Holistic Assessment of Students in Undergraduate Industrial Technology Programs

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"External constituents are demanding not only that departments say they are doing good things and not only that they measure how hard they are trying, but also that they measure outcomes" (Walvoord et al., 2000). "[Colleges] should be focused on the 'value added' of the student experience. In today's society, the need to educate for understanding—not just grades—has never been more important" (Merrow, 2004). "What counts most is what students DO in college, not who they are, or where they go to college, or what their grades are" (Edgerton as cited in Merrow, 2004).

As evidenced by these quotations, the nature and assessment of education is changing significantly, and the assessment trajectory is away from sole reliance on the traditional perspective of student grades. Technology faculty must respond to the changing requirements of student assessment and ensure that graduates of the program meet both the expectations and standards of the institution as well as those of other stakeholders, particularly the private sector that typically employs those graduates.

We are reevaluating ways in which students in their departments are assessed. The three-step "backward design" process recommended by Wiggins and McTighe (1998) has served as a conceptual framework and useful design perspective. Broadly, these steps condense to (a) identify desired results, (b) determine acceptable evidence, and (c) plan learning experiences and instruction. Wiggins and McTighe offered a number of practical guidelines to the design and development of curricula, including the assessment process. They stated that "the backward design approach encourages us to think about a unit or course in terms of the collected assessment evidence needed to document and validate that the desired learning has been achieved, so that the course is not just content to be covered or a series of learning activities" (p. 12).

We have identified a number of elements driving assessments at the departmental level as well as those that address the degree candidates' needs. We have explored non-classroom-centered assessment methods and have collected and analyzed preliminary data towards reaching the goal of more holistic assessment of student progression. The planning, work, and outcomes to date that support the learning goals and expected outcomes set forth by stakeholders follow. However, a point of reference must be set prior to any attempt to address the dual issues of student and program assessment by industrial technology faculty in higher education. For example, consistent with both our experiences and the recommendations outlined in step one of the three-step "backward design" process, one must have a fairly specific vision of the knowledge, skills, and attitudes a technology student should develop prior to embarking on his or her career before formulating an assessment plan. In other words, what is to be assessed? This might include such things as knowledge of technology and its associated processes; practical skills associated with materials, tools, processes, and systems related to technology; ethics related to technology development and application; attitudes toward technology; and issues impacting student learning.

A clear understanding of the reasons for assessing technology students is also critical. These reasons may originate in basic requirements to uncover information regarding students' knowledge, skills, or attitudes. One may wish to verify that students can demonstrate practical technology skills and related professional skills, or one may desire to motivate and enhance learning. Ultimately, it is a goal of the faculty to have more than just course grades to reflect student performance. As noted by Wiggins and McTighe (1998), "Too often as teachers, we rely on only one or two types of assessment, then compound that error by concentrating on those aspects of the curriculum that are most easily tested by multiple-choice or short answer items" (p. 65). A well-structured program should include assessment by a variety of methods and from a more holistic perspective than is often currently employed. An ancillary benefit of a more holistic assessment may be a more positive student attitude toward the discipline.

From the departmental perspective, improved student assessment allows faculty to do a better job evaluating and adjusting the technology curricula and program options (e.g., manufacturing and occupational safety) to meet educational objectives. Improved assessment also increases faculty credibility with other stakeholders in the educational process, such as administration, parents, and employers. Given a clear understanding of the overall educational objectives and forces driving the need for assessment, one may turn to questions of available assessment strategies and benefits they provide for the learner and the instructor.

We three authors formed an action research collaborative with the central goal being to develop, implement, and evaluate innovative forms of assessment that document student growth in a holistic manner. The alternative forms of assessment that we advance are not envisioned as wholesale replacements for existing knowledge-based tests; rather, we suggest they supplement existing grade data with assessments targeted toward technological capability and problem solving. Outcomes of an improved assessment process allow faculty to make adjustments to both curricula and extracurricular activities with greater clarity regarding the impact of such changes on the industrial technology program and students. Ultimately, the faculty hope to accelerate the students' learning more effectively and efficiently and "jumpstart" them into their profession.

Technology Learning Community

Changes to assessment processes are complicated by simultaneous changes to the program. For example, the context for our action research is a Technology "Learning Community" (TLC) that we established within the industrial technology curriculum at Iowa State University. Learning communities are relatively recent additions to the landscape of American universities. Research by Lenning and Ebbers (1999) has indicated improved student retention and satisfaction with the academic experience through the use of learning communities. The TLC is an induction and support activity for freshmen and transfer students in the industrial technology program. The purpose of the TLC is to help entering students (regardless of their academic stage) maximize their educational experience and begin their professional acculturation within the discipline of industrial technology. TLC participants are organized into small groups of students. Each student group works with a peer mentor, an industrial mentor (an industrial technologist practicing in industry), a graduate assistant, the academic advisor, and industrial technology faculty members. In addition to more formal assessments, TLC students evaluate their experience each week in reflective summaries. Below are some comments selected from TLC students' summaries:

- This was a very helpful class since it provided to me a strong idea of what I can expect, and in turn what is expected of me. Peer mentor groups met in class and we exchanged phone #'s and E-mail addresses.

- Last class we had speakers come in from SME [Society of Manufacturing Engineers], ASSE [American Society of Safety Engineers], and SPE [Society of Plastics Engineers] clubs who talked about what their organizations do and how to get involved in these clubs. I think this was a very good class day because most people are unaware of how they can get involved in something like this and what they actually do in these clubs. I am very interested in SME and hope to join next fall. I would have liked to join this semester but with my current schedule and obligations this is impossible.

- Last week our group met with our peer mentor for half an hour. We talked about our schedules and how classes are going. Our peer mentor suggested that we do our resumes and turn them in to him the next time we meet. We discussed how important it is to go to Career Day on Feb 19th. He wants our resumes so he can go over them and make possible corrections so we can have them with us for career day. We have assigned a day and time for our meetings, which is Wed. at 5 p.m. in the TLC room.

- Last week's class helped me to more fully understand the full potential that an Industrial Technology major could provide for me in the future. In our group meeting we talked about how to improve our resumes and how to sign up for ECS [Engineering Career Services].

At the end of each semester, TLC students were asked to evaluate the ability of the TLC experience to meet the goals of the TLC initiative using *excellent, good, fair*, or *poor* ratings. When questioned about their experiences with respect to the goals of "Orientation to the industrial technology discipline and profession" and the "Process of developing realistic self-assessments, career goals," 93% of the students reported *good/excellent*. The responses were even more positive regarding the goals of "Connections with faculty, other students, and industry professionals" and the "Process of introducing the variety of professional roles available through an industrial technology degree," with 96% of the students reporting *good/excellent* experiences.

The experiences within the introductory course were crafted to establish both the small group cohesiveness and interaction with peers that is so essential to effective team-based technological problem solving that employers demand of industrial technology (ITEC) graduates. Another key to the success of the TLC is the use of industrial mentors. ITEC students are very pragmatic—most have their sights set firmly on a career in industry. Hence, inputs from industrial mentors are highly valued and persuasive. They convey high expectations while demonstrating realistic practice and applications in industry.

Student learning has been enhanced through cooperative interaction with their TLC group members and mentoring team. The industrial and peer mentors have increased the TLC students' understanding of the discipline and the importance of curriculum components beyond what individual faculty members can accomplish in the classroom. The TLC students have a better understanding of their personal learning styles and how that impacts their studying habits and classroom interactions. By the end of the semester, TLC students have generated or updated their resumes, started professional portfolios, and set the foundation of team building and awareness of technology that they will continue to enhance and build upon throughout their academic career and beyond. Additional information regarding the Iowa State University TLC may be found in Freeman, Field, and Dyrenfurth (2001).

Student Outcomes Assessment

Desired student outcomes include enhanced capability with technology, increased student satisfaction, higher academic performance, refined career goals, and a greater awareness of one's learning style and how to most effectively utilize that information. When students conclude their studies within technology programs, it would be desirable for them to have indicators of capability to demonstrate academic proficiency, beyond just course grades.

In order to assess student outcomes in a more holistic way, appropriate instruments must be available. Efforts are underway to identify and evaluate such instruments for use in the undergraduate industrial technology curricula. In addition to the qualitative and quantitative analyses related to the TLC, activities include an evaluation of the use of Dyrenfurth's (1991) technological literacy instrument based on the work reported in Dyrenfurth and Kozak (1991), the ACT Work Keys employability skills exams, and the National Association of Industrial Technology (NAIT) certification exam; reviews of each student's portfolio by faculty and an industrial team; and comparison of participant satisfaction and academic performance with other students not participating in TLC activities.

A number of other key targets have been included as initial assessment areas. These targets include student demographics, academic performance, learning styles, technological understanding and capability, and ethical dimensions of technology.

With these assessments, faculty hope to benchmark both the initial and exit competence of students, document students' progression over the course of their academic experiences, document differences among groups and types of students, and investigate implications arising from these differences for program design and development. The assessments are also designed to focus attention on the various components of competence (e.g., technical, managerial, foundational, personal) and to increase attention to the assessment process in order to strengthen its validity and reliability.

The faculty has synthesized a set of targeted industrial technology competencies for students at Iowa State University through the efforts of individual instructors responsible for specific courses, the departmental curriculum committee, and other stakeholders (e.g., Industrial Advisory Council and NAIT). It would be advantageous for faculty to be able to collect a wide variety of demographic data and longitudinal data for tracking student performance, as well as data indicating performance against desired outcomes; however, they recognize that constraints exist on the amount of data that can be collected and analyzed.

The NAIT accredits industrial technology programs. Department missions are expected to be compatible with the approved definition of industrial technology. The mission, as listed in the 2002 *NAIT Self Study Report* (Department of Industrial Education and Technology, 2002), states: "The Department of Industrial Education and Technology at Iowa State University prepares technically oriented professionals to provide leadership in manufacturing technology and occupational safety through an undergraduate industrial technology program" (p. 6.2-2).

A second necessary, but not sufficient, condition for accreditation listed in the 2002 *NAIT Self Study Report* requires that competencies shall be identified that are relevant to employment opportunities available to graduates. While the accreditation process serves as one driving force for curriculum review and outcomes assessment, there are others. Apart from the expected continuous improvement efforts of the faculty, the department retains an Industrial Advisory Council to assure that the industrial technology curriculum addresses the current and future needs of business and industry. The Council recommends and reviews curriculum and program changes that will enable the department to be responsive to business and industry (Department of Industrial Education and Technology, 1998). The department faculty, NAIT, and the Industrial Advisory Council all play an important role in defining and refining the competencies expected of industrial technology graduates.

Ultimately, a reevaluation and alignment of course content offered in the programs was needed to ensure that the competencies expected of industrial technology graduates were realized. This involved a comparison of curricular content with required NAIT objectives. Gaps and/or superfluous material were identified and addressed. Faculty members led this effort, but they were not without guidance with respect to the process. The aforementioned three-step design process by Wiggins and McTighe (1998) and work by Kenealy and Skaar (1997) offered useful frameworks. Kenealy and Skaar suggested an interesting outcomes-defined curriculum renewal process that has continued to influence this effort. Kenealy and Skaar described a multistep "action planning" process that has been adapted so that a large number of diverse faculty and students could contribute cooperatively and with a sense of ownership. The needs of clientele groups led to the definition of major educational outcomes for the program, which in turn formed the foundation for learning experiences that would serve to meet student needs. Kenealy and Skaar stated that by grouping learning experiences, course titles and objectives are defined for a renewed curriculum. Subsequently, courses are defined by specific learner competencies, which are edited for proper sequencing. They also examined cognitive learning skills to ensure that upper level skills were represented throughout the curriculum.

Assessment Instruments

Assessment instruments exist that are appropriate and readily available and for which validity and reliability studies are already well documented. We entered into discussions with ACT, Inc., regarding the use of the Work Keys® system at the undergraduate level. This is a system designed to quantitatively measure certain employability skills. It includes job profiling and work-related assessments and serves a variety of needs in the industrial and educational arenas. For example, the test component of the Work Keys system is designed to assess personal skill levels in important areas of employability skills (ACT, 1997). There are currently eight tests: (a) applied mathematics, (b) applied technology, (c) listening, (d) locating information, (e) observation, (f) reading for information, (g) teamwork, and (h) writing. ACT (1997) stated that educators can use the Work Keys information to develop appropriate curricula and instruction that target skills needed in the workplace. The Work Keys instruments have extensive reliability and validity studies completed (ACT, 1997) at the secondary level, but little information was available demonstrating that its use could be extended to the baccalaureate level. Our preliminary research results with undergraduates would seem to warrant additional investigation of the Work Keys system. Five of the eight tests were administered to undergraduates, including (a) applied mathematics, (b) applied technology, (c) locating information,

(d) teamwork, and (e) writing. Our primary concern was that a majority of the students would score at the highest scale level of the exams, thus diminishing the usefulness of the exams for assessment purposes at the baccalaureate level. This did not prove to be the case as only 9.1% (n = 33) achieved this level in the Applied Technology exam, 14.8% (n = 27) achieved this level in the Locating Information exam, and no students achieved the highest level in the Teamwork and Writing exams (n = 26 and n = 22, respectively). Applied Mathematics yielded the only exam where significant numbers of students (45.2%, n = 31) scored at the highest level.

The ITEC program enrolls numerous transfer students from engineering. Many of these students have not had a great deal of academic success in the engineering program, but most seem to thrive in the industrial technology program. It has been posited that a mismatch between instructional style and learning style has been a leading cause of at least some of these students' previous academic problems and that a change to a more "hands-on" curriculum has allowed them to flourish. While there may indeed be systemic differences in the instructional approaches taken by engineering and industrial technology faculty, a recent study undertaken to investigate this question found that there were no statistically significant differences in learning styles between groups of engineering students and industrial technology students at either Iowa State University or North Carolina A & T State University (Fazarro, 2001). Fazarro used the Productivity Environmental Preference Survey to evaluate learning style differences (Dunn, Dunn, & Price, 1996).

A number of other planned assessment instruments require some additional development prior to their wholesale use. Some are lacking sufficient reliability and validity data, whereas some offer only partial coverage of desired content areas. For example, the NAIT certification test currently covers only four technology categories: (a) production planning and control, (b) safety, (c) quality control, and (d) management and supervision. There are other topics that fall under the technology umbrella such as materials and processing, industrial training and development, energy, instrumentation and control, and information technology. Rowe (2001) suggested an updated test blueprint for the NAIT certification exam. Rowe used a modified Delphi technique to identify core content, subject areas, and competencies. Thirteen core competency areas were identified including (a) leadership skills for supervisors, (b) teamwork, (c) fundamentals of management, (d) safety management, (e) technical graphics/CADD, (f) quality, (g) electronics, (h) human resource management, (i) technical writing, (j) written communication, (k) verbal communication, (l) computer integrated manufacturing, and (m) manufacturing automation. Rowe's findings indicated a need for expanding the use of written and verbal information, particularly with respect to communicating technical information.

The current NAIT certification test is a cognitive, norm-based, multiple-choice test. It contains four 40-question subsections: production planning and control, quality control, safety, and management/supervision. Summary statistics, including classical difficulty and discrimination coefficients (point biserial correlation) based on a sample size of approximately 1,200 students, are available from the authors. Efforts are also underway to analyze these exam items using item response theory (IRT) methods. There appears to be a significant level of interest by NAIT-accredited programs for use of the certification exam in both program and student evaluations.

Description and sequencing of the test construction process (preparing test specifications, item construction and review, detecting item bias, estimating reliability, etc.) are readily available in, for example, Crocker and Algina (1986). All tests used for assessment are expected to pass a review against generally accepted test construction guidelines.

Other instruments currently under consideration include Dyrenfurth's (1991) technology literacy test, a survey of attitudes toward technology (DeVries, Dugger, & Bame, 1993; Raat & DeVries, 1986), multiple technological problem-solving appraisals developed in the manner suggested by Kimbell and Stables (1999), and the assessment of technology projects and activities using group process and student individualized performance rubrics suggested by Custer, Valesey, and Burke (2001).

We envisioned the deployment of the aforementioned assessment instruments across the department and longitudinally over the students' four-year period of study. The plan would have the department's faculty establish a database of specific course goals and objectives and then crosswalk each to the department outcomes. Existing tests and other assessments would be cross-indexed to these goals and objectives. Tables of specification would be used to identify weighting and/or coverage gaps, inappropriate proportions, etc.

Subsequently, innovative assessment mechanisms, such as authentic assessments, portfolios, rubrics, and adaptive testing, would be expanded to complement and/or modify the current assessment strategies. Some authentic assessment activities are currently in place in the industrial technology program at Iowa State University. Freeman and Field (1999) discussed assignments given to groups of safety students that involve job safety analyses, along with equipment and process reviews in labs run for manufacturing students. These assignments are identical to the tasks safety students might find when working in an industrial setting following graduation. Students have also been asked, for example, to develop and construct tooling for specific tasks in metallic materials and processes labs. Many of these laboratory-based activities offer opportunities for authentic assessment.

Multiple-choice assessments will be subject to item analysis and will be recorded in the item database. These assessments have their place as tests of technological knowledge; however, Kimbell and Stables (1999) do not consider them to be valid tests of technological problem solving. Kimbell and Stables offer a great deal of insight into the development of performance assessment instruments for technological problem solving and the development of assessment rubrics to translate performance qualities into numeric data for statistical analysis.

A summary listing of the anticipated system development activities are shown below:

- Conceptualize outcomes based on inputs from faculty, NAIT, and the Advisory Council.
- Analyze objectives for each course in program.
- Analyze NAIT certification examination table of specifications.
- Crosswalk course outcomes to objectives.
- Crosswalk objectives to NAIT certification examination table of specifications and exams for each course.
- Select instruments:
  - Conduct additional literature review.
  - Review American Educational Research Association presentations.
  - Explore available tests or identify and develop appropriate new instruments.
- Define benchmarking process.
- Finalize assessment timing.
- Develop assessment-sampling matrix that secures data, which may then be aggregated without imposing all tests on all students.
- Bring test administration and analysis online through the use of off-the-shelf software.
- Develop analysis plan.

Student performance will also be recorded in a database and, within legal guidelines and pending student approval, certain elements of the information will be available to assist peer and industrial mentors in conducting discussions with students. Peer and industrial mentors will be expected to offer each student constructive perspectives as to how his or her performance is progressing against personal and professional standards. Assessment validation will involve the program's industrial advisory council members so that real-world standards are not only employed but are also made clear to students. A key goal is to demonstrate student awareness of growth over time. Potentially confidential topics from a student perspective will be handled through discussions with faculty and faculty mentors.

Summary

There are clear and persistent indicators that changes are needed and expected in our system of education. In 1999, the National Research Council reported, "The goals and expectations for schooling have changed quite dramatically during the past century, and new goals suggest the need to rethink such questions as what is taught, how it is taught, and how students are assessed" (pp. 152-153). In 2001, the Council reviewed and expanded on trends, which "are changing expectations for student learning and the assessment of that learning" (National Research Council, 2001, p. 22). Efforts to design and implement a more holistic assessment of students in industrial technology programs are certainly timely and in keeping with the spirit of the recommendations by the National Research Council and others. Our work represents an initial step towards capitalizing on some of the innovation that, while important, nevertheless reflects singular enhancements. Our goal was also to integrate several of these innovations into a more systematic approach. To this end, we have conceptualized a framework for moving forward, we have established the feasibility of using the Work Keys® employability skills instrumentation, and we have described some necessary implementation steps. We invite members of the profession to join in the challenge of implementation of such enhanced systems of assessment.

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