Developing competency-based, industry-driven manufacturing education in the USA: bringing together industry, government and education sectors

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Abstract

In recent years, the U.S. has been experiencing a shift in technical and professional education. Industry, education and government stakeholders are redefining their partnerships and working together to create competency-based, industry-driven education at the local, state, and national levels. These form the fundamental principles of a paradigm shift in education needed to combine and enhance innovative educational approaches from different research fields, as well as best-practice models from other countries. This paradigm shift presents a challenge, as education and public sectors are typically not familiar with matured (project) management principles, and often follow the “Garbage Can- Model”(Cohen, 1964), while, simultaneously, industry experts lack experience and knowledge about the academic and public world. But both have to answer questions like: How can PM measure progress in an educational project? Which PM methods are most/least helpful?

Using a case study approach to the research, this paper will analyze several highly visible and innovative stakeholder partnerships that are breaking traditional curriculum and assessment models. Using industry subject matter experts, both the Michigan Advanced Technician Training (MAT2) program have developed a competency-based curriculum that incorporates a sophisticated methodology of assessments using the industry-driven DACUM
approach as the foundation. The new model requires a sophisticated methodology for tracking learning analytics including performance, completion rates, and learning gaps. This paper will propose a solution.

Keywords: competency, education, government sector, curriculum, stakeholder

1 Introduction

In order to compete globally, US manufacturers must be agile and innovative in their ability to utilize evolving technologies for both product and process improvement (McKinsey Study, 2012). Their ability to do so, however, is contingent on the talent pipeline, which, over the last several decades, has not produced [enough] skilled workers with the knowledge and abilities necessary to operate and maintain modern technologies (Manufacturing Institute Report, 2012). As US manufacturers continue to report a significant skills deficit, the demand for educators to meet the talent requirements of global industry has reached a critical juncture. The growing disconnect between industry and education sectors has resulted in a departure from traditional college programs.

The US education system, which has [largely] been unable to meet industry standards for skills and development training, is now facing a paradigm shift in technical and professional education. Efforts lead by community colleges and/or industry have been launched throughout the US; however, in order to comprehensively meet the needs of advanced manufacturers, government, education and industry stakeholders need to form a strategic alliance and create competency-based, industry driven education (Gupta, B.L., 2008). The MAT² (Michigan Advanced Technician Training) Mechatronics Program is a state-lead effort to implement such a system, and if successful, could serve as the national model for technical and professional education.

2 Purpose and Objectives

MAT² is a [state] government lead initiative; however, its steering committee (SC) is comprised of government, academic, and industry representatives- all led by an independently contracted project manager. Their primary objective(s) is to implement an innovative and industry-defined approach to education which will offer (a) companies - competent employees, (b) young adults - a financially viable education and career pathway, and (c) Michigan - a talent pipeline of skilled workers. In order to achieve their vision of nationally and internationally recognized dual education standards, MAT² partners needed to establish an organizational structure of shared responsibility and common developmental objectives. Most importantly, however, they needed to implement standardized competency-based curriculum and assessment methods which meet the global skills requirements of manufacturers. With this mandate, MAT² was given nine months to benchmark, develop, implement, and launch a dual education system and mechatronics program; therefore, an aggressive timeline and project plan was adopted to meet the system and program objectives. Acknowledging the MAT² content objectives, the stakeholders entered into both a program [pilot] Letter of Intent (MEDC, companies, colleges) as well as a curriculum development contract (MEDC & colleges). The following elements were included to specifically reflect the content objectives and purpose:

- Industry-Driven, Competency-Based Curriculum and Assessments
- Standardized Curriculum Elements (DACUM, course/program outcomes, competency-based testing)
- Assignment of Company Instructors (to both the development and management of the program)
- Standardized Reporting and Evaluation

Using MAT² as a case study example, this paper argues that best-practice project management principles are necessary to successfully design, implement, and operate industry-driven, competency-based education systems and harmonize stakeholder expectations.
3 Approach

For the program’s success it was crucial to distinguish between two inter-related and synchronized approaches:

- **Academic approach** - which would ensure that the academic concept, content, design, development and [later] execution meet the standards of modern competency-based education in an academic world where the requirement for this type of education and educational partnership (industry and colleges as equal partners) has typically met “significant design and implementation problems” (Guskey & Bailey, 2010).

- **Program management approach** - which would ensure that the program is planned, executed, and monitored in a professional way, while managing partners who have varying knowledge, approaches, expectations and experiences.

3.1 Academic approach and methodology

The academic approach used in the development of MAT² and other similar initiatives (e.g. AMTEC)\(^1\) establishes a commitment to matured product development and continuous improvement through the alignment of industry competence requirements with academic and credentialing institutions. In doing so, a process was developed using acknowledged industry tools and techniques which bridged the cultural and communication distinctions between stakeholders and created accountability between them. The curriculum and assessment development process described is a formalized, repeatable approach to instructional design which results in a systematic curriculum for any technical program aligned to industry-identified standards and industry-developed certification tests. The need for such a model is evident, as US-based manufactures continue to demand, or independently develop, training programs. Furthermore, content standards, which are defined, developed and released by both industry and educators, must be defined (B.L. Gupta, 2008) in order to achieve the quality demands of such a model. The core content requirements below outline the 1curriculum, 2assessment, and 3quality standards necessary for any MAT² program. Due to the limitations of this paper, only the core elements of the content standard areas will be described.

3.1.2 Developing and validating industry-driven curriculum

The first function of the content development process, which serves as the curriculum core of MAT², was to develop and validate occupational standards using a DACUM* process. Widely recognized as a unique, innovative, and very effective method of job, and/or occupational analysis, the MAT² mechatronic DACUM analysis workshop(s) included a committee of 5-7 subject matter experts (representing various hierarchies from the developing pilot companies), led by a facilitator (DeOnna, J., 2002). This group identified the primary tasks of a mechatronic technician (e.g. non-industry specific), and established the occupational standards for the MAT² mechatronics curriculum. Clear, comprehensive competency statements represent the industry-desired outcomes and incorporate the performance-based tasks. They are also well within the cultural mindset of academic institutions and thereby form a common ground from which the educational community could launch its activities. With the common ground established, a tool known as Qualify Function Deployment (QFD) was utilized for mapping industry standards to academic outcomes (Chan & Wu, 2002). The QFD process will be discussed later in section 3.1.3; however, Figure 1 outlines the process for competency-based learning program development, and as well as the partnership process by which the academic and industry stakeholders developed and validated the

\(^{1}\) AMTEC: AMTEC is a collaboration of community and technical colleges and industry partners, established in 2005 and became a "National Center for Excellence in Advanced Automotive Manufacturing." AMTEC developed a GENERAL MAINTENANCE MECHATRONICS CURRICULUM which was benchmarked by the MAT² Mechatronic Developer group. Some AMTEC curricula elements were used in the MAT² curriculum.

\(^{1}\) DACUM: Development of a Curriculum
curriculum content. The established MAT²-mechatronic DACUM was aligned with existing courses at the [pilot] colleges and with AMTEC courses in order to determine the necessary levels of development. The primary academic responsibility, however, was to establish standard program and course-level learning outcomes which align with the industry-defined competency statements, and which require students to demonstrate skill mastery in both technical and behavioral areas.

![Diagram](image)

**Figure 1: Process for competency based learning program development**

The tasks associated with each statement then informed performance-based learning objectives for each course outcome. In doing so, industry and educators established the competency-based curriculum standards (DACUM, outcomes, and objectives) for the MAT² mechatronics program.

### 3.1.3 Credentialing and assessment standards

MAT²’s comprehensive assessment system was designed to collect and use meaningful information for continuous improvement, as well as to implement a standardized assessment process. The project developed and implemented an effective process for assessing student achievement, through the use of existing (e.g. AMTEC post-course assessments, PAL test/certification¹) and new (e.g. mechatractica, MI mechatronic Exam) content. Data collected during this process will be used to improve the educational design and delivery, as well as (if necessary) the occupational standards identified in the DACUM. Assessment development and implementation is an integral part of the curriculum, as it provides information about student progress through the industry-defined occupational standards (DeOnna, J., 2002). MAT² uses a balanced approach to assessment and focuses on three key transition points in the career pathway:

- Level 1 - Diagnostic assessments at the course level (AMTEC)
- Level 2 - Demonstration of competencies at the school-period level
- Level 3 - Certification assessment(s) at the end-of-program level

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¹ PAL - Prüfungsaufgaben- und Lehrmittelentwicklungsstelle der IHK Region Stuttgart is a German organization developing mid and end term examination (also Mechatronic). To achieve the German Certificate as additional Credential MAT students are taking the PAL examination as well.
As shown in Figure 2, the levels of assessments help gauge the attainment of learning in order to improve instructional practices and the curriculum. The project developed its system of assessments in response to the needs of all partners. The entire assessment system provides a systematic approach to career planning, instructional support and program evaluation.

![Levels of a Balanced Assessment System](image)

Diagnostic assessments provide an in-depth, reliable assessment of targeted skills. AMTEC used industry subject matter experts to develop standardized, end-of-course (topic level), assessments aligned to the respective subset of occupational standards allocated to the courses (Manley, 2013). The primary objective of these assessments is to provide information for planning more effective, targeted instruction and interventions for students as they progress through the program, and to measure the extent to which students have met the occupational standards defined by the industry partners. The assessments include a variety of methods (applications, scenarios, etc.) to ensure that the typical “6 step - competence creation process” (1: Knowledge, 2: Understanding, 3: Application, 4: Analyzing, 5: Synthesizing, 6: Evaluating [Krathwohl, D., Bloom, B., Masia, B., 1978,]) is considered. Results also help to monitor student progress throughout the program, giving students the opportunity for enrichment or remediation, and providing faculty with diagnostic information about the strengths/weaknesses in the curriculum. Although AMTEC courses/assessment were aligned for much of the MAT® curriculum in years one and two, new assessments will need to be developed for the courses (other levels of development) using the AMTEC model of competency-based assessment of occupational standards. Establishing program-level certifications for MAT2 provides an overall assessment of a student’s entire experiences in the program, and results in an industry-recognized credential and quality measure. Standardized assessment signals completion or validation (skill mastery) of the core occupational standards identified by industry experts, thereby creating a pipeline of employable, skilled talent. Therefore, establishing a series of credentialing assessments tied to the original MAT® mechatronic DACUM- was a critical conclusion of the process and ensures the following program targets:

- **Portability**: For students, the assessment leads to certification, assists in initial job entry and upward and horizontal career mobility, and in the context of lifelong learning, provides a method of documenting mastered competencies.
- **Quality**: For employers, certifications and assessment assists in hiring, promotion, and planning for internal training.
- **Dual System Maturity**: For educational institutions, certification and assessments provide a method for benchmarking the quality of skills and knowledge provided against the occupational standards actually required in an occupation.

### 3.1.3 Quality and validation

For an industry partner, engaging in a Task QFD process provides a weighted mapping of the tasks to the competency statements and gives the educational providers a means to determine priority of content (Mazer, 1993). Once courses and learning outcomes have been identified, a second QFD exercise – an Outcomes QFD-
provides a mapping of the academic content (course outcomes) to the tasks by referencing the original Task QFD. This approach facilitates the communication between industry and education partners so that they can agree upon competency goals and their respective priority ratings, providing educators with validated occupational standards relevant in actual workplace applications (Figure 3).

Additionally, for the Mechatronics program, the use of AMTEC material provided MAT² with an industry-developed and validated source of curriculum, as well as a new learning model for encouraging increased “hands-on” classroom/lab time. This learning model—the “flipped classroom”—is a model in which instruction takes place outside the classroom, with students learning background knowledge about a concept or skill through online video lectures, animated Flash learning objects, and digital lessons (Tucker, 2012). The actual classroom time then becomes a site for practice, peer coaching and mentoring, rather than lectures and direct instruction. Lecture-free classroom time provides students with more time for hands-on practice with integrated systems and other lab equipment. Both the competency-based learning model and the “flipped classroom” have resulted in a need for college faculty/company instructor development sessions in order to implement the “learn-on-demand” course structure successfully. Colleges offering programs like AMTEC are encouraged to implement the modules in a “flipped classroom” format as well as participate in faculty-development. This is, however, a quality standard that MAT² will require for company instructors so that they understand the competency-based education and evaluation principles and can execute them effectively during their workplace training.

3.3 Program Management: Partnership Approach

For project managers, a critical research question remains: how should program management be designed to meet the varying PM experiences, expectations and interests of an organization’s stakeholders? Furthermore, how can stakeholders, who often compete in their respective market sectors, work together to define an innovative educational model which comprehensively meets their needs? While all the general PM-related activities are described in the professional paper for this conference (Baumann, Harfst, Cell, Dunn, 2013) and will not be repeated here, this paper will look at the project’s culture of trust and partnership and its critical role in the management of MAT’s academic approach. New academic pathways between stakeholders are only feasible if a solid foundation of trust and accountability is established. Therefore, partnership principles are the foundation for academic success and were important (1) to ensure target orientation, leadership, processes, resource allocation and the teamwork, and (2) to achieve the desired results (target achievement and satisfaction of customer and other relevant stakeholders (see also IPMA PE- project excellence criteria [IPMA, 2013][Westerveld, 2002]. The importance of an initial stakeholder analysis and subsequent stakeholder management strategy is often described as critical to the success of a complex project [Baumann T., Schmitz J., Fajerski J (2011), [Baumann, T. (2007)], [Dworatschek, Kruse, A. Baumann, T.]. This is particularly relevant when each stakeholder represents their unique organization as well as its contribution to a shared vision; therefore, MAT² stakeholder “education” and
target conformity was crucial in establishing foundational partnership principles and creating a sustainable relationship. Partnerships between competing stakeholders, however, present a unique situation where it is not predictable if and how the existing parallel relations (competition and cooperation, autonomy and dependencies, trust/ fairness and monitoring) will impact the program and even product success [Sydow, J., Duschek, S., 2011]. While any potential negative impacts from this stakeholder dynamic need to be managed, the automotive industry is typically familiar with providing transparency and discipline prior to Start of Production (SOP). Conversely, educators tend to vary from traditional models (compromised DM strategy, politically driven outcomes which are acceptable to many external constituencies), incremental or marginal choices and decisions (incl. adjustments) [Harrison, 2010]. Therefore, the following approach elements were utilized to address and handle the PM maturity differences across MAT² stakeholders:

- **Identify and analyze each stakeholder’s PM level (e.g. complexity, process, structure, measures, etc.) and understand the management culture within each of their respective organizations [Baumann, T., Haasis, H.H., Nehlsen-Pein, T., (2013)], [Baumann, T., Spang K., Albrecht J. (2010)] [Baumann, T. (2010]. Each relevant MAT² stakeholder was included in a thorough analysis to understand their existing PM culture (e.g. management understanding and demand of PM, organizational PM- mindset, etc.) and formally established PM elements (PM processes, tools, instruments, templates, PM documents, qualification). As part of a benchmark and feasibility study, executed through qualitative interviews, the stakeholder analysis presented a comparison of the PM- maturity differences between stakeholders as well as program and stakeholder-specific conclusions regarding each program manager’s minimum resource ability. Furthermore, it defined the minimum PM maturity requirements for planning, executing and controlling the program within the given stakeholder parameters.

- **Establish an empowered steering organization which enables itself to manage and overcome risk behaviors and problems stemming from the differences between organizational cultures.** Such differences in corporate cultures (e.g. specific levels of behavior dimensions (organizational citizen behavior (OCB), Contextual Performance (CP) [Borman, W.C., Motowidlo, S.J. 1993], Organizational Spontaneity (OS) (Organ, D. W./Podsakoff, P. M./MacKenzie, S. B. 2006), Pro-social Behavior (PSOB) (Brief, A.P., Motowidlo, S.J. 1986). … ) are typical for such a stakeholder situation. It must be ensured that the program organization is not negatively impacted by the differences in corporate culture. As one approach, MAT2 established a steering organization in which committee representatives acted as the voice of their home organization. Members operate on a basis of partnership (i.e. rules of consensus) in order to reach official decisions, which allows them to reduce and manage these existing differences.

- **Assign an effective program manager who can understand and handle the existing PM skill gaps, as well as understand how humans act as individuals and within organizational contexts.** In order to successfully convince project partners to engage in “inter-organizational project citizenship behavior,” it requires knowledge both of the mechanisms how humans make decisions as well as how one can motivate them to change their behavior [Baumann, T., Nehlsen, T., Roth, G. (2006)], [Stagner, R., (1969)], [Sydow, J./Staber, U. (2002)], [Sydow, J. (2010)]. Based on the stakeholder PM maturity analysis, the ideal role, tasks, abilities, capabilities and experiences of each stakeholder’s respective program manager were defined. The agreed-upon role description (esp. with the colleges) established transparent expectations between the stakeholders and PM, proving advantageous in the selection of their program managers.

- **Create a stakeholder partnership using the primary elements of a successful partnership [Baumann, Roth, Spang, 2009], [Baumann, T., Spang K., Albrecht J. (2010)].**
  - (1) Understand partnership principles: Even if a partnership is formally considered an agreement between (legal) entities (enterprises, organizations, etc.), each of the entities is also a social system containing a certain number of individuals. The humans within each entity act during the assessment of the partnership concept (i.e. the decision process of whether or not to partner). In doing so, they evaluate the concept, contract and results by using evaluation parameters- each having his own priority ranking. Therefore, in order to define how a partnership should be designed, one must understand (1) the human decision making process, (2) the crucial decision-making factors regarding partnership and rewards during this decision process and (3) the implication to the real partnership concepts and (4) the situation in MAT2 environment.
(2) Conscious use of Network Citizen (NC) relations: People who have frequently worked together in the past often establish a long-term relationship, a network which they use even after the project has ended. Such networks, and the individual behavior in such networks (NCB), are very useful for the project performance and results because those persons are willing to act as “matured” network citizens [Sydow, J., Windeler, A., 1999], [Starkey et al., 2000].

The creation of successful stakeholder partnerships, especially under complex conditions (e.g. varying PM experiences, expectations and interests of an organization’s stakeholders), should also consider modern partnership models [Baumann, T., Spang K., Albrecht J. (2010)]. Such models provided insight about human behavior and decision-making principles, and allowed the MAT² stakeholders to understand one another’s perceived incentives and rewards for engaging in the partnership. This is of particular importance in the human decision-making process and the human reward system (HRS), because each individual stakeholder assesses their own rewards expectations. The partnership design, therefore, can only be successfully realized if each stakeholder understands the situational dynamics and stakeholder complexities. The fairness and trust realized in the subsequent interactions is now more related to liking and emotional competence, rather than to intellectual or practical competence. Thereby, the critical importance of establishing a foundation of partnership principles is repeated.

4 Realization

The assignment and selection of project leaders (in each stakeholder group/organizational level) was an important element in realizing the stakeholder partnership. To ensure the success of this matching process and to identify the “best available resources/knowledge,” the selection of persons and their assignment to the MAT² program considered the existing expert pool as well as potential contacts outside of the existing stakeholder groups (e.g. former AMTEC and TAACCCT§ grants developers). This was critical in harmonizing the MAT² PM and academic approaches, considering the distinct operational differences of industry (represented by automotive suppliers) and academic organizations.

4.1 Expectation management

The MAT² expectations, key success factors and acceptance criteria most relevant to the industry partners have been discussed, and are clearly defined as an expectation of educators to:

- teach to competency-based learning outcomes and objectives
- provide a statewide system which teaches to a standardized set of occupational standards—regardless of the educational provider

The colleges, however, define the following relevant expectations, key success factors and acceptance criteria for industry as an obligation of:

- consistent student & program development support (i.e. DACUM process, matured work assignments,)
- integration of competency-based education, assessment, and instruction in the workplace

Although the defined stakeholder expectations are subject to change, they were clearly defined so that a culture of understanding and expectation management could be realized.

4.2 Trust management

MAT² industry stakeholders established AND realized “equal play” principles (salary, student selection, company fair,...) in order to avoid distrust or competitive behavior which could potentially detract from the overall program vision. Likewise, the subject of intellectual property was openly discussed between the “developer” companies and colleges, resulting in a mindset of shared-ownership and trust. Establishing a system of transparency, openness and common understanding enabled the state to realize their vision of an open-source curriculum model, which will make the MAT² program(s) available to any interested college willing to fulfill the program and content requirements. Establishing trust performance indicators as the basis of their partnership allowed academic and

§TAACCCT: Trade Adjustment Assistance Community College and Career Training
industry stakeholders to successfully collaborate in the “academic approach” process, and resulted in the design and implementation of an industry accepted review and release process.

5 Conclusions

The state of Michigan plays a uniquely important role in workforce development, as it oversees workforce investment and most higher education. Over the past few years, states have placed a major emphasis on both, recognizing the role of knowledge workers in the new economy. The end result, however, is that every business is part of the new economy and every worker needs more education and better skills work for them. This undeniable fact requires states to devote more time, money and attention to technical education, and to make sure that the workforce needs of their most important industries are being met in a way that is both specific and responsive. MAT² provides the state of Michigan with comprehensive solution to these challenges. Although the MAT² pilot was limited to the manufacturing industry, it provides a scalable model for ANY workforce education program or industry. By establishing common industry standards and delivering competency-based learning outcomes, a program can grow to meet the talent demands of its profession. The new economy requires skill diversity, and cannot be [solely] sustained by a white-collar workforce. It will increasingly demand a workforce of technicians with the technical skills and problem-solving abilities necessary to maintain innovative technologies, because its prosperity will depend on them. The magnitude of this need is so great that successful technical education must be replicated across industry sectors.

6 Outlook

MAT² is moving from the pilot development to execution and will support sustainable, systemic changes on state and national levels. The described program standards and principles will remain as part of a continuous feedback and improvement process, and will require a continued foundation of trust and partnership between stakeholders. Honest feedback and evaluations (from students, colleges, companies, etc.) will be collected through progress reports, feedback forms, and focus groups. The standards (process, instruments) for those elements have been openly discussed and agreed-upon, and are measured against stakeholder-specific success factors. Because the program is focused to delivering industry-defined competencies, the entire reporting system is rooted in the achievement of those standards and requires outcome-focused reporting from college faculty (courses and labs) and company instructors (work assignments). This common reporting and communication system will more closely align industry expectations with academic results. MAT² will initiate transformational change, reforming the American community college systems, and the systems of our workforce and economic development partners, to meet the needs of students and the business sector. In this critically important work, the project will collaborate and leverage resources at all levels to realize long-term, sustainable gains. For the initiative to have a long-term impact and sustainability, the colleges will be expected to integrate MAT²'s system and content innovation into their institutional strategic plans and budgets.

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