should be linked to the U.S. Department of Labor SCANS Commission on Workplace Skills, and may be link to competencies sought by employers.

Actions:
Advocated in Tech *Tally.*

2. Obstacles to initiating and continuing courses on technology.

Lack of peer and administrative support were the most frequently cited resistances. Additional “top down” interest from college and university administrations is needed.

Actions: None specifically.

3. Learning objectives and student outcomes.

The diversity of student learning objectives in existing technological literacy courses reflects the diversity in local definitions of technological literacy. Refining the definition of technological literacy must precede development of consensus learning objectives and student outcomes.

Actions:
Tech Tally identifies Content Areas and Cognitive Dimensions as a starting point.

4. Relevant assessment tools and techniques.

Technological literacy may be defined as appropriate knowledge, skills and attitudes. Assessment possibilities for these attributes need development and testing.

Actions:
Tech Tally (Ch 5) has provided an overview of existing methods.

<u>Specific Assessment Needs</u>
Develop a rubric for evaluating socio-technical design projects which involve both social and technical innovation. Develop a reliable method for assessing the ability to make sense of unfamiliar problems. Identify and measure the factors that influence someone to

become, or want to become, technologically literate. Develop a way of measuring a decrease in fear of science and technology

Actions:

1. *Tech Tally* (Ch 5) has provided an overview of existing methods.
2. Use of MSLQ to measure attitudes, Krupczak, J.J., et. al, "Work in Progress: Case Study of a Technological Literacy and Non-majors Engineering Course," *Proceeding of the 35th ASEE/IEEE Frontiers in Education Conference*, October 19 – 22, 2005,

5. Strategies for developing a scholarly community.

Use Existing Organizations

A firm consensus emerged to use existing organizations and groups to develop a scholarly community. Such a community should provide a locus for supporting faculty who teach technological literacy, an acceptable place to publish work, and mechanisms for drawing in other interested groups and institutions such as International Technology Education Association (ITEA). In response to this recommendation, The American Society for Engineering Educations (ASEE) created in June of 2005 a Technological Literacy Constitutive Committee whose first program will occur at the 2006 Annual Meeting.

Actions:

1. ASEE Technological Literacy Constituent Committee created June 2005, currently 87 members.
2. ITEA and ASEE K-12 Collaboration
3. ITEA members: Mark Sanders and M. Annette Rose participants in 2007 Workshop

Assess Faculty Crossing Boundaries and Cross-College Efforts

Develop protocols for assessing scholarly contributions of faculty who cross disciplinary boundaries in research, teaching, or scholarly activities. This would include faculty who are teaching with non-engineering faculty or teaching non-engineering students.

Actions: None

6. Potential means of stimulating growth of interest in the topic.

A new NSF program to stimulate faculty interest was ranked as the strongest choice, a not unexpected result , given the logic and the NSF workshop sponsorship. There is need for a best practice collection of easily adopted materials, not just a journal devoted to the topic. A loosely organized user affiliation such as a Yahoo group would facilitate communication among peer groups of instructors. Development of textbooks around a well-defined core would facilitate offerings in both four year and community colleges.

Actions: 2007 Workshop to identify course models.

7. Implementation in different types of institutions including community colleges

In many ways, the institutional issues are not unique to technological literacy. Respondents felt that smaller, liberal arts campuses might be easier locations to initiate new courses. Implementation in community colleges must include minimizing the preparation time needed by instructors, especially for laboratory activities.

Actions:
Ollis, D. and J. J. Krupczak, "Hands-On Activities For Technological Literacy," Workshop held at the *2006 American Society for Engineering Education Annual Conference*.

Mikic, Borjana and Susan Voss, "Engineering For Everyone: Charging Students With The Task Of Designing Creative Solutions To The Problem Of Technology Literacy," *Proceedings of the 2006 American Society for Engineering Education Annual Conference* (2006)

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10. Bibliography and Reference Information

This is a compilation of publications on technological literacy of undergraduates and courses about engineering topics for non-engineering students appearing in the engineering education literature over approximately the last ten years. An effort was made to make this a comprehensive list however, as working document; there is the possibility that some articles have been missed.

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Converging Technologies at Union College, Union College, <http://www.union.edu/CT>.

Daniels, S., M. Collura, B. Aliane, J. Nocito-Gobel, "Project-Based Introduction to Engineering – Course Assessment, *Proceedings of the 2004 American Society for Engineering Education Annual Conference* (2004). American Society for Engineering Education. <http://www.asee.org/acPapers/2004-1969_Final.pdf>.

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