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Building Assessment and Evaluation Capacity of Engineering Educators Through ASSESS

Dr. Jennifer E LeBeau, Washington State University

Jennifer LeBeau conducts program and project evaluation through the Learning and Performance Research Center and teaches in the Department of Educational Leadership, Sport Science, and Educational/Counseling Psychology. Dr. LeBeau's primary interests lie in evaluation of projects related to STEM education and student success.

Dr. Denny C. Davis P.E., Washington State University

Dr, Denny Davis is Emeritus Professor at Washington State University, after over 25 years of engineering education contributions. He has led numerous projects funded by the National Science Foundation, focused on development of instructional materials and assessments for engineering learning outcomes. He is recipient of several awards for teaching excellence and leadership in engineering education and is a Fellow of the American Society for Engineering Education.

Dr. Noah L Schroeder, Washington State University
Dr. Brian F French, Washington State University

Brian F. French is a Professor of Psychometrics and Research Methods in the area of Educational Psychology at Washington State University. He area of research focus is test score validity.

Dr. Shane A. Brown P.E., Washington State University
Dr. Howard P Davis, Washington State University

Dr. Davis received degrees from The Evergreen State College (BA 1976), WSU (BS 1981, MS 1988) and the University of Oregon (Ph.D. 1993). He is currently the Director of the Harold Frank Institute at WSU. He has been the president and CEO of IPM, a medical device company and Total Dynamics LLC a software company. He is also on the board of directors of Developing World Technologies, a company started by former students of the capstone class that he teaches. His interests include engineering and entrepreneurship pedagogy and assessment, technology development and clinical applications of biomedical instrumentation.

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Abstract

In recent years, assessment and evaluation have become vital to engineering educators for both program accreditation and judging the impacts of educational innovations. For effective assessment, engineering faculty must understand assessment, be able to select appropriate assessment instruments, administer assessments suitably to gain accurate measures of outcomes, and interpret results for properly informed decision making. Yet, engineering faculty often do not receive training to adequately incorporate assessment into daily practice. Others face ongoing challenges of locating assessment instruments suitable for their specific needs and knowing how to use them competently. A need exists to identify ways of incorporating assessment instruments into evaluation of educational innovations and outcomes in engineering contexts.

This paper aims to build the evaluation and assessment capacity of engineering educators by unfolding the final version of the Appraisal System for Superior Engineering Education Evaluation-instrument Sharing and Scholarship (ASSESS), a web-based repository and search engine for finding desired assessment instruments. The paper provides an overview of the engineering assessment landscape and ways in which assessment can be used to effectively evaluate educational practices. The paper characterizes assessment instruments currently used in engineering education and tabulates characteristics of assessment instruments necessary for sound assessment and evaluation. Specific cases from ASSESS are examined for assessing selected outcomes, and gaps are identified where additional instruments are needed. The paper describes lessons learned from developing the database as well as recommendations for using ASSESS to locate assessment information for use in engineering education contexts. Focus is placed on building the assessment and evaluation capacity of engineering educators and others involved in the assessment of engineering education innovations.

The Engineering Education Assessment Landscape

Institutions across the nation seek to produce highly skilled and qualified graduates from nationally accredited engineering education programs. As a result, engineering education professionals require resources for evaluating student progress, assessing student learning outcomes, and understanding impact of educational projects and programs. Several websites, many of which are supported by the National Science Foundation (NSF), address the growing need for easily accessible assessment and evaluation instruments. For example, the Assessing Women and Men in Engineering Project (AWE)[1] is a multi-institutional project offering assessment instruments for K-16 engineering education outreach activities. Purdue's INSPIRE[2] focuses on engineering education instruments at the P-12 level. Similarly, the Engineering Pathways[3] project offers assessment instruments for K-12 and higher education. Several other websites exist that offer information on assessment instruments used in engineering education (e.g., ciHUB, FLAG, OERL, E2020).[4-7] This paper describes ASSESS, one of the most comprehensive websites available for engineering education professionals and evaluators of engineering education projects. ASSESS is an NSF TUES Type 2 project (DUE 1065486) that builds, supports, and sustains the assessment and evaluation capacity of a broad community of engineering education professionals. This paper describes characterization of the instruments within ASSESS as well as lessons learned throughout the project's development. In addition, two examples are offered to describe ways in which ASSESS may be used by the engineering education community.

Instrument Characterization

Over the life of the project, a variety of instruments were identified for inclusion in the ASSESS database. In the first year, instruments were identified by searching peer-reviewed journal articles, using branching techniques from reference sections of papers and reports, and identifying innovative projects that may have developed and employed evaluation instruments. While comprehensive, this three-pronged strategy proved to be somewhat challenging for locating instruments. Thus, the second year was devoted to contacting engineering faculty and adoption research participants, developing an information-gathering tool for entering instruments directly into ASSESS, and working with the consultant team to identify candidate instruments, instrument developers, and contacts for establishing collaborations.

To date, ASSESS includes complete information for 135 instruments that fall into six content domains: (a) Knowledge, (b) Attitudes, (c) Behaviors, (d) Professional Skills, (e) Learning Environment, and (f) Institutional Data. Tables A1-A6 in Appendix A document the instruments categorized into each domain. In summary, the Knowledge domain includes information for 58 instruments, including concept inventories, design assessments, critical thinking assessments, and metacognition measures. Approximately 72 instruments comprise the Attitudes domain. Thirty (30) instruments are classified in the Behavior domain, including instruments related to motivation, engineering design self-efficacy, and team effectiveness. The Professional Skills domain is comprised of 33 instruments related to critical thinking, writing, teamwork, and design. Nine instruments are related to Learning Environment, and four instruments fall under the Institutional Data domain. Certain instruments, such as the Achievement Motivation Inventory, are categorized in more than one domain.

Within ASSESS, instruments are searchable by domain as well as by other filtering criteria, including ABET Student Learning Outcomes (3a-k)[8], reliability and validity evidence, format information (e.g. item type, language, etc.), and administration information (e.g., cost, administration time, discipline, and intended audience). Listings for each instrument include a summary of uses in engineering education, recommendations for use, reliability and validity information, a description of the instrument characteristics and availability, and references. The site also contains a placeholder for user reviews and ratings.

A key aspect of instrument characterization added in Year Three was increasing credibility and validity of the information in ASSESS by asking instrument owners or authors to review their instrument's listing once the ASSESS team entered as much information as possible. Instruments are now posted tentatively while data is entered and verified by the authors. An asterisk is placed by the instrument name on the ASSESS website if the instrument has been author-approved. On the administrative side of the database, instruments are characterized as: Draft, Submitted, Under Review, Waiting Author Approval, Approved/Active, Author Denied, or Admin Denied. This allows the ASSESS team to maintain control over the website by reviewing author suggestions and ensuring only accurate information is posted. To date, the response rate for authors providing feedback is approximately 39%, meaning responses were received for 39% of instruments in which author/owner contacts were attempted. In addition to information regarding individual instruments, ASSESS offers links to reputable professional affiliations as well as testing, evaluation, engineering education, and additional instrument resources.

ASSESSing Outcomes

For engineering educators and evaluators of engineering education projects, ASSESS offers a one-stop website for making informed decisions about instruments that can be used to most effectively measure desired outcomes. Below are two scenarios in which assessment information can be located using ASSESS. A third scenario describes the use of ASSESS by an instrument developer. It should be noted that the ASSESS team is not endorsing or intentionally promoting any instrument used in the examples.

Scenario One. An engineering program at a research university has stressed the importance of meeting ABET Criterion 3d, in which students must possess the ability to function on multidisciplinary teams. In response to this call, a professor in the mechanical engineering department decides she would like to measure the effectiveness of the teamwork experiences she is currently offering students. The professor goes to the ASSESS website, http://assess.tidee.org, clicks on Search, and types in the phrase "Teamwork effectiveness." Three results appear: (1) the Comprehensive Assessment of Team Member Effectiveness (CATME), (2) the Modified National Engineering Students' Learning Outcomes Survey (MNESLOS), and (3) the Team Effectiveness Questionnaire (TEQ). The professor sees that the CATME and the MNESLOS instruments are author-approved, as indicated by the asterisk next to each instrument name. She also sees that the CATME has the most information for uses in engineering, reliability, and validity, as indicated by a large green circle. None of the instruments have been rated. The professor clicks on the CATME and reads through the summary information, noting that the instrument is actually a system that includes a peer-evaluation instrument called the CATME Peer Evaluation as well as "…a web-based administration of the behaviorally anchored rating scale (BARS) version of the Comprehensive Assessment of Team Member Effectiveness (CATME) instrument, developed by Ohland et al. (2012)." The professor also notes that the instrument has been used by many students, faculty, and institutions in several countries. She reads that the instrument has strong psychometric properties (reliability and validity) as well;

however, she is unclear for which population the psychometrics were conducted, so she goes to the Reference section at the end of the summary and is able to look up the papers that detail the psychometric information. Although the professor is pleased with the CATME, she also reads through the descriptions of the other two instruments (MNESLOS and TEQ) to make an informed decision as to which instrument best meets her needs. She chooses the CATME, as the instrument most closely measures her desired outcomes, has sound psychometric properties, has been tested in a context similar to her classroom setting, and is known to address ABET criterion 3d. She looks to the Availability section in ASSESS to locate the instrument system, found at www.CATME.org, and implements the assessment in her classroom, making sure to interpret the results as outlined in the manual found on the CATME website.

Scenario Two. The primary goal of an engineering education research project is to improve undergraduate students' professional skills. In discussions with the project team, the external evaluator suggests that the team use a valid and reliable measure to provide data on changes in students' professional skills over the course of the project. The evaluator has heard of ASSESS and offers to locate an appropriate instrument. On the ASSESS Search page, the evaluator chooses to conduct an advanced search that will show all instruments in the database related to Professional Skills. The evaluator clicks on "Advanced Search" on the left side of the Search page, which offers three drop-down options: Technical Aspects, Format Information, and Administration Information. The evaluator clicks on Technical Aspects, marks "Professional Skills," and clicks on the Search button under the Advanced Search. A total of 25 results appear. Only 10 results show up on the first page, so the evaluator scrolls to the bottom of the page, changes the number to show "All," and clicks the Update button. Once he can see all of the instruments in ASSESS related to Professional Skills, the evaluator sorts the results by reliability by clicking on the Reliability column heading. The evaluator can now see six instruments that have more reliability information than the other 25. Four of the six instruments also have more validity information. Since the evaluator is interested in finding an instrument with sound psychometric properties, he decides to first read through the summary descriptions of the four instruments that have more information for both reliability and validity (the Career Decision-Making System-Revised, Level 1; the CATME; the Creative Engineering Design Assessment-Revised; and the Critical Thinking Assessment Test). The evaluator also skims through the list of other instruments and notes that there are writing assessments, design instruments, teamwork assessments, an ethical survey, and critical thinking tests, among several others. The evaluator decides that, based on the information available, he needs to visit with the research team again to better delineate the professional skills the team would like to assess. After visiting with the team, the evaluator goes back to ASSESS and locates an instrument that best meets the team's goals and logistical capabilities for implementing the selected assessment.

Scenario Three. An instrument developer is seeking ways to make information about her instrument known to the engineering education community. At an Annual Conference of the American Society for Engineering Education (ASEE), the developer learns of ASSESS and decides to look into the website to determine if the website is an adequate location for her instrument information. She uses the “Show All” function on the Search page to read through the types of information available in ASSESS. She also reads through the other pages on the ASSESS website, including the Learn, Rate, About, and Help pages. The developer decides that ASSESS would be an appropriate venue for her instrument, so she clicks on the “Propose” tab. Once on the Propose page, the developer clicks on “Propose an Addition to our Website Database,” and a new page opens on which the developer is able to enter brief information related to the constructs for which evaluation is desired, the intended audience to be evaluated, the purpose for which the instrument will be used, other information about the instrument, and her contact information. The developer completes the application by typing in the Captcha designation and clicking “Submit Proposal.” The new instrument information is then sent to an ASSESS administrator who locates any remaining information and sends the instrument description back to the developer for her approval. The developer and the ASSESS administrator work together to ensure accuracy of the listing. Upon her final approval, the instrument developer sees her instrument listed in ASSESS with an asterisk next to the listing to indicate the instrument is “author-approved.”

Guidance for Selecting and Using Instruments

The aforementioned examples offer scenarios in which ASSESS may be used to locate instruments for assessing various outcomes and to add instruments for inclusion in ASSESS. Below are additional tips users may find helpful in selecting and using assessment instruments:

- Proper assessment and evaluation begins with a clear purpose or goal. Assessment may be formative or summative in nature, and assessment measures can take many forms. Prior to using ASSESS, users should determine their purpose or goals for seeking an assessment instrument, the population with which the instrument will be used, and the context in which the instrument will be utilized. Users should then select instruments that most closely align to the user’s purpose, population, and context.

- ASSESS users may search for all instruments using the “Show All” function and then filter the information based on selected criteria, such as psychometric information, ABET criteria, formatting requirements, or administration specifics. Alternatively, users may search based on domain or they may enter the exact name of an instrument to determine the psychometric, technical, and administrative properties of the instrument as well as any previous uses of the instrument in the field of engineering education.

- Prior to selecting an instrument, careful consideration of the available validity and reliability information is necessary. ASSESS reports validity and reliability evidence; however, recommendations are not made on the strength of the evidence. Instruments should be selected that have been tested with similar populations and in similar contexts to the intended use, in order to maintain accurate interpretations of the results.

- To learn more about assessment and evaluation, users may click on the Learn tab. The Learn page provides an overview of assessment, a glossary of assessment and evaluation terms, and additional resources for locating engineering education assessment instruments and instrument information.

- Upon using an instrument found in ASSESS, users may rate instruments by clicking on the Rate tab. Users may also click on the Rate tab to provide feedback on the ASSESS website.

Lessons Learned

Over the course of the ASSESS project, the team learned many valuable lessons in database and website development. Progress toward the final product relied heavily upon interplay among web programming, instrument identification and entry, and adoption research conducted throughout the project. A website structure was put in place, but could only be tested with an adequate number of instruments. Identifying instruments and locating instrument information was challenging and time-consuming; however, the process of receiving author-approval added necessary credibility to the site. Adoption research and consultant feedback drove modifications necessary for achieving a product that could be utilized by different types of users. Although the ASSESS database is comprehensive, the team is seeking to add information for a greater number of instruments. Currently, the website houses instruments used primarily in higher education; however, beginning Spring 2014, information for P-12 engineering assessment instruments will be included in ASSESS. Additional information for instruments in each domain is also necessary to adequately populate the database.

The development team also learned about the availability of assessment instruments for use in the engineering education community. As shown in Tables A1-A6, information could be located for several attitudinal measures. Many instruments were also easily identified for assessing knowledge, behaviors, and professional skills. Fewer instruments were located for assessing the learning environment or using institutional data to measure various outcomes. One trend that occurred in the early 1990’s and 2000’s was the development of numerous concept inventories intended to improve classroom teaching and learning. During this time, the need for valid and reliable measures, and the understanding of reliability and validity concepts by engineering educators, to assess student outcomes was also highlighted.[9-11] Yet, as shown in Figures 1 and 2 below, only a limited number of instruments in ASSESS are classified as having “More” reliability and validity evidence. Thus, a need still exists for more clear documentation of psychometric evidence to support engineering education outcome measures.

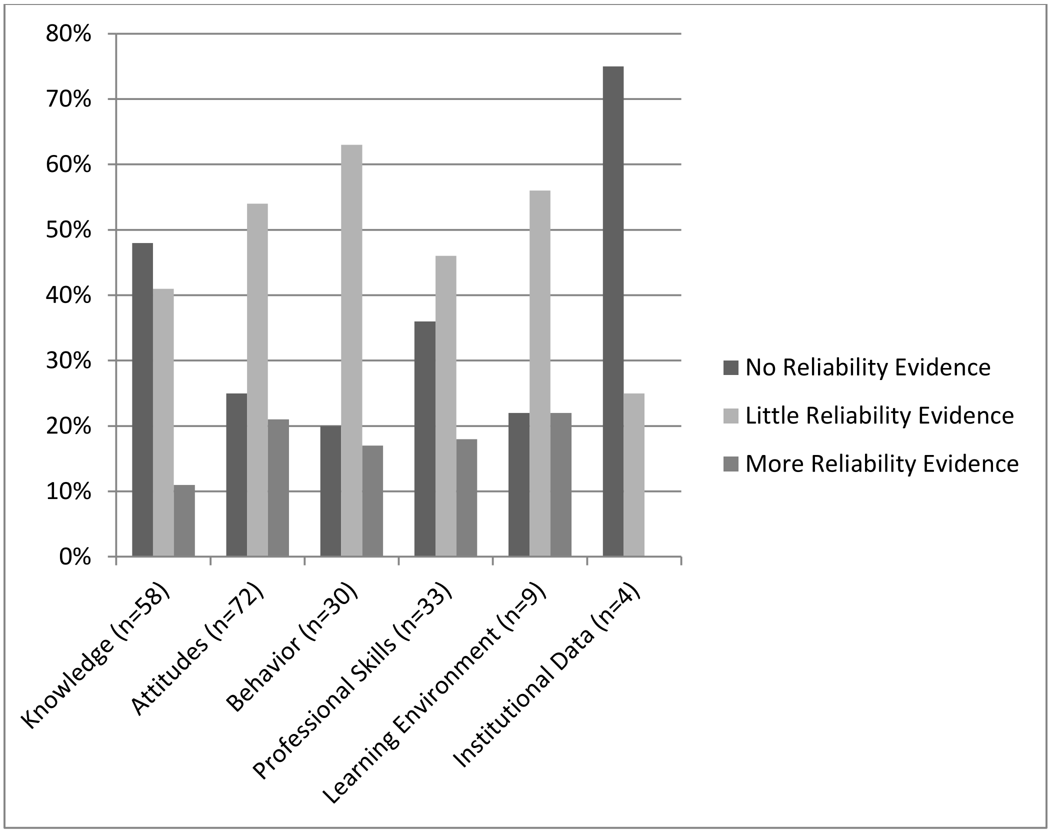

Figure 1. Percentage of instruments in ASSESS having no, little, or more reliability evidence, by domain. No evidence indicates information was not reported or found regarding reliability; Little evidence indicates one type of reliability evidence was located; More evidence indicates two or more types of reliability evidence were available for the instrument.

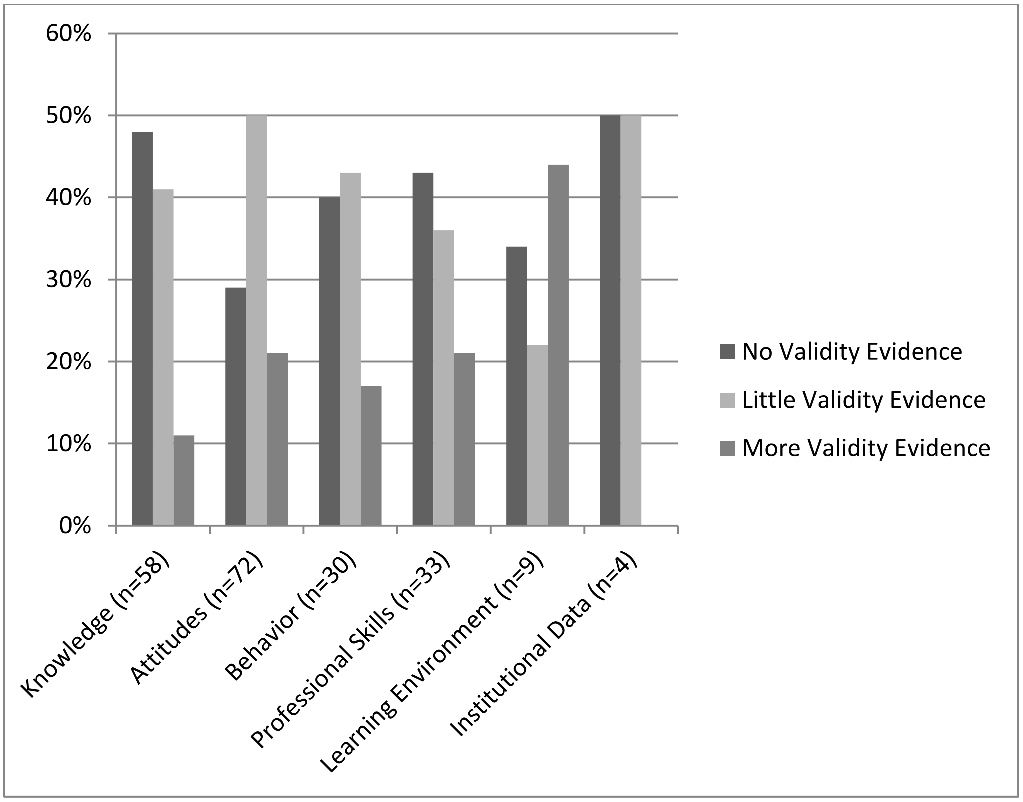

Figure 2. Percentage of instruments in ASSESS having no, little, or more validity evidence, by domain. No evidence indicates no validity information was available; Little evidence indicates less than three types of validity evidence were available; More evidence indicates at least three types of validity evidence were found.

Conclusion

The overarching goal of the ASSESS project was to build on previous proof-of-concept work to create, thoroughly test, and strategically communicate the ASSESS system, positioning it for successful adoption and implementation by the engineering education community. Over the course of the project, a website was developed that enables engineering educators to locate and effectively deploy superior evaluation instruments to enhance engineering education project discoveries and successes. ASSESS offers an easily accessible warehouse with synthesized information for assessment instruments.

To promote awareness of ASSESS and to begin building the evaluation capacity[12] of a community of engineering educators and professionals, the ASSESS team spent the latter part of Year Three considering best practices for developing partnerships with other organizations with whom ASSESS can engage in win-win relationships. To be successful long-term, ASSESS will require a community that supports the database, more people using assessment instruments properly, demonstrated assessment capacity in the community, and partnerships with evaluation service providers. To move toward greater sustainability, the ASSESS team will increase the number of instruments for which complete information is contained in ASSESS, invite broad use of ASSESS to increase user traffic and attract more instruments, gather data to document user access to the ASSESS site and to identify information being sought by users, and explore relationships that will move ASSESS toward sustainability.

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Table A1
Instruments within the Knowledge Domain

Knowledge
ABET Civil Engineering Program Criteria Survey
Binghamton University Circuits Concept Inventory
Chemistry Concept Inventory
Computer-Assisted Performance Assessments
Concept Maps for Engineering Education
Conceptual Survey of Electricity and Magnetism
Control Systems Concept Inventory
Creative Engineering Design Assessment - Revised
Critical Engineering Literacy Test - Revised
Critical Thinking Assessment Test
Design Process Knowledge Instruments
Determining and Interpreting Resistive Electric Circuit Concepts Test (DIRECT)
Diffusion of Engineering Education Innovations Survey
Digital Logic Concept Inventory
Draw an Engineer Test
Dynamics Concept Inventory
Electric Circuits Concept Inventory
Electromagnetics Concept Inventory
Engineering Economy Concept Inventory
Engineering Education Beliefs and Expectations Instrument *
Engineering Failure Concept Inventory
Engineering Graphics Concept Inventory
Entrepreneurship Knowledge Inventory
Environmental Knowledge and Attitudes in Engineering Students *
Faculty Survey on Undergraduate Research
Fluid Mechanics Concept Inventory *
Force Concept Inventory
Fundamentals of Environmental Engineering Concept Inventory
Graduate Teaching Assistant Survey
Heat and Energy Concept Inventory *
Hofstra Alumni Survey
Mastery Exam
Materials Concept Inventory
Mechanics of Materials Concept Inventory
Metacognitive Awareness Inventory
Model-Eliciting Activities
Modified National Engineering Students’ Learning Outcomes Survey *
Nanoelectronics Concept Inventory
National Engineering Students’ Learning Outcomes Survey

Nature of Scientific Knowledge Scale
Non-technical Team Skills for Teaming Survey
Parents' Engineering Awareness Survey
Perceptions of Engineering Survey
Piezoelectric Material Concept Inventory
Prior Experience Questionnaire
Purdue Spatial Visualization Test: Rotations
Revised Purdue Spatial Visualization Tests: Visualization of Rotations
Self-Assessment of Problem Solving Strategies
Self-Directed Learning Readiness Scale (Learning Preference Assessment) *
Shape Memory Alloy Concept Inventory
Signals and Systems Concept Inventory
State Metacognitive Inventory
Statics Concept Inventory
Statistics Concept Inventory
Thermodynamics Concept Inventory
Traffic Signals Concept Inventory
Views of Nature of Science Questionnaire *
Wave Concepts Inventory

* Author-approved instrument

Table A2
Instruments within the Attitudes Domain

Attitudes
ABET Civil Engineering Program Criteria Survey
Achievement Motivation Inventory
Adult Learner Inventory
Affiliation Motivation Inventory
Attitude Toward Chemistry Lessons Scale
Attitudes and Beliefs about the Nature of and the Teaching of Mathematics and Science
Attitudes Toward Science Inventory
Biology Attitude Scale *
Career Decision-Making System-Revised; Level 1
Colorado Learning Attitudes about Science Survey
Computer Science (CS) Attitude Survey *
Computing Self-Efficacy Survey *
Draw an Engineer Test
Electromagnetics Mathematics Anxiety Rating Scale (EMARS)
Engineering Attitude Survey
Engineering Education Beliefs and Expectations Instrument *
Engineering Identity Development Scale
Engineering Modeling Self-Efficacy Scale
Environmental Knowledge and Attitudes in Engineering Students *
Epistemological Beliefs Assessment for Engineering *
Faculty Survey on Undergraduate Research
Freshman Engineering Attitude Survey
Freshman Engineering Perception Test
Graduate Teaching Assistant Survey
High School Distance Education Survey
Hofstra Alumni Survey
Index of Learning Styles *
Information Technology (IT) Attitude Survey *
Innovation Self-Efficacy Survey *
Institutional Priorities Survey
Java Programming Self-Efficacy Survey
Leadership Self-Perception Instrument
Learning Combination Inventory
Lucas, Cooper, Ward, & Cave's Venturing and Technology Self-Efficacy Scale
Maryland Physics Expectations Survey
Metacognitive Awareness Inventory
Motivation, Attitude, and Retention Survey
National Engineering Students' Learning Outcomes Survey
New Ecological Paradigm Scale *

Non-technical Team Skills for Teaming Survey
Parent Satisfaction Inventory
Parents’ Engineering Awareness Survey
Perceptions of Engineering Survey
Persistence in Engineering
Pittsburgh Freshman Engineering Attitudes Scale - Revised
Pittsburgh Freshman Engineering Attitudes Survey
Pre-Survey of Student Perceptions
Principles of Scientific Inquiry-Student
Principles of Scientific Inquiry-Teacher
Priorities Survey for Online Learners
Purdue Interest Questionnaire
Revised Environmental Scale
Science and Engineering as Choices for Students with Disabilities
Science Attitude Scale for Middle School Students
Science Laboratory Environment Inventory
Science Motivation Questionnaire II *
Scientific Attitude Instrument II
Self-Efficacy for Cross-Disciplinary Team Learning
Socialized Power Motivation Inventory
Student Assessment of Learning Gains
Student Attitude Survey
Student Satisfaction Inventory
Students' Approaches to Learning Instrument
Teaching Design, Engineering, and Technology Survey
Teaching Engineering Self-Efficacy Scale
Team Effectiveness Questionnaire
Technical Writing Attitude Measurement
Value Survey *
Views about Sciences Survey
Views about Writing Survey
Views on Science-Technology-Society
Web Course Survey

* Author-approved instrument

Table A3
Instruments within the Behaviors Domain

Behaviors
Achievement Motivation Inventory
Affiliation Motivation Inventory
Attitudes and Beliefs about the Nature of and the Teaching of Mathematics and Science
Creative Engineering Design Assessment - Revised
Diffusion of Engineering Education Innovations Survey
Engineering Design Self-Efficacy Instrument *
Engineering Education Beliefs and Expectations Instrument *
Environmental Knowledge and Attitudes in Engineering Students *
Faculty Survey on Undergraduate Research
Graduate Teaching Assistant Survey
How People Learn Index
Index of Learning Styles *
Managerial Behavior Instrument
Metacognitive Awareness Inventory
Model-Eliciting Activities
Modified National Engineering Students' Learning Outcomes Survey *
Motivation, Attitude, and Retention Survey
National Engineering Students' Learning Outcomes Survey
Non-technical Team Skills for Teaming Survey
Parents' Engineering Awareness Survey
Perceptions of Engineering Survey
Persistence in Engineering
Principles of Scientific Inquiry-Student
Principles of Scientific Inquiry-Teacher
Self-Assessment of Problem Solving Strategies
Socialized Power Motivation Inventory
State Metacognitive Inventory
Students' Approaches to Learning Instrument
Team Effectiveness Questionnaire
VaNTH Observation System (VOS)

* Author-approved instrument

Table A4
Instruments within the Professional Skills Domain

Professional Skills
ABET Civil Engineering Program Criteria Survey
Calibrated Peer Review
California Critical Thinking Dispositions Inventory
California Critical Thinking Skills Test
Career Decision-Making System-Revised; Level 1
Cognitive Level and Quality of Writing Assessment
Comprehensive Assessment of Team Member Effectiveness *
Creative Engineering Design Assessment - Revised
Critical Engineering Literacy Test - Revised
Critical Thinking Assessment Test
Customer Satisfaction Questionnaire *
Design Quality Rubric *
Engineering Graphics Concept Inventory
Ennis-Weir Critical Thinking Essay Test
Faculty Survey on Undergraduate Research
Graduate Teaching Assistant Survey
Hofstra Alumni Survey
Learning Combination Inventory
Managerial Behavior Instrument
Mechanics of Materials Concept Inventory
Model-Eliciting Activities
Modified National Engineering Students' Learning Outcomes Survey *
NAFSA/AID Management Skills Survey
National Engineering Students' Learning Outcomes Survey
Non-technical Team Skills for Teaming Survey
Perceptions of Engineering Survey
Purdue Spatial Visualization Test: Rotations
Revised Purdue Spatial Visualization Tests: Visualization of Rotations
Student Engineering Ethical Development Survey
Team Effectiveness Questionnaire
Teamwork Achieved
Technical Writing Attitude Measurement
Views about Writing Survey

* Author-approved instrument

Table A5
Instruments within the Learning Environment Domain

Learning Environment
Faculty Survey on Undergraduate Research
High School Distance Education Survey
Index of Learning Styles *
Institutional Integration Scale
National Engineering Students' Learning Outcomes Survey
Self-Directed Learning Readiness Scale (Learning Preference Assessment) *
Student Engineering Ethical Development Survey
Students' Approaches to Learning Instrument
VaNTH Observation System

* Author-approved instrument

Table A6
Instruments within the Institutional Domain

Institutional Data
Computational Paradigm Survey
Diffusion of Engineering Education Innovations Survey
Hofstra Alumni Survey
National Engineering Students' Learning Outcomes Survey