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***An Update on Applied Quality Science at
Bowling Green State University and the
Instructional Use of Student-Based Applied
Research as a Technology Transfer Mechanism:
A Critical Element of Education for Technologists***

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Techologists are a special breed of practitioner who employ knowledge and skills from an array of disciplines to solve problems. They typically use some variation of a problem-solving heuristic to define a problem, investigate and model possible solutions, analyze results, and ultimately to implement a single, best solution. Many times the results of this process are feedback to be inputted into future technological ventures.

An Update on Applied Quality Science at Bowling Green State University and the Instructional Use of Student-Based Applied Research as a Technology Transfer Mechanism: A Critical Element of Education for Technologists

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Educating students to be proficient at this process is a considerable task. In addition to imparting a solid body of base knowledge, focused both on a specialty and upon broad-based interdisciplinary tools, educators must also facilitate the development of process skills. The particular heuristic used is not so important as insuring that the learner is able to put all of his or her tools together in a cohesive manner when it comes time to solve problems. Traditional behaviorism is a well-established mechanism for imparting bodies of static knowledge. The difficulty lies in teaching the process of applying a body of knowledge in a disciplined manner to the solving of technical problems.

The faculty in the Applied Quality Sciences (AQS) option, within the Manufacturing Technology Program at Bowling Green State University (BGSU), has been developing an innovative approach to educating students so that they do learn to be proficient technologists. The specialization contains a core of classes, capped by a contracted work experience that focuses on cultural, documentation, data, and synchronous management tools. Students apply course principles to help solve problems for real-world clients. Projects are generated, guided, and monitored by AQS faculty and its partners in the business community. This serves as an outreach mechanism for building alliances with the business community, as well as an opportunity for faculty to build a knowledge base from project results.

Several authors in recent years have chronicled the development of the Center for Quality, Measurement, and Automation (CQMA) and the AQS option, within the Manufacturing Technology program, which developed concurrently with the center. Mead,

Sinn, and Haren (1994) introduced CQMA and its technology transfer system. Sinn (1996) carried the work forward by presenting a model for technological problem solving, then presented a case for content (1997) and delivery methods (1998). Barker and Sinn (1997) classified the content into the groups of tools mentioned above. Finally, Sinn and Shipman (1997) discussed the possible future directions for CQMA and its technology transfer activities.

This article will present an update on the AQS option and revisit the issues of growth in its technology transfer model and its delivery mechanisms. In light of this, it will: (a) touch on the history of CQMA and revisit its mission, now being pursued programmatically, (b) present a rationale for the project-based, two-way technology transfer model in education about quality, and (c) explore the development of the model by incorporating electronic delivery methods.

Mission and History

The mission of the CQMA has been to develop and transfer state of the art knowledge and technology related to quality and process improvement, a mission that has been added to the AQS program option. It has also been to advance the embracing and growth of an ever-improving concept and practice of technology transfer. Technology transfer is treated as the development and exchange of technical information and knowledge in a two-way process between academia and organizations both within and external to the university.

In the early 1990's Bowling Green State University (BGSU) and the Edison Industrial Systems Center (EISC) in Toledo, Ohio formed the Center for Quality, Measurement, and

Automation (CQMA) as an applied manufacturing research platform and two-way technology transfer mechanism. Early efforts established a full-sized physical work cell and other infrastructure, consisting of numerous systems and pieces of equipment, put into operation to address various aspects of innovative projects. CQMA has provided technical assistance on campus through mentored applied research projects and regionally through over 160 contracted applied research projects. Most projects provided opportunities to strengthen and develop CQMA's technology transfer systems, based on a model for technology transfer and education throughout northwest Ohio and beyond.

One key element in building the model was and continues to be the existence of a network made up of both campus personnel and advisors from the business community. To this end, an industrial network was developed using the existing Manufacturing Program advisory committee within the Technology Systems Department. The network also includes the newly formed AQS advisory committee. This network is important because it strengthens ties with area industry. The total membership in the AQS advisory committee is approximately 25.

The key drivers for outreach are broadly identified as systems technology, government and business, and education. These drivers are grouped into three main areas:

- The technological driver is a focus on management systems related to the development of organizational culture, the creation of documentation systems, the use of data tools for process control and improvement, and the promotion of synchronous management techniques to promote concurrent engineering. These tools can be equally applied to industrial processes and business systems in the service sector.
- The government and business driver is a focus on the production of goods and services within organizations with up to 500 employees.
- The educational driver concerns

graduate and undergraduate students and programs at BGSU, two-year technical colleges, and secondary schools in the region. This also includes continuing education, such as the quality and metrology symposium and custom training sessions.

Elements of the innovative approaches and their relationships are noted in figure 1, the technology change model.

Several types of project activities have been carried out in pursuit of the mission. In addition to impacting the college and the business community, projects have been very beneficial to students. Each project intimately involves learners in research, teamwork, and communications. The projects are for the students and the students are the prime movers. They are accountable to faculty and personnel at partner businesses both orally and in writing. The list below highlights some successful projects:

- Training.
- Incubation and new product development.
- Rapid prototyping.
- Designed factorial experiments.
- Dimensional analysis and reverse engineering.
- Equipment lease and mentoring.
- Development of two-year technical college curriculum.
- Building relationships between academic programs.
- Streamlining processes within college offices and academic departments.

As CQMA evolved, it developed relationships with departments external to the college. These relationships provided fertile ground for developing an interdisciplinary perspective on technology. These relationships have been primarily with the undergraduate and graduate programs in applied statistics, business, physics and other sciences, in addition to other departments within the College of Technology. Several of these departments have representatives in the AQS advisory committee. It is anticipated that these relationships will continue to evolve and additional interdisciplinary activities will emerge over the next several years.

Rationale for the Technology Transfer Model

CQMA treats technology transfer as a two-way mechanism. In the short term, students gain first hand experience with real-world application of toolkit principles, and customers gain innovative solutions to technical challenges. In the long-term, relationships are developed with project partners.

Building working relationships with other colleges, departments and offices strengthens the programs and services offered by the university. These relationships facilitate integrated student services, improved interdisciplinary studies, and a shared information base related to research activities. Long term relationships benefit both the university and its external partners. Creating long-term partnerships with industry provides a critical avenue of



Figure 1. The Technology Change Model

support for all participating programs, as evidenced by the creation of the AQS advisory committee, increases in cooperative job placements, and valuable monetary and physical support. Industry also benefits from these partnerships, as evidenced by the valuable services obtained from the university and the rate of long-term hires resulting from external project relationships.

The technology transfer model centers around conducting student projects for customers, focused on innovation and process improvement. This model can be applied equally well with both internal and external constituents. The essence of the model is that students conduct applied research in cross-functional teams, using systems tools to carry projects through assessment, analysis, and action phases.

Another critical component of the system is the use of ongoing evaluation by faculty, mentors, and the students themselves. Students evaluate their own work as well as that of other students, where applicable. This element introduces formative and summative feedback for the purpose of continuous improvement, which is fundamental to quality sciences and to technology in general.

Thus the model incorporates several key elements that are crucial to attaining high level learning. In summary, its application is based on the following rubric:

- Assessment: Placing teams in real environments to define the problem and map out the solution process.
- Analysis: Using data tools to make informed decisions about proposed solutions.
- Action: Using documentation and synchronous management tools to implement solutions.
- Evaluation: Ongoing and summative evaluation as a mechanism for feedback and improvement.

Student achievement is crucial to this whole process. Benefits to faculty and staff and to the business community help to fulfill the university's

mission, but the mission to teach students is ill served if the learners are not obtaining the knowledge and skills that they need. There is an underlying need to be very selective and deliberate in framing learning activities. Traditional instructional design, rooted in behaviorism, is tried and true for delivering a body of static knowledge. This is the foundation from which technologists begin to develop skills that will help them to function in their chosen career paths. However, it is only a start.

Application is the crucial element that pushes learning beyond the rote knowledge and reflected attitudes associated with traditional instruction. It is the means by which students synthesize information and develop their own attitudes and behaviors. Use of the model in projects is founded on the principle that students learn to use the knowledge they are gaining by applying it in situations where they can address real opportunities for change. This foundation is based on the construction of knowledge by the learner. Choi and Hannafin (1997) asserted that students could be taught to behave in certain ways by providing context in which to apply knowledge. They stated that mentors should model behaviors and thought processes in appropriate ways. What this means is that if the goal is to get students to behave like a technologist then learning activities should be structured so that students are engaged in application activities under the guidance of technologists who are capable of modeling appropriate behaviors.

This does not mean that educators should abandon the imparting of a solid base of disciplinary knowledge as they focus more on student-constructed learning. Choi and Hannafin (1997) also stated that learning abstract knowledge in the absence of application can enhance critical thinking. This, they concluded, is a key element in the learning process and it must be used in conjunction with application. Without a base of knowledge, it is easy to become trapped in behavioral paradigms and to lack a complete set of tools to solve complex problems.

Higher-level learning combines cognitive processes and content knowledge into new ways of thinking and doing. Perkins and Salomon (1989) stated that experts rely on content knowledge to recognize complex patterns of information when dealing with common situations and then combine their expertise with general cognitive skills to deal with new situations. However, cognitive processes can not be taught separately from content. Bransford, et. al. (1986), asserted that people tend to build schemata for dealing with knowledge in the context of their activities and they do not tend to transfer knowledge into useful schemes unless they are first prompted to do so, even if they have been given useful analogies ahead of time. Perkins and Salomon (1989) stated that the way to facilitate transfer is to help the learner decontextualize the cognitive skills that they develop so that they may be applied to other areas of content knowledge.

One way to help students in decontextualizing their cognitive skills is to engage them in metacognition. Herschbach (1998) stated that students are engaged in metacognition when they "guide their own learning through the application of conditional knowledge". He explained that this involves thinking about a task, choosing strategies to accomplish objectives, gauging performance against those objectives, and making corrective actions. Getting students to analyze their own thought processes will help them to internalize their cognitive skills so they can use them in other areas of their work.

Basing instruction upon activities and getting students to analyze their thought processes will help learners to attain higher level skills and to build the linkages necessary for transfer. This is why the model is so effective. Toolkits supply the knowledge base. Projects provide the environment for application. Written responses, coupled with peer evaluations, provide the means for engaging in metacognition.

There are some significant considerations to be made when designing instruction according to the framework discussed above. Blumenfeld, et al.

(1991) provided some guidelines for insuring that student experiences deliver desired learning outcomes. They stated that projects should incorporate varied tasks. They should also be novel, challenging, and achievable. They should also provide closure. If they are too demanding, focus may shift to getting the work done at the expense of learning.

Choi and Hannafin (1997) discussed some project design elements that can be used to help guarantee successful projects. First, there must be mentors who can appropriately model correct behaviors. Both instructors and mentors can also coach and advise. This can help make the tasks more achievable. Choi and Hannafin also encourage the use of scaffolding. This means structuring activities in such a way that students can participate without too large of a gap in abilities. As students progress, the level of scaffolding can be reduced. Finally, Choi and Hannafin discussed the use of collaboration, which will be discussed more in a later section.

AQS faculty consider all of the above issues when selecting and designing projects for students. Proposed projects are carefully considered before being adapted to student use so that they are reality based, they are focused on solid deliverables, they are achievable by students (under the proper guidance), and rooted squarely in relevant principles. Faculty also insists that the appropriate personnel within the soliciting organization be dedicated to completing the projects and to offering appropriate guidance.

These projects combine acquiring background knowledge and skills and employing them in the course of working toward project deliverables. Individual projects employ tools from the AQS repertoire as needed to satisfy the needs of the project, rolled out according to agendas that are worked out to match project needs with the learner needs.

The project approach is good at matching these needs because technologists need a mixed bag of skills and, in order to successfully accomplish objectives, organizations must employ talented individuals who

possess skills from all necessary disciplines. Managers must effectively pool employees with the proper mix of backgrounds and talents, then lead them toward a common vision and direct their efforts in an efficient manner. Failure to do these things brings failure of the organization, at least when the organization is subject to competition. In light of the idea that applied student activities should model reality and work toward real outcomes, educators should conduct team projects in a like manner.

Working in cross-functional teams requires employees and students to possess skills and knowledge outside of the realm of their chosen field. Collaboration can not occur effectively when team members can not communicate with or comprehend the functions performed by team members who represent other disciplines. Decisions that must be made in technological pursuits are interdependent. For example, a feature designed into a system or an artifact may not be feasible if its cost is prohibitive or if it can not be delivered using available processes. Team members must have an adequate grasp of other disciplines if they are to cooperatively work out solutions to technical problems.

Conducting applied research projects in cooperation with students and mentors from other disciplines can enrich the learning process. Yet traditional university structures sometimes makes it difficult to conduct interdisciplinary endeavors. Competition for resources and students between colleges and programs, as well as longstanding philosophical differences in educational philosophy, etc., can stand in the way. The project system has elements to account for this challenge. Supervisory personnel from the customer's organization mentor all projects, and it is a prerequisite for the acceptance of a project that the customer must commit to lending the support of key personnel and other resources. Additionally students from a variety of backgrounds are recruited into the AQS courses. When teams are formed, one requirement is that the selected students bring a variety of skills and experiences to the team.

Selecting and formatting projects that are within the reach of student capabilities, with a little stretching, and then properly assigning individuals to teams is not an easy task. Many times the critical issues and circumstances surrounding particular projects and groups of students are not easy to identify and deal with. Yet Bento, (1997) suggested that team composition and project design issues must be faced as a set of considerations that will greatly affect learning outcomes. All aspects of team and project formation must be treated as instructional design factors. She stated that many times the formatting of courses and teams in a project environment are not given sufficient consideration by instructors because it is assumed that the most apparent way to arrange things is the only way they can be set up. Her challenge to instructors was to look beyond the obvious and make intelligent choices regarding how to design projects and compose teams.

Bento (1997) presents her design factors in three broad categories. These are team composition issues, pedagogical fit of the project to the course objectives, and the performance appraisal and reward system. Students conducting contracted projects are hand picked based upon their qualifications and their fit within the prospective customer's organization. Students in ASQ courses are placed in mixes on teams based upon several criteria. These are; (a) past experience with similarly conducted projects, (b) level of academic achievement and intellectual maturity, (c) relevant work experience, (d) level of associated technical skills, and (e) where appropriate and possible, personality. As stated earlier, all projects are examined for pedagogical fit before they are accepted, and project statements are sometimes reworked to make the fit better. The evaluation and reward system will be discussed later.

Properly formed teams, whether they are composed of students and employees or primarily of students, are ideally suited to engage in high quality technological problem solving. This problem solving is where learning takes place. Agostinho, Lefoe, and

Hedberg (1997) listed four behaviors that must be exhibited for a project to be classified as what they call problem-based learning. These are self-directed inquiry, the creation of learner constructed knowledge, engagement in metacognition, and social negotiation, or collaboration.

The two-way technology transfer model has built in systems to facilitate all of these behaviors. Toolkits are designed to present foundational knowledge and to introduce problem-solving tools in their basic forms. Beyond this, students must indeed construct their own knowledge, using the context provided by the demands of the project to shape their inquiries. In AQS courses this behavior is further reinforced by requirements for students to include summaries of their inquiries within weekly progress reports. These inquiries can be in the form of outside readings, interviews, or meetings and activities with mentors. As teams process toolkit information, conduct inquiries, divide responsibilities and combine their efforts, they are both constructing knowledge and engaging in social negotiation.

The other behavior Agostinho, Lefoe, and Hedberg (1997) discussed was Metacognition. This is an important process that ties all other team activities together. The act of reflecting upon individual and team cognitive activities helps students to gain additional perspectives, a more mature intellect, and sharper skills. AQS courses have structural mechanisms for the inclusion of metacognition. They are built into the evaluation procedures conducted by the students themselves.

Student work is posted in an electronic forum. Then it is first evaluated by the instructor, who posts the evaluation as a reply to the original file. The team being critiqued uses the evaluative comments to bolster its work on the project.

In cases where multiple teams exist, all teams are required to look over the work of all other teams, view the instructor evaluations, and then formulate their own evaluations of their peers' work. These peer evaluations must be included in written summaries attached to weekly reports. Finally, the

mentors and the teams trade evaluations of each other in order to smooth out any budding problems or to improve an already efficient system.

All of these evaluation activities involve significant metacognitive elements. This process of reflecting upon intellectual activities and then incorporating the lessons learned into future work is a healthy improvement mechanism. When students find ways to work and investigate better, they are synthesizing, evaluating, and characterizing. This is what higher level learning is all about.

Electronic Delivery Methods

The AQS faculty conducts much of its business via electronic means. Interactions between the center, its clients, and the advisory committee are conducted using a mixture of person to person meetings and on-line collaboration techniques. These techniques are being deliberately phased into relations in order to develop and standardize the mediums through which both business and courses are conducted.

The electronic means used for collaboration are simple, effective tools that have proved, through experience, to best serve the needs of students and partners. Students use email and chat to collaborate, then they post their work and perform interactive evaluations via an electronic forum. Their work is catalogued and protected within a course shell called WebCT. This is system that is now being introduced to partners in the business community.

The purpose behind this is that external partners are vital to generating new project opportunities, obtaining support in the form of funds and equipment, and helping to guide curricular innovations. Projects (and courses) are often conducted within the place of business. A primary goal is to obtain more and ever improving projects for students to pursue. The interaction that occurs when projects are conducted is the very essence of how learning occurs and how partners are brought into intimate relationships with the AQS program, departments and the college, and the entire university infrastructure.

As students collaborate over the internet, they are building a rich database full of intellectual capital, as well as ironing out a viable set of methodologies for conducting projects. Now that these methodologies are maturing, the AQS faculty is bringing its partners into the system. The goal is for students, faculty, staff, and employees of the center's partners to collaborate seamlessly and share in the benefits of the growing database. The growing database represents a wealth of experience and expertise that can be adapted and/or built upon by others.

Future projects and interactions will benefit from an ever maturing system and from better, more advanced electronic tools. To this end the AQS faculty is moving toward the implementation of an electronic database. In addition to the security and central gathering of data, this will provide a true database that can be configured to share indexed access across departments, colleges, and corporations.

As the system for conducting projects grows and becomes increasingly defined and effective, the authors will continue to publish updates. Future topics will include discussions about the programmatic, organizational, and infrastructural systems needed to support education that is centered around student based, applied research and two-way technology transfer.

Summary and Future Directions

The AQS model emphasizes two-way technology transfer through the conducting of student-based projects with partners within the business community. These projects are viewed as the backbone of the transfer process, in which students gain invaluable learning experiences and partners gain both new expertise and new working relationships external to themselves.

The projects are built around teams composed of a student or students working with the staff of the project partner. Students are guided by a hierarchy of faculty and staff as well as by appointed mentors within the partner organization. They apply concepts learned from cultural, documentation, data, and synchronous management concepts, embodied in

course tools, to the solution of real world challenges. In the process they investigate outside sources of information, collaborate with practitioners in real organizations, build actual solution systems, and engage in continuous evaluation (both formative and summative) with the intent of continuous improvement in learning and performance.

Collaborating electronically adds a higher degree of realism to student interactions by taking them out of the classroom and placing them in real, situated environments. Students are faced with the dynamics of team leadership, cooperation, scheduling, planning, and performing. They are tasked with pulling these elements together in the face of conflicting needs and schedules, and given the guidance and tools to make it happen. This positions students and others squarely in an environment of practicing professional technologists' behaviors via the application of core technological knowledge.

As the system grows and matures, the faculty is engaging its partners in ever more intimate dealings. The hope is to create a seamless environment in which students, faculty members, and project partner personnel can interact, access expertise, and build new relationships. Ultimately the goal is to create an environment in which students are engaging partners in projects that cross the borders of departments and colleges and in which any party to the system can access and build upon data that is incorporated in the system.

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