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Introduction

With the increasing demands on organizations to do "more with less," and produce acceptable market results, productivity and performance standards continually raise the expectations on competitive success. To meet these expectations, organizations should create learning opportunities that combine the application of technical management skills along with the softer skills involved in people management. Technical managers with little training or past experience with non-technical skills often perform poorly in technical management positions (Kroecker, 2007). Because this generation lives in a highly technical environment, managers need to be proficient in dealing with knowledge workers and systems; therefore, there is a growing emphasis on the application of management competencies (Thamhain, 1990). Additionally, as the baby boomers shift from the marketplace to retirement, experienced technical leaders will be exiting the workplace. Within the next 10 years, the U.S. will experience a greater than threefold surge in leadership turnover in engineering and technical organizations, increasing the competition for a progressively scarce resource (Vieth & Smith, 2008). As indicated above, the necessity for competent technical managers will be a critical success factor for organizations to stay competitive.

Given that today's labor market demands graduates who are competent in both technology and management, higher education has the opportunity to produce these graduates. For example, the Dulaimi study (2005) highlighted the need for academic and professional development programs to provide the right balance, in content and emphasis, between the technical knowledge and the people management skills for young professionals. Unfortunately, higher education is reacting slowly despite the need to develop graduates who are technically competent managerial professionals. The mission of the Association of Technology, Management, and Applied Engineering (ATMAE) is to educate professionals dedicated to solving complex technological problems and developing the competitive technologist and applied engineering workforce. These technology management professionals or technologists are described in various ways.

The National Research Council defined technology management as the link between science, engineering, and management (1987) and (ATMAE) described it as the "field concerned with the supervision of personnel across the technical spectrum and a wide variety of complex technological systems" (2009, para. 6). The International Technology Education Association (ITEA) identified the characteristics of a technologically literate person as an individual who has knowledge of processes to develop systems within practical contexts that solve problems and extend human capabilities (2006). With such a wide variance of characteristics used to describe the technologist, i.e., technical managers, the body of knowledge is not clearly defined for technology management. The authors of this paper support the development of a common technology management core with appropriate and defined competencies. The purpose of this paper is to describe a core body of knowledge using competencies as a base for a technology management model. In order to accomplish the purpose, the authors asked the following questions:

- What is the core body of knowledge for an entry-level technical manager?
- What are the core competencies for an entry-level technical manager?

The remainder of this paper will focus on the basic elements of a technology management core body of knowledge, entry-level competencies of technical managers, and introduce a competency model.

Technology Management Core Body of Knowledge

As organizations advance technologically, the need for technical leaders will be vital. In benchmark companies like Rockwell Automation and GE Healthcare, the identification and development of the next generation of technical leaders is a strategic imperative (Vieth & Smith, 2008). Promoting individuals based solely on technical knowledge is becoming more difficult due to the need for sound managerial decisions across technically complex environments. Nair, Patil and Mertova (2009) found a competency gap between engineering traits of graduates and the expectations of employers. They asserted that students need a combination of technical (hard), managerial (soft) and global (multicultural communication) competencies to be successful. Additionally, the Society of Manufacturing Engineers' (SME) Manufacturing Education Plan: Phase 1 (1997) and Phase 3 (2001-2002) reported the following competency gaps in order of importance: business knowledge skills, project management, written communication, supply chain management, oral communication, international perspective, quality, problem solving and teamwork. The proficiency of graduates is measured by entry into the job market and long-term career success. Education and professional development increase the proficiency of graduates and close the competency gaps.

Historically, higher education focused on the education process or the inputs into the systems. Now, higher education is increasingly asked to provide student outcomes or competencies (Allen, Ramaekers & Velden, 2005). At the university level "Technology Management programs typically include instruction in production and operations management, project management, computer applications, quality control, safety and health issues, statistics, and general management principles" (ATMAE, 2009, para. 6). In fact, a required management curriculum is what distinguishes ATMAE accredited four-year programs from two-year programs. It also distinguishes the discipline from pure engineering programs (i.e., mechanical, electrical, civil, etc.). The American Society for Quality (ASQ), the Association for Operations Management (APICS), and the Project Management Institute (PMI) all have well-recognized bodies of knowledge for their professional constituents. However, ATMAE accrediting standards do not specify a core body of knowledge for management; only a range of required hours (12-24) and a list of potential subjects. In addition, the current content areas of production planning and control, quality, safety, and management on the Certified Technology Manager (CTM) exam are not aligned with the accrediting standards or with a recognized body of knowledge for technical management. Although there are planned revisions to both accreditation and certification standards, there is no coordinated effort to align these revisions with a recognized body of knowledge.

Using published literature and previous studies, a common perspective of technology management is attainable within the discipline. However, as Minty (2003) explained, this must be undertaken with knowledge that technology management is neither grounded in general business nor engineering, but is a unique body of knowledge grounded in sociotechnical management. The term socio-technical refers to people and technology or systems. Engineering and industrial technology programs have used terms associated with socio-technical theory such as six sigma, continuous improvement, autonomous teaming and re-engineering (Shaughnessy, 1977). Sociotechnical systems reveal the interdependence of technology, people, the external environment and the work design (Hendrick & Kleiner, 2001, p. 26). As the authors gathered a sociotechnical framework for a body of knowledge, it was necessary to determine the appropriate competencies.

Technology Management Competencies

The progression toward competencies is recognized by higher education. Educational institutions are now being asked to provide measurement of student learning. Developing a competency model for technical managers enables higher education to prepare students for the workforce. Meier, Williams, and Humphreys (1997) summarized the competencies deemed essential for success of newly hired employees. The competencies were grouped into seven thematic areas ranked in order of importance: communications, quality, cultural values, team development, technology, contemporary business concepts and problem solving. Additionally, Meier and Brown conducted a follow-up study in 2008, which yielded similar competencies.

Competency modeling is an organized structure for defining the skill; knowledge and attitude (SKAs) that students need to know to be proficient in their field of study and ultimately their career. Competence is a function of performance that goes beyond knowledge. Competencies can be defined as observable behaviors exhibited by technical mangers that are successful, both in terms of their results and the process or behavior, in enabling those results (Teodorescu, 2004). Approaches to competency model development include selecting competencies from lists to field research on competencies. Calhoun (2008) created a Health Leadership Competency Model through a literature review, expert panels and surveys. She described the development of the model using reverse engineering. The model development included approaching sought after outcomes, then determining the appropriate behaviors and developing the core technical and managerial competencies. Rifkin, Fineman, and Ruhnke (1999) developed a competency model that contained a hierarchical framework of the technical manager's role, critical accomplishments, work activities, skills, knowledge and personal attributes. Because of the sheer rigor, expense and time commitment of competency development, other methods have surfaced that are also reliable. The panel method is a where a group of experts collaborate to develop a set of competencies (Rajadhyaksha, 2005).

Choosing a competency-based model for the technology management core supports the change of ATMAE accreditation standards from a traditional approach to an outcomes based approach (ATMAE, 2009). The Outcomes Based Accreditation Model is based on the philosophy that programs are educating technical managers on student learning outcomes that are in high demand from industries that hire technical management graduates. The traditional approach to accreditation was to create a set of standards and activities that each program aspired to achieve. The outcomes-based model strives to create a closed-looped process that defines technical management competencies, assesses effectiveness through placement and success of graduates, and improved upon by industry expectations.

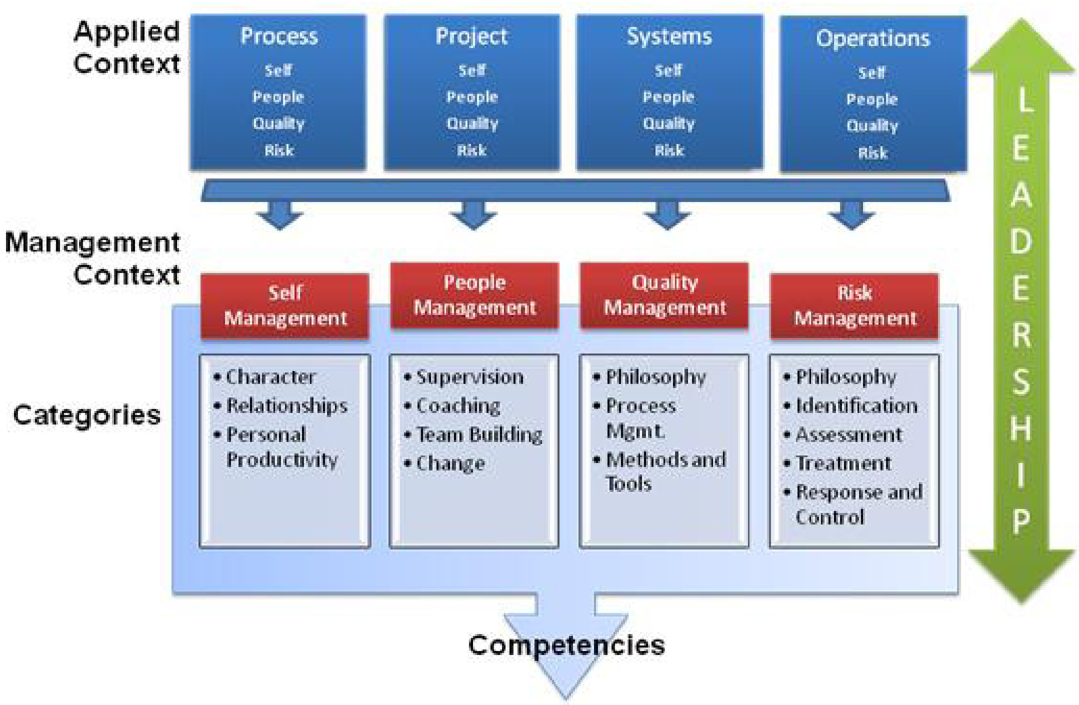
Methodology

The competency development approach used in this paper is based on research of existing models and panels of industry and educator expertise. The Management Division of ATMAE formed a sub-group in 2010 to begin to define a technology management body of knowledge and a set of core competencies. Based on the sub-groups interaction with industry, industry experience, and academic experience in technical management, the sub-group developed an initial competency model. The initial competency model was discussed with industry professionals and networks of the sub-group, presented to advisory board members of ATMAE accredited programs, and reviewed by ATMAE members at a conference forum. In addition, the competency model was benchmarked against existing literature and research. After multiple revisions, based on input from educators, industry professionals, and research, a management core model was developed and presented below.

ATMAE Technology Management Competency Model

The management core model shows the generic entry-level competencies for a technology manager within a category of knowledge for a specific managerial context. The competencies are applicable to systems, operations, processes, or projects and linked throughout by accepted leadership principles. See Figure 1 for an overview of the model.

Figure 1. Technology Management Model



To understand the model, it is important to define the contexts, which are the situations or environments where the competencies are applied. The project and process environments are well known with projects being the one-time application of processes to produce a unique product or service. Systems refer to the management of technology across disciplines and companies in an integrated fashion for the purpose business venture and development. Supply chain management is an example. Operations, on the other hand, are the management of technology within a specific industrial specialty. Common industrial contexts would include those listed by the Bureau of Labor Statistics (BLS, 2011) such as manufacturing, construction, telecommunications, or retail trade. It is the assertion of the authors that the same competencies are utilized regardless of the applied context and can be classified into four management areas. The managerial context areas are self-management, people-management, quality-management, and risk-management and are well-supported in literature. While the literature may refer to them using slightly different terms, they are mentioned in leadership and management writings frequently. For example, it is well-accepted that in order lead people effectively a manager must have self-management (Covey, 2004; Rajadhyaksha, 2005). The other two threads that run through literature consistently are managing quality and risk.

Within each management context, competencies are categorized into generic and recognizable themes. From this, specific competencies were developed to assess content and outcomes. The competencies are purposely broad to allow for flexibility and interpretation. The competencies may have popular synonyms that could be justifiably used instead. Rather, the intent is to establish a baseline for further refinement. See the Appendix for the full model. To illustrate, the competencies for the self-management context are shown in Table 1.

Table 1. Self-Management Competencies.

Category	Competency
Character	• Values • Integrity • Responsible • Capable • Enthusiasm
Relationships	• Communication • Cooperation • Emotional/Social • Spiritual • Trust • Influence
Personal Productivity	• Motivation • Resourcefulness • Discipline • Knowledge • Passion • Vision

Next Steps and Future Challenges

Without a recognized and accepted body of knowledge for technology management, the discipline of industrial technology, engineering technology, and applied engineering will continue to be confused with other technical disciplines. Clarity regarding the socio-technical competencies of technology management is imperative. These competencies should be congruent with ATMAE accreditation standards and CTM certification. In order for technology management programs to survive and thrive, these competencies should be recognized internationally. ATMAE membership and industry advisory boards should discuss and provide feedback on these technology management competencies. In particular, the Management Division of ATMAE must take a lead role in its refinement. Adoption of technology management core competencies should be incorporated into the CTM exam. With an agreed upon and certified body of knowledge, educational learning outcomes that are congruent with industry needs and revised accreditation standards for technology management will result. The next steps are to gather additional expert feedback through panel discussions with educators and industry personnel; sending the model for adoption by ATMAE through a vote of the Management Division members; and aligning the model to certification.

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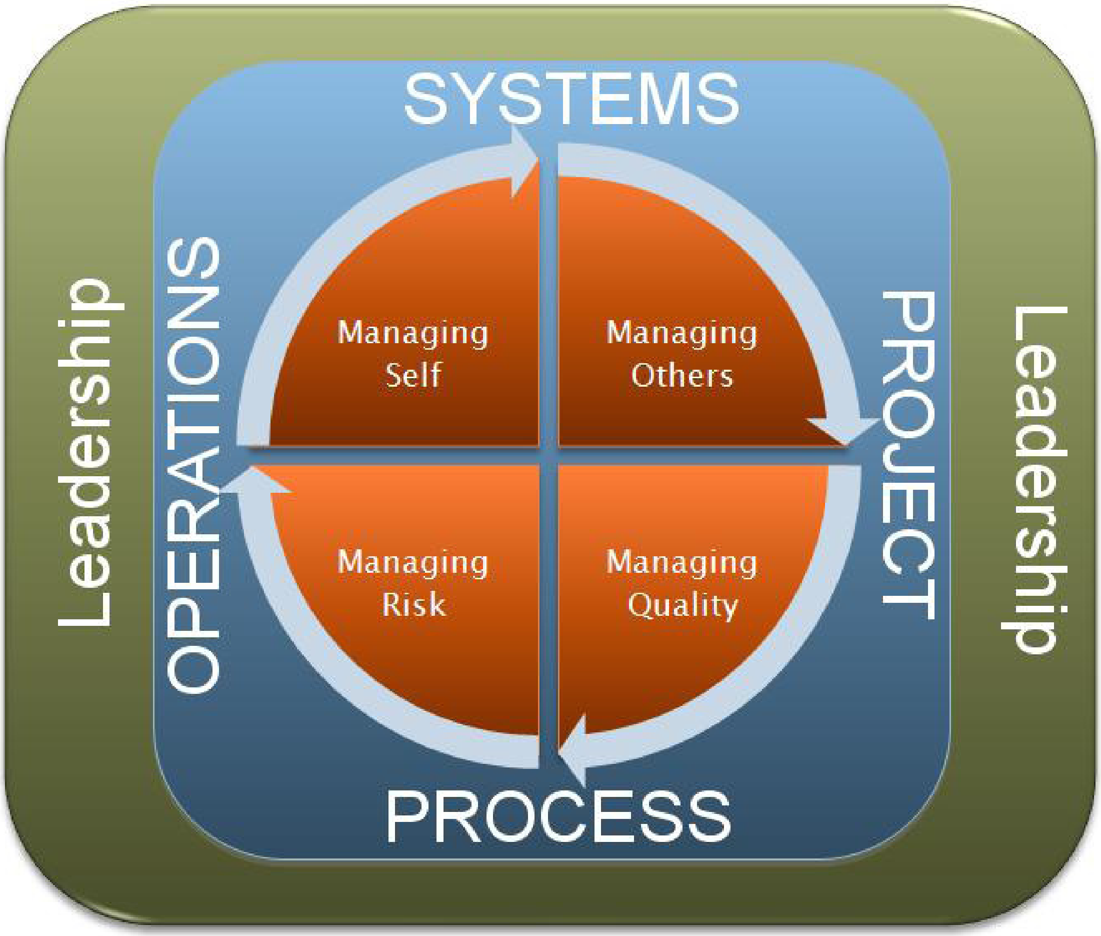
Appendix - Technology Management Competency Model

Figure A1. ATMAE Management Model



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Personal Productivity	•Motivation •Resourcefulness •Discipline •Knowledge •Passion •Vision

Table A2. People Management Competencies

Category	Competency
Supervision	•Planning •Organizing •Staffing •Leading •Controls/reporting •Resource allocation •Decision-making •Listening
Coaching	•Mentoring •Counseling •Appraisal
Team Building	•Facilitation •Problem solving •Group dynamics
Change	•Alignment •Empowerment •Respect •Support

Table A3. Quality Management Competencies

Category	Competency
Supervision	•Planning •Organizing •Staffing •Leading •Controls/reporting •Resource allocation •Decision-making •Listening
Coaching	•Mentoring •Counseling •Appraisal
Team Building	•Facilitation •Problem solving •Group dynamics
Change	•Alignment •Empowerment •Respect •Support

Table A4. Risk Management Competencies

Category	Competency
Philosophy	•Culture and context •Objectives •Risk tolerance/appetite
Identification	•Opportunities •Tools and techniques •Risk taxonomies
Assessment	•Analysis •Drivers •Prioritization
Treatment	•Treatment selection •Action planning/mitigation
Response and Control	•Policy deployment •Governance •Evaluation •Compliance and reporting

Figure A2. Technology Management: The Full Model