
AC 2012-3028: ASSESSING THE APPLICABILITY OF TECHNOLOGY STUDIES THROUGH AN EXAMINATION OF INNOVATION, THE SYSTEMS INTEGRATION MODEL, AND SYSTEMS INTEGRATOR ROLE

Dr. Mitchell L. Springer P.M.P., S.P.H.R., Purdue University, West Lafayette

Mitchell Springer is an Associate Professor in technology leadership and innovation and currently serves as the Director of the Purdue University College of Technology Academic Center for Professional Studies in Technology and Applied Research (ProSTAR) located in West Lafayette, Ind. He possesses more than 30 years of theoretical and industry-based practical experience from four disciplines: software engineering, systems engineering, program management, and human resources. He sits on many university and community boards and advisory committees. Springer is internationally recognized, has authored numerous books and articles, and has lectured on software development methodologies, management practices, and program management. Springer received his bachelor's of science in computer science from Purdue University, and his M.B.A. and doctorate in adult and community education with a cognate in executive development from Ball State University. He is certified as both a Project Management Professional (PMP) and a Senior Professional in Human Resources (SPHR).

Dr. Gary R. Bertoline, Purdue University, West Lafayette

Assessing the Applicability of Technology Studies through an Examination of Innovation, the Systems Integration Model and Systems Integrator Role

This paper will examine the role of a major tier 1 research university in defining and developing the 21st Century Technologist through an understanding of the relationship between innovation, technology as a discipline, the systems integration model and the knowledge-based model of the systems integrator. This paper will examine how the relationship of these many seemingly unrelated, yet believed to be highly interconnected concepts, contribute to the comprehensiveness of understanding of graduate technology studies and provide insight into advancing the definition and development of the 21st Century Technologist.

Taken as a given that innovation is a process, then it can be shown, innovation and the manifestation of the innovation process is intrinsically interconnected to the role of the systems integrator. Given this, if systems integrators are capable of “seeing” the interrelatedness of whole systems, and those who can “see” the interrelatedness of whole systems are considered individuals with an innovator’s DNA, then it stands to reason that systems integrators are prone to being classified as having the characteristically defined DNA of successful innovators; yielding the connection between innovators, innovation and systems integrators.

Understanding the discipline of technology promotes a conversational understanding of the role of the *technologist*. The role of the technologist is argued to be closely aligned to the definition of the systems integrator, through the underlying characteristically defined neural thread of innovation.

The intent of this paper is not to define the process of innovation or the discipline of technology, but to understand how these many seemingly different, yet highly interrelated concepts contribute to the further definition and development of the 21st Century Technologist.

Innovation -

Technology and the process of creating it, innovation, is moving at a thunderous pace throughout world societies. Our rate of technological advancements dwarfs any previous period in our world history. It is nearly inconceivable what will be created next, as organizations small and large are busily working to create the next iPhone, robotic life-like animal, electric car, cloned DNA structure, or, death ray.

There is no shortfall of innovation discussion and innovation recognized as a governmental imperative. Zakaria¹ (2011) states “...Innovation is as American as apple pie. It seems to accord with so many elements of our national character – ingenuity, freedom, flexibility, the willingness

to question conventional wisdom and defy authority. But politicians are pinning their hopes for innovation on more urgent reasons. America's future growth will have to come from new industries that create new products and processes.”

Given the significant attention to innovation, what then, is innovation? Is there a process to follow for innovation? How do you measure the success of following an innovation process? Are there corollary concepts to the innovation process? All of these questions, and a dozen more, are valid and predictable discussion topics addressed in numerous business books, texts and articles. The intent of this paper is not to explicitly contribute to answering these questions, but to suggest if innovation is a process, then it has to have multiple activities with attendant products as output of the process.

Taken as a given that innovation is a process with multiple activities and attendant outputs, then to a large extent innovation and the manifestation of the innovation process is intrinsically interconnected to the role of the systems integrator. Systems integration is the higher level of cognitive understanding of the many separate, yet highly related disciplines/functions of a product or service. Those practicing systems integration are capable of “seeing” whole system connections. Be able to “see” connectivity between seemingly unrelated architectures has been recently characterized as “associational thinking”⁵. Given this, if systems integrators are capable of “seeing” the interrelatedness of whole systems, and those who can “see” the interrelatedness of whole systems are considered individuals with an innovator's DNA, then it stands to reason that systems integrators are prone to be classified as having the characteristically defined DNA of successful innovators; yielding the connection between innovators, innovation and systems integrators.

The basic element of successful systems integration is the vision of interrelatedness of the many attendant knowledge domains; vision, that acts as the common thread through the innovation process. The evolution of this concept resides between the philosophical underpinnings of innovation leadership, and, the tactical realities of curriculum design, development and implementation.

Technology as a discipline -

As in the previous section, the intent is not to define the innovation process, nor is it to define the discipline of technology. The intent is to understand and critically reflect on the meaning of these two concepts and draw associations between them in an evolving effort to define and develop the 21st Century Technologist. It is only through a comprehensive understanding of these related concepts that we can draw parallels and capitalize on existing bodies of knowledge.

As discussed by Bertoline⁶, technology is a pervasive feature of our contemporary culture but it is more than that; it is a defining feature of the human condition.

We know a great deal about technologies in an individual sense, but much less about technology in the way of general understanding. We have detailed studies about the history of individual technologies, analysis of the design process, economic impacts of technology, and the societal impacts of technology. However, we have no agreement on the meaning of the word “technology”. We also have no overall theory of how technologies are accepted and integrated into society, no deep understanding of innovation, and no theory of evolution for technology. Unlike other disciplines or knowledge areas, there is no set of overall principles that would give technology, as a subject, a logical structure. Critically required is a Body of Knowledge for technology.

Technology has a process for the way new artifacts are developed and used. It, also, has an accumulated body of knowledge that explains existing technologies and provides the foundation for new technological advancements.

The discipline of Technology has established a way to structure the knowledge of technology, which includes the productive human activities of communication, construction, manufacturing, and transportation as well as energy, information and material processing... Technology is not a natural phenomenon. It is a product of human choice. People saw its development, production, and use as necessary or economically profitable.

Technology is not an isolated body of knowledge. It is intricately intertwined with all other areas of knowledge. Science explains the natural laws that are applied by technology. Engineering is used to design systems, processes, and the artifacts that comprise our technological world. Mathematics and mathematical models explain the operation of technological systems. Language and art can be used to describe technology and its impacts. The social studies can describe how technology has, is, and may well impact and be impacted by people and society.

The essence of a technologist is the mastery of a whole field with a broad and deep understanding of the technology; the processes, systems, tools, and techniques necessary to construct, modify, innovate, operate, and maintain the engineering design.

There is a continuum in technology that moves from vocationally trained skilled craftsmen at one end, to technicians narrowly focused on one aspect of technology, to technologists who have mastered a whole field of technology, to the engineer who have mastered whole technological systems. There is a clear distinction between a technician and a technologist. The technologist is a highly skilled professional that is positioned in the “sweet spot” between the engineer and the technician/skilled craftsmen. Technologists serve an important and unique role as the “integrators” in

business and industry. Technologists have a deep understanding of the human-made world and use a problem solving methodology that can lead to innovation through the development of new and improved artifacts, systems, and processes.

The above makes the connection between the evolving discipline of technology, the technologist and the systems integrator. The neural thread through all three entities is the ability to “see” the interrelatedness of the contextual differences. The “seeing” of the interrelatedness again resides as a common characteristic of successful innovators.

Defining the Systems Integration Model -

Assuming there exist a relationship between the 21st Century Technologist and the systems integrator, through characteristics defined as the DNA of innovation, then it reasons we should explore the systems integrator and the systems integration model further.

Systems integration, as a discipline, is well founded in industry and exists at many levels. Within a given discipline, e.g., software engineering or hardware engineering, systems integration involves bringing together those many aspects of sub-knowledge within the specific discipline. At the lowest level, integrating two components together of a given discipline, within a larger system, serves as an example of an integration function to be performed; this given the increasingly complex hierarchy of components, sub-assemblies, assemblies, systems and platforms. At each level in our overall system, there exists a level-specific integration function. For our purposes, we are defining and differentiating between two different systems integration functions: (1) the integration of a given discipline and its components, and (2) the integration function which brings together multiple disciplines within a given system. Our interests in systems integration does not extend to the lowest component integration level.

To illustrate our areas of interests, assume a system made up of software and hardware with mechanical operational requirements. An iPhone serves this purpose, wherein, the placement of the buttons the user employs is orchestrated by the mechanical discipline, the physical internal hardware chips and accessories are the domain of the hardware discipline, and, the software which allows the iPhone to operate being the domain of the software discipline. Within the software of the system, to be designed, developed, integrated and tested are the following components: an operating system, database management system and user applications. Within the operating system there exist lower-level modules to be designed, developed, integrated and tested, namely, the central processing unit, memory management unit, input/output interface and others. At the lowest level, we will integrate and test, from the bottom-up the modules within the operating system, then, we will integrate the operating system with the database management system and the user applications. Our first level of interest in systems integration is at the entire software discipline level; someone commonly referred to as a *software systems integrator/engineer*. Our second level of interest in systems integration is at the systems level

where we bring together the software discipline, hardware discipline and mechanical discipline; this level of individual is commonly referred to as a *systems integrator/engineer*.

To this end, the tactical implementation with courses and curriculum implications is hinged on a strategic decision of which level of systems integration one is most interested in pursuing; namely, discipline-specific systems integration (e.g. software systems integration), or, the higher level systems integration function (systems integration). The implication of this strategic decision is critical to further evolution of a tactical decision on curriculum. Figure 1 depicts these two levels of hierarchical integration.

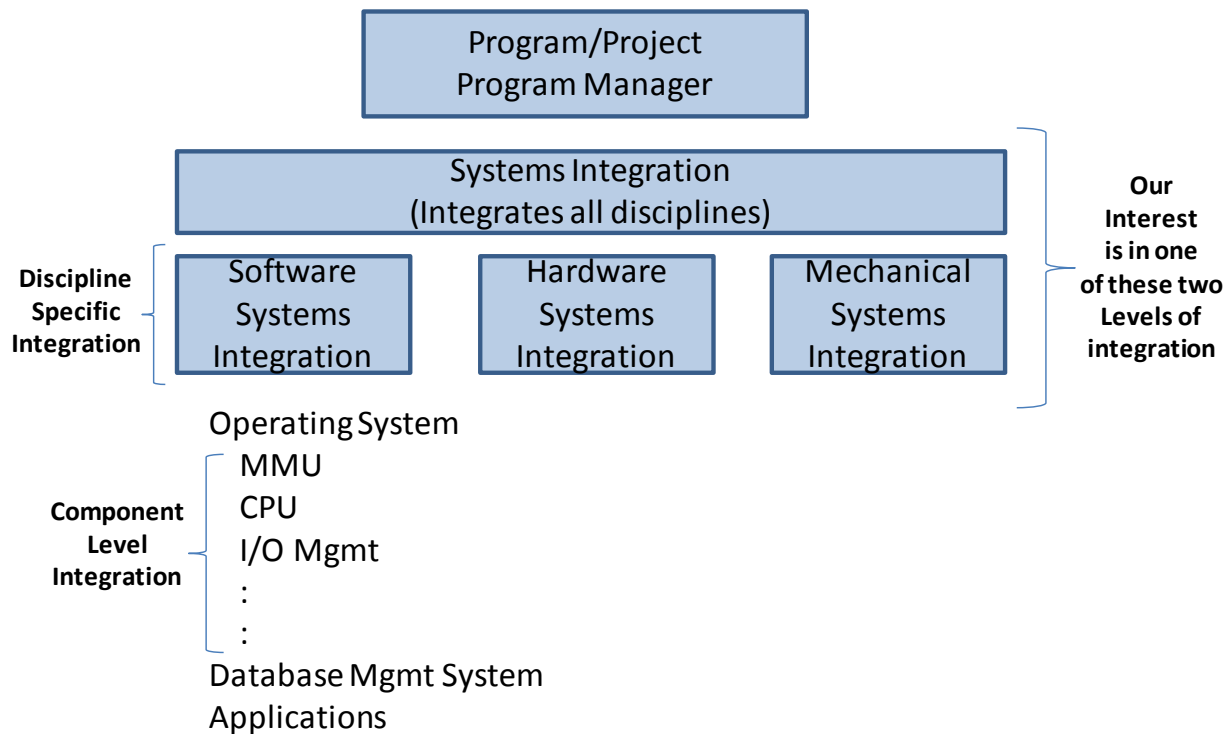


Figure 1: Levels of Integration

Discipline-Specific Systems Integration/Integrator -

If one chooses the path of a discipline-specific systems integrator, then the core curriculum will be domain-specific and offer courses as an umbrella which provides systems integration knowledge. This given, systems integration is, in fact, a process with multiple activities and attendant products.

For example, a student would enroll in Computer Graphics Technology, and, made room for in the curriculum would be perhaps as many as four courses which provide the body of knowledge

for systems integration as it relates to Computer Graphics Technology. Now, the immediate implication is the systems integration courses are tailored to a given discipline; this is not necessarily required in that systems integration, as mentioned above, is a process in and of itself with activities and attendant outputs. The systems integration body of knowledge assumes if you follow the process, perform the activities and generate the attendant outputs along the way, a systems integrator can help to ensure a consistent and coherent output from the process.

While it may be easy to visualize disciplines such as computer graphics, information technology, building construction and others as possessing a body of knowledge and therefore serving as a discipline-specific knowledge domain to underlie core knowledge of the systems integration process, it is equally possible to bring together the many aspects of technology leadership in such a manner to also benefit from a higher level understanding of systems integration. Should one pursue this level of discipline-specific systems integration, each of the above many disciplines would be reviewed with an eye to tailoring the umbrella systems integration process core curriculum.

Systems Integration/Integrator -

If, on the other hand, the strategic interest is to educate the 21st Century Technologist in whole systems integration, then we would want to pull together into a single curriculum those related disciplines within the college or university, and, then, offer the same four or more core courses in the systems integration process, as we proposed in the above discipline-specific systems integration alternative. This creates an eclectic collection of seemingly unrelated disciplines, but in reality, brings together a sufficient overview of disciplines that may play together in future innovative or disruptive systems. An example of this may be a curriculum composed of courses from computer graphics, information technology and technology leadership, with courses on the systems integration body of knowledge and others as deemed to complete a whole curriculum. Point being, we have introduced into this level of curriculum other discipline-specific bodies of knowledge.

In some regards, we are deciding between advancing directional knowledge versus intersectional knowledge⁷. Where, directional knowledge and ideas are those ideas that evolve through the recognized and accepted “normal” process of advancing the basic body of a given discipline. Directional ideas are generally identified as improvements of a given product or service in a fairly predictable way along defined measures and dimensions. Intersectional knowledge and ideas evolve through the combining of knowledge between and across multiple “pure” fields of study or disciplines. Intersectional ideas are those ideas that change the way we perceive the world.

In the end, subsequent tactical discussions related to curriculum, are contingent upon our strategic intent; systems integration, or, discipline-specific systems integration?

Knowledge-Based Model of the Systems Integrator -

To truly have a discipline, there must be a body of knowledge. Technology leadership is no different. There is significant literature detailing leadership theories; trait, behavioral, situational and the like. But what does it mean to have a discipline in technology leadership? What would the basic body of knowledge in technology leadership look like? The following paragraphs examine technology leadership and propose the basic knowledge and skill set required to function in the discipline of technology leadership. The resultant individual, educated in the discipline of technology leadership, may be categorically defined as a systems integrator.

Looking at systems integration as either discipline-specific or the more general systems integrator, aligns to common accepted understanding and practice in industry. Another way, however, to view the systems integrator role is to define a basic body of general knowledge that can be applied across any number of industrially-based disciplines. Figure 2 below depicts a general model forming the basic body of knowledge for the systems integrator^(8,9,10).

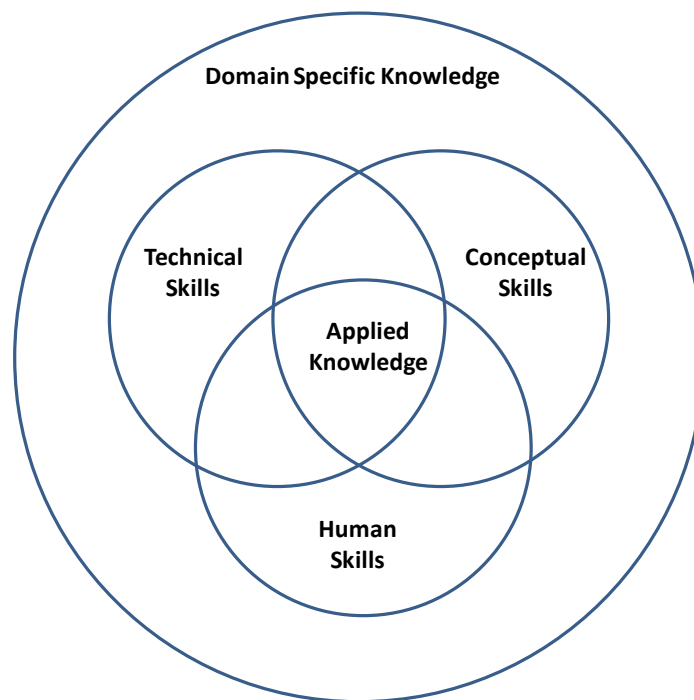


Figure 2: Systems Integrator Knowledge-Base

The above model proposes the ideal systems integrator is one who possesses a basic body of knowledge in three primary areas: technical skills, human skills and conceptual skills. The entire three-pronged skill set is embedded within discipline specific knowledge. In other words, once the basic skill sets defined by the above model are learned, then those learned skill sets form a toolbox with general applicability across unlimited industrial disciplines.

Technical Skills -

Technical skills are not domain specific skills. Instead, they represent knowledge focused on better understanding past and present processes as well as having a basic knowledge of technology and its implications on society, cultures and economic prosperities.

Process knowledge, both past and present, encompasses heightened awareness of such initiatives as:

- ❑ ISO (9000) Standards
- ❑ Quality Function Deployment (QFD)
- ❑ Continuous Improvement (Japanese termed Kaizen)
- ❑ Zero Defect Programs – based on statistical process control
- ❑ PDCA – plan, do check, act cycle
- ❑ Quality Circles
- ❑ Department Quality Teams (DQTs)
- ❑ Taguchi Methods
- ❑ Total Quality Management (TQM)
- ❑ Business Process Reengineering (BPR)
- ❑ Deming (14 points)
- ❑ Object Oriented Quality Management (OQD)
- ❑ Lean thinking
- ❑ Six Sigma

Additionally, technical skills include technology awareness, meaning:

- ❑ The history of technology
- ❑ Technology policy and economics
- ❑ The philosophy of technology
- ❑ Technology from a global perspective
- ❑ Technology and society

Human Skills -

Human skills are those skills required to “lead” or “manage” a group of individuals within or across multiple disciplines. Human skills include skills typically conceived as critical to individuals that transition from an individual contributor role to an increasingly higher role with superior-subordinate relationships. Underlying this skill set are skills depicted below:

- ❑ Human resources
- ❑ Motivational
- ❑ Conflict management

- ❑ Negotiation
- ❑ Ethics
- ❑ Change management
- ❑ Group dynamics
- ❑ Interpersonal

Some of the skills defined as “leadership” may be more appropriately categorized as “management” skills. It is not the intent of this paper to debate or differentiate the definition of leadership versus management, as others have long since discovered this as an effort in futility given the current and continuing controversy¹¹. It is more important in defining the body of knowledge for technology leadership to identify those skills organizations would like their individual contributors to have as they transition into first line or subsequent leadership/management roles with attendant responsibilities. To this end, the above list is indicative of those skills and not all encompassing.

Conceptual Skills -

Conceptual skills are premised on a general analytical ability. Conceptual skills may be thought of as:

- ❑ Logical thinking
- ❑ Proficiency in concept formation
- ❑ Conceptualization of complex and ambiguous relationships
- ❑ Creativity in idea generation and problem solving
- ❑ Ability to analyze events and perceive trends
- ❑ Ability to anticipate changes
- ❑ Ability to recognize opportunities and potential problems (both inductively and deductively)
- ❑ Possessing an understanding of entrepreneurship and intrapreneurship
- ❑ Broad-based knowledge of innovation and commercialization

The body of knowledge, relative to conceptual skills would be those educational entities contributing to the above. Additional areas of study would include:

- ❑ Strategic planning
- ❑ Critical thinking
- ❑ Problem solving techniques
- ❑ Effectiveness and efficiency understanding

In some regards, it is expected all participants with an awareness of the technology leadership body of knowledge would be equally educated in these conceptual skills and possess the ability to function in a conceptual capacity. In reality however, varying levels of leadership, relative to

management, is expected to demonstrate an increased conceptual capability with a declining expectation in technical skills. Figure 3 below depicts this understanding.

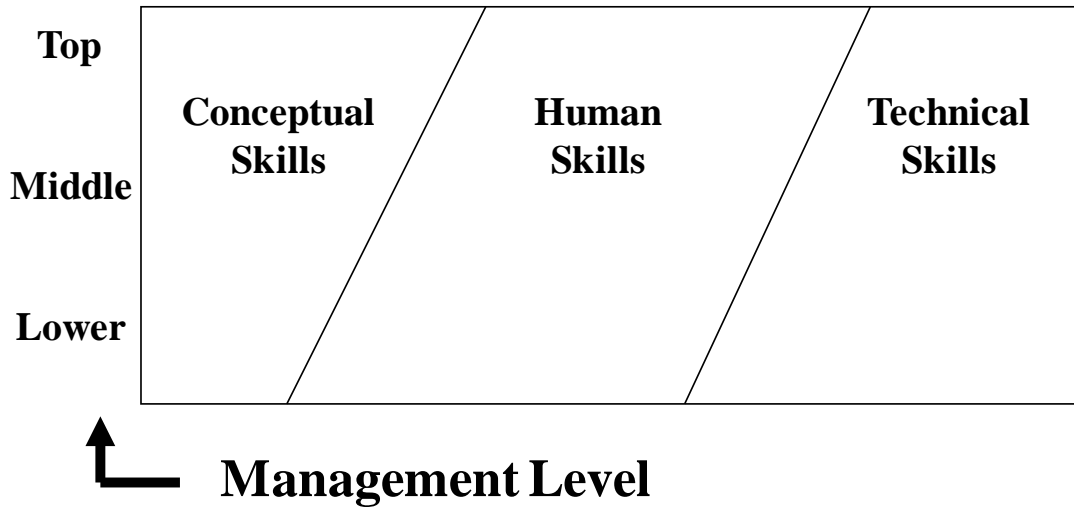


Figure 3: Management Level versus Expected Skill Set

Technical skills are those that support the knowledge of, or actual doing, of the tasks to be performed. This is especially true of middle management, or better yet, first line supervisors. These individuals are more involved with the day to day operations of the organization.

As an individual moves into hierarchical levels of management, it is not expected that individual will maintain as sharp technical skills. In fact, as individuals progress into higher levels of management they are expected to contribute in a different manner, and apply a different set of skills, such as human or conceptual¹².

Next Steps toward Curriculum Development -

If we were to accept the above definition of what constitutes the basic body of knowledge for technology leadership, then the next step would be to further evolve the requirements into a curriculum; clearly not a small undertaking. Each of the courses forming the underlying premise of the curriculum would have to have an empirically conceptual as well as procedural foundation. Meaning, for each module defined and developed there would be underlying evidence characterized by observation or experiment versus being based solely on theory. This combination of empirically-based and procedurally-based education would provide a basis for application and individual theory formulation based on a deeper and richer understanding of observable phenomena. This, then, would work towards advancing the agreed to technology leadership body of knowledge through directional ideas and their subsequent formalization and directly supports the continuation and advancement of the technology leadership body of knowledge and survival and growth of the discipline.

Conclusion and Areas for Future Study -

Through an enhanced understanding of innovation, the discipline of technology, the systems integrator and the systems integration model, and the anticipated knowledge and skill of a systems integrator as defined by technology leadership, we can ascertain key components of relatedness:

- ❑ Innovation requires the ability to “see” the interrelatedness of seemingly independent systems/subsystems
- ❑ Innovators are characteristically defined as having high levels of associational thinking
- ❑ Systems integrators are characterized as being able to “see” the interrelatedness of a multitude of seemingly independent subsystems
- ❑ Innovators and systems integrators are linked through, and share, high levels of associational thinking indicative of the definition of innovation
- ❑ Understanding the discipline of technology yields a conversational understanding of the role of the technologist
- ❑ The role of the technologist is positioned as a discipline-specific systems integrator
- ❑ The technologist, as a discipline-specific systems integrator, may possess the characteristically defined DNA of innovation

In further understanding the role of the technologist mapped to the role of the discipline-specific systems integrator, we can pursue a theme of curriculum differentiated by general systems integration or discipline-specific systems integration. This understanding and agreed to approach yields a path for graduate curricular design and development.

In understanding the expected knowledge and skills of a leader of technology, we can again pursue the evolution of a targeted graduate curriculum.

As hypothesized, understanding the relationships of innovation, the discipline of technology, the systems integrator, the systems integration model, and the anticipated knowledge and skill of a systems integrator as defined by technology leadership provides rich insight into advancing the definition and development of the 21st Century Technologist through graduate education.

Credit and Special Acknowledgement -

Credit for introducing and advancing the definition and development of the 21st Century Technologist is premised on the seminal work of Gary R. Bertoline, Dean, College of Technology at Purdue University. Dean Bertoline penned an unpublished work titled Future College of Technology. This document formed the underlying vision and detailed plan for creating preeminence in defining and developing the 21st Century Technologist; this, through reinvention of the College of Technology at a tier 1 research intensive university. Subsequent conversations to advance this objective yielded the collection of thought reflected in this paper.

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