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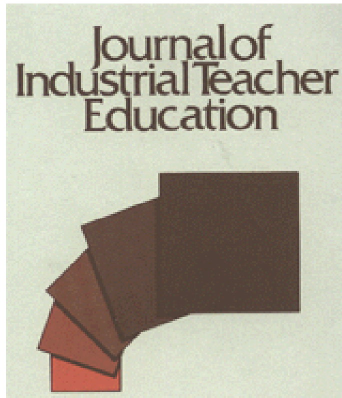

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Using Contextual Learning to Build Cross-Functional Skills in Industrial Technology Curricula

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To develop manufacturing and safety graduates with the requisite knowledge and skills, industrial technology faculty must be cognizant of both the need to develop emerging skills as well as the advantages of newer learning methodologies. This article addresses these two imperatives. In particular, and with respect to the first imperative of developing emerging skills, we focus on cross functional skills which are increasingly called for and recognized as essential to today's rapidly changing economic realities (Pearlman, 1997). Then, with respect to learning methodologies, we describe a viable industrial technology strategy for employing contextual learning to build cross-functional skills.

Since the early 1990s, cross-functional skills have been viewed with increasing importance in the literature associated with technological competence, transfer, and problem-solving. Some of the foundational concepts that have been addressed include integrating academic and practical learning, cognitive apprenticeship, and the interaction between education and the economy (Berryman & Bailey, 1992; Collins, Brown, & Holum, 1991; Grubb, Davis, Lum, Plihal, & Morgaine, 1991). Parker (1994) published a pivotal book outlining how cross-functional teams can work. More recently, Stiles (1998) discussed how businesses are becoming more cross-functional as a response to economic competition. A sign of the maturity of this construct is that no less reputable a group than the Board on Testing and Assessment of the Commission on Behavioral and Social Sciences and Education of the National Research Council has addressed the challenge of assessing cross-functional skills:

> Cross-functional skills such as teamwork, communication, leadership, coaching/mentoring, conflict management, negotiating, customer service, decision

> making, managing resources, and information gathering are among the most important for effective contextual performance and employment stability and security for workers. Unfortunately, such skills are also the most problematic to define, assess, and develop, largely due to the absence of rigorous, comprehensive, work-analytic or construct-oriented research on such skills. There is as yet no systematic mapping of such skills to either the content or the context of the emerging workplace. (Pearlman, 1997, p. 137)

The need for attention to and research on both the development of programs to inculcate cross-functional skills as well as for establishing a better theoretical understanding of the training and assessment of cross-functional skills was also highlighted by the Board:

> The utility of programs and initiatives designed to shape and motivate the education, training, or development of the skills and knowledge needed in the emerging workplace depends on research and information that is incomplete in several key aspects, such as the relative importance and the relative trainability of different types of skills …. The above points present numerous challenges for assessment, the most urgent of which is the need for technically sound and widely deployable measures of cross-functional skills. On a system level, there is a need for better integration of the three conventional roles of assessment: diagnosis (enabling inferences regarding what has and has not been learned); prediction function (enabling inferences regarding future performance or behavior); and evaluation (enabling inferences regarding level, status, or progress of either individuals or institutions, which can influence the degree and direction of individual and institutional investment in skill, knowledge, and ability development). (Pearlman, 1997, p. 137)

We cannot assume that the sole reliance on traditional lecture formats, accompanied by practice problems found so often at the end of chapters in textbooks, will build the kind of academically oriented "hands-on" practitioner we want to see in new graduates of our programs. Additionally, the authors do not believe that such an approach builds student abilities to interact with others outside their field of study (i.e., cross-functional competencies). This concern regarding the preeminence of lecture as a teaching methodology is shared by others. For example, Finkel (2000) argues that some alternative learning environments are more conducive to learning than a teacher's telling students what they are supposed to know. Cooper and Robinson (2000) also report that the research on the efficacy of lectures is fairly consistent and "the news is not good," while at the same time reporting that most of the professorate choose lecturing as their primary instructional strategy. Others (Johnson, Johnson, & Smith, 1998) suggest that many instructors consider the old paradigm-lecturing while requiring students to be passive, silent, isolated, and in competition with each other-to be the only way to teach. A growing dissatisfaction with the value of lecture as the primary method of teaching is suggested by their comment that "the tradition of the old paradigm is carried forward by sheer momentum, while almost everyone persists in the hollow pretense that all is well. All is not well." (p. 1:7).

This is not to suggest that lecture has no place in the repertoire of teachers. The National Research Council Committee on Learning Research and Educational Practice (1999) notes that, "Books and lectures can be wonderfully efficient modes of transmitting new information for learning, exciting the imagination, and honing students' critical faculties-but one would choose other kinds of activities to elicit from students their preconceptions and level of understanding…" (p. 19). The Council elaborates by suggesting that learning with understanding is often harder to accomplish than simply memorizing, and that many curricula fail to support learning with understanding because they present too many disconnected facts in too short a time, i.e., the "mile wide, inch deep" problem. It is for these reasons that the authors have purposefully looked for teaching strategies, other than class-based lectures, that will meet the requirements for hands-on practitioners who are able to effectively interact across functional boundaries. A starting point for the design of these kinds of educational experiences is a review of literature and an assessment of the theory upon which the suggested approaches are based. Elements drawn from works in the areas of cooperative learning (including learning communities), contextual learning, and experiential learning provided the theoretical base for this design effort.

Cooperative learning. Johnson et al. (1998) define cooperative learning as the instructional use of small groups so that students work together to maximize their own and each other's learning. They report from the research that cooperative learning, compared with competitive and individualistic efforts, typically results in greater efforts to achieve, more positive relationships among students, and greater psychological health. McKeachie (1999) refers to cooperative learning as "peer" learning. He states that peer learning benefits the student both motivationally and cognitively. Motivationally, it provides the advantages of interaction with a peer and opportunities for mutual support and stimulation. Cognitively, it provides the student with the opportunity to put material in one's own words and begin using the language of the discipline.

Contextual learning. According to Hull (1995), contextual learning theory says that learning occurs only when students process new information or knowledge in such a way that it makes sense in their frame of reference. He further states that this approach to learning and teaching assumes that the mind naturally seeks meaning in context and does so by searching for relationships that make sense and appear useful. The 1991 report by the Secretary's Commission on Achieving Necessary Skills (SCANS) includes the following statement:

> We believe, after examining the findings of cognitive science, that the most effective way of learning skills is "in context," placing learning objectives within a real environment rather than insisting that students first learn in the abstract what they will be expected to apply (SCANS, 1991, p. xv).

Other researchers (e.g., Keif & Stewart, 1996; Resnick & Klopfer, 1989) have also cited contextual learning as a particularly effective educational process.

Experiential learning. Dewey, in 1938, stated "all genuine education comes through experience" (p. 25). The core practices of the Foxfire Approach to Teaching and Learning (Starnes, 1999) define the most powerful learning experiences as those that "engage learners in posing and solving problems, making meaning, producing products, and building understandings" (p. 2). McKeachie (1999) includes a broad spectrum of education experiences under the heading of experiential learning, such as community service, fieldwork, internships, cooperative education involving work in business or industry, and undergraduate work in faculty research.

One promising approach involves the overlap of these theories through expanded and systematic use of cooperative, experiential learning in context. Expanding the use of this sort of contextual learning in an Industrial Technology (IT) degree program does not require a major shift in direction; indeed, most IT programs already emphasize "learning by doing." What it does require is explicit attention to a goal of providing students alternatives to lecture-based learning experiences.

The authors believe that there are unique opportunities to expand cooperative contextual learning in Industrial Technology by integrating and building on existing concepts of learning communities and service learning, and by increasing cross-functional curricular student interactions as suggested by Freeman and Field (1999). IT programs already employ more extensive use of "hands-on" laboratory work and internship opportunities than do many other academic programs. However, faculty may not always take full advantage of the opportunities for contextual learning in IT degree programs. An analysis of the Industrial Technology program (consisting of two options-occupational safety and manufacturing technology) at Iowa State University (ISU) suggested that such opportunities take the form of: (1) cooperative interactions, including formal learning communities; (2) cross-functional academic interactions; and (3) experiential learning, including internships and service learning. This manuscript describes current efforts by the authors to improve the IT curriculum at ISU by enhancing opportunities for contextual learning via these three methods.

Cooperative Learning

The IT program at ISU has a long history of incorporating cooperative, group learning activities throughout the curriculum. Regardless of the path IT students take upon graduation, they will be required to work effectively as part of a team. With the encouragement of the program's Industrial Advisory Council, the faculty incorporated team activities into nearly every course in the curriculum. This process has helped students develop needed team skills while taking advantage of the many benefits of cooperative-based learning. Collaborative interactions have been shown to increase student academic performance, student retention, structured thinking, and improved ability to work together (American Association for Higher Education, American College Personnel Association, & National Association of Student Personnel Administrators, 1998). In addition to the cooperative activities at the individual course level, the authors have also established a cooperative learning environment that cuts across the entire curriculum with the development of a learning community.

Figure 1

A cross-functional service learning problem (Example 1).

> The first thing you will need to do is to clearly define the problem your group has been assigned. Schedule a time to meet with the appropriate faculty members to obtain additional background information about the problem. You may also need to…. After you have a clear understanding of the problem, start conducting a hazard assessment and documenting relevant background information (e.g., OSHA regulations,…, etc.) addressing the hazards. Once you have accumulated the background information and finished the hazard assessment you can begin to develop possible solutions. Your solutions need to be realistic, accounting for standard industrial constraints (time, money, continued production, etc.). The final step in the process will be to analyze your possible solutions and make a recommendation to correct or mitigate the problem. The documentation of your work will be written-up as a project report.
>
> The Project report should be 15-20 pages in length and include documentation of the hazards, relevant safety and health regulations or guidelines, at least two alternatives for elimination or mitigation of the hazards, and a final recommended solution that includes a cost benefit analysis.
>
> In addition to the written report, each group will also make a short presentation to a panel of faculty summarizing your project and justifying your recommended solution.

Learning Communities

Cross (1998) defines learning communities broadly as "groups of people engaged in intellectual interaction for the purpose of learning" (p. 4) and believes that "service learning is the ultimate learning community" (p. 10). The Technology Learning Community (TLC) is a learning community for freshmen and transfer students in the Department of Industrial Education and Technology at ISU. The TLC is designed to help these entering students maximize their educational experience and begin their professional acculturation within the discipline of industrial technology. TLC participants are organized into small groups of 5-7 students. Each group works with a peer mentor, an industrial mentor, the academic advisor, and a team of industrial technology faculty members throughout the program. The TLC experience includes structured educational activities, professional exploration and development, and social activities. All TLC participants are also introduced to the program's student professional organizations.

Through interaction with peer mentors, industrial mentors, and faculty TLC participants will begin to place their educational experiences in the context of an industrial technologist's role. This approach, in particular, offers significant hope for developing awareness of the affective dimensions of the role and the expectation levels associated with it. We seek thereby to capture some of the same sense of purpose faculty often see when students return to their academic setting following an internship or experience in the field. Through the use of industrial mentoring associated with the TLC, students are afforded year-round opportunities to discuss the importance of coursework and receive feedback and positive reinforcement from industrial mentors regarding the relevance of academic topics. Research has also indicated that the use of learning communities increases student satisfaction with their academic experience (Lenning & Ebbers, 1999), which also reflects positively on their acculturation within their chosen discipline.

Cross-Functional Activities

The authors have operationally defined cross-functional competence as the ability to move across functional (i.e., typical role) boundaries and apply one's skills in environments other than those indigenous to one's root discipline. Examples of such cross-functional activities include:

- having design students complete product component drawings to be used by students in the introductory metallic materials course,
- having materials testing students develop testing procedures to be used by students in the introductory metallic materials course,[1]
- having facility planning students consider long-term facility plans for foundation laboratory classes,[1,2] and
- having safety students conduct safety audits and evaluate safe working practices used by students in foundation laboratory classes.[1,2]

Such cross-functional activities may involve introductory courses, upper-division courses, or some combination of the two. For example, upper-division safety and manufacturing students evaluated introductory manufacturing processing courses to determine the required equipment guarding/shielding and appropriate safety training associated with laboratory processes as cross-functional service learning experience. Figure 1 is an example of the types of instructions provided to students for these types of cross-functional group service learning activities. A more detailed examination of cross-functional activities in the ISU IT curriculum can be found in Freeman and Field (1999).

Experiential Learning

Internships and/or coops have long been a required experiential learning component within the IT curriculum at ISU. This requirement is usually met with a 400 hour paid industrial internship experience. However, the authors have recently added cooperative-based service learning activities into the upper-division courses they teach. The term *service learning* is used to describe these activities because students are working with Iowa businesses to solve real-life problems they are facing, or they are actively working with faculty to strengthen introductory courses within the curriculum by focusing the application of more advanced material within the introductory courses. Cross (1998) lists a number of reasons why service learning appeals to people, including the attraction to Dewey's notions of learning while doing and the disciplinary integration that is required in addressing real problems. Examples of the types of service learning group activities incorporated into the authors' courses include the following:

- Senior facility planning students have developed five-year facilities plans for both the introductory metallic materials laboratory and the introductory polymers and woods laboratory. These plans included space, equipment, and safety considerations. Their discussions of the need and their recommendations provide faculty with concrete examples to pass on to college development officers for use during fund raising.
- Junior safety and manufacturing students have worked with a variety of Iowa businesses to address safety and health concerns. Industrial sponsors have included international, national, and regional manufacturers (e.g., John Deere, 3-M, Kiefer Industrial, White Oaks Cabinetry) and governmental agencies (e.g., Iowa Department of Transportation, USDA Animal Disease Diagnostic Laboratory, and the city governments of Ames, IA and Boone, IA).

Many opportunities and benefits result from establishing these types of service learning activities. However, pitfalls also exist and they have to be guarded against. Cross (1998) lists some of the problems, including that too much time may be required of faculty to arrange the experiences, the possible exploitation of students to perform services that are not educational, and concerns related to using short-term novices to address serious concerns. The existence of potential difficulties, however, should not deter IT faculty from employing contextual learning when there is much to be gained. For example, Figure 2 summarizes a complex service learning activity that the authors felt was appropriate even given the aforementioned concerns.

Figure 2

A cross-functional service learning problem (Example 2).

An expanding Iowa business approached the authors asking for a review of their manufacturing facility plan. The authors assigned the review to several groups of students. The student groups were assembled from two courses: a senior-level facilities planning class and a junior-level manufacturing safety class. The use of novices on the project was not a concern because the students did not have the actual design responsibility, but were merely engaged for review purposes. That is, the students were asked to evaluate the current facilities plan and report on any changes that they deemed necessary to improve the factory flow and optimize employee safety.

The two groups, each consisting of students from both classes, visited with the business owners and conducted site visits of their current facilities and the site that would house their expanded facility. The students talked to managers and employees and then completed their reviews in consultation with the faculty. At the end of the semester, each group presented their reviews to the owners and provided them with reports documenting their process.

The owners received the assistance they requested. The students applied their knowledge and skills in context by combining concepts presented in several courses towards the solution of an industrial problem. The faculty were able to assist students in a manner that is not possible with purely contrived problems.

ISU IT faculty have an established relationship with the field agents of the Manufacturing Extension Partnership in Iowa. These field agents are able to identify opportunities (such as the one described in Figure 2) for collaboration between faculty, students, and local businesses. Leveraging other members of the academic, extension, and business community to identify and help arrange these types of service learning experiences can significantly cut down on faculty time requirements.

Interdisciplinary Collaboration

Interdisciplinary collaboration for undergraduate curriculum development is active on several fronts. The Industrial Technology undergraduate program at Iowa State University consists of two options: occupational safety and manufacturing technology. In preceding sections, this manuscript outlined a number of efforts to formalize contextual learning through cooperative, cross-functional, and/or experiential activities within the two undergraduate options. However, additional interaction has taken place between IT and other units on campus as well, and for similar reasons.

IT faculty and students are working with faculty scholars and students from the College of Business and the College of Engineering on multidisciplinary teams applying their education to real world business situations as members of the ISU Business Laboratory. Here students work on real, rather than simulated, projects that have been identified by corporate Business Lab partners.

IT undergraduates also have the opportunity to experience work taking place at the Center for Nondestructive Evaluation and the US Department of Energy's Ames Laboratory on the ISU campus as part of their undergraduate course work. These organizations routinely conduct development and analytical work for both private and public entities. For example, the Ames Laboratory partners with companies such as Maytag, General Motors, Ford, DuPont and American Superconductor Corporation and has contributed to the startup of a number of new companies, including Carbon Energy Technology Inc., Advanced Analytical Technologies Inc., MTEC Photoacoustics, and Edge Technologies (Ames Laboratory, 2001).

Additionally, IT and Materials Science and Engineering (MSE) faculty have collaborated to provide students in each department opportunities that might not typically be a part of that department's educational experience at ISU. IT students have been able to attend seminars on scanning and transmission electron microscopy, while MSE students have been provided instruction and lab time on machine shop equipment.

Assessing Contextual Learning

The concept of focusing on student outcomes is well embedded in the faculty mindset and not coincidentally in the National Association of Industrial Technology (NAIT) accreditation process. Given this, it was natural to consider how the use of outcome assessment might strengthen faculty initiatives towards increasing the contextual learning dimensions of their students' baccalaureate experience. After some reflection, faculty determined the key principle was participation-participation of students in the outcomes assessment process, in establishing the outcomes to be assessed, in establishing the criteria that would be used to assess performance, and in evolving and implementing measures suitable for assessing the outcomes. Significant change such as this comes only from systematic and long-term activity. Accordingly, the department's students are being introduced to the concept of outcome assessment in their very first introductory course. Here they will be shown the existing outcome matrix for the program. Subsequent TLC interaction will evolve increased understanding and meaning associated with each outcome. Then gradually in the various courses they take, students and their faculty will increasingly shift assessment away from instructor-determined measures towards more student-tailored and reflective approaches. Throughout their four-year experience, students can also be encouraged to document their progress using CD-ROM based portfolios.

Summary

The authors first build the case that lectures, as an instructional methodology, are ill suited to achieve desired learning outcomes; i.e., to develop academically oriented "hands-on" practitioners who have the ability to interact with others outside their field of study. Alternative contextual methodologies, such as cooperative, cross-functional, and experiential learning, are identified and examples of their implementation in the Iowa State University Industrial Technology program are provided. The most significant benefit of efforts to provide contextual cooperative, cross-functional, and experiential learning opportunities for the students is the ability to practice their profession in a work-like environment while they are learning industrial technology principles as part of the undergraduate curriculum. This practical, and often collaborative, application of their discipline, which frequently occurs under typical manufacturing constraints (budget and training requirements, safety and regulatory issues, and production pressures), promotes realistic solutions to industrial technology problems. The process of interacting with other students and faculty/industry professionals provides the students with practical examples of professional collaboration as well as insight as to how the various industrial technology disciplines interact (e.g., training, safety, and manufacturing disciplines all influence the manner in which the students perform the manufacturing processes that are incorporated into laboratory activities). Additionally, students participating in the learning community have industrial professionals and upper-division students to reinforce the importance of introductory/foundation material by placing that material in the context of the industrial technology discipline.

In the larger context, the goal is to develop in students what Thomas and Rohwer (1993) call "proficient autonomous learning." They state that current portrayals of productive outcomes of learning often contrast sharply with actual outcomes, and refer to descriptions of the capabilities of high school and college graduates by Schoenfeld (1985), who reported that their learning as students equipped them, at best, to solve only stylized textbook problems. Thomas and Rohwer go on to say:

> If students are to become better at learning on their own, they must not be left simply to read texts or to do exercises on their own. Students must be allowed to discover what is important in a domain, to define as well as solve problems, to construct rather than learn about relationships between concepts, to set not merely meet goals, to construct schedules not just follow them, and to learn to live with ambiguity. … In contexts that provide and require autonomy, and that embody practices of importance to them, students will engage in forms of learning that result in productive outcomes. (p. 26-27)

This is the challenge facing our faculty; that is, to develop and apply methods of instruction that will encourage students to become autonomous learners. Opportunities abound in Industrial Technology curricula for the implementation of cooperative, contextual learning experiences. The previously mentioned cases are simply examples of learning activities incorporated in the Iowa State program.

The authors close with one final observation: students are not the sole beneficiaries of contextual learning. Faculty who incorporate contextual learning activities also benefit through the opportunity to provide their students with more realistic problems. By furthering their students' understanding of the interrelationships of various technical disciplines and by placing foundation materials in the context of professional practice they increase interest levels and retention rates of new students. The process of planning and implementing contextual learning also helps faculty more realistically assess student learning by tying student outcomes to specific tasks.

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Notes

[1] Also an example of cooperative, group learning.

[2] Also an example of service learning.

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