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An introduction to Management of Technology pedagogy (andragogy)

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ABSTRACT

In this introduction we leverage efforts of three professionals involved in the practice and use of MoT education. These professionals each discuss MoT from different perspectives. One is primarily interested in MoT pedagogy from a practitioner point of view. Another is a progenitor of the field. The third is an emergent MoT professor. The fourth and fifth utilize their efforts to focus on the importance of MoT education, and how MoT programs, courses and course materials can be presented to managers and technical professionals using both traditional and emergent methods. 21st century managers and students are either participating in or entering into a marketplace where the effective Management of Technology is key both to their professional development and to the effectiveness of large, small and medium enterprises, entrepreneurial activities, NGO operations, government policies and regional development. The Special Issue editors then provide a view of how the authors incorporated in this Special Issue provide the basis for 21st century MoT pedagogy for lifelong learners

Management of Technology (MoT) pedagogy, more rightly described as adult learning or andragogy, is a young field. Here we provide some insight into the importance of "lifelong" MoT learning from a number of separate perspectives. Prof. Daniel Berg's perspective is that of a progenitor of the MoT field, a former President of Rensselaer Polytechnic Institute (RPI) and Technology Director at Westinghouse. Another is one of the field's most accomplished practitioners, Prof. H.S. Mani. Dr. Mani retired as dean from the prestigious Indian Institute of Technology (IIT) Kanpur and was the initiating director of Meta Research Institute. He holds India's coveted Lifetime Achievement Award for Physics and was named one of India's Science Instructor of the Year. We also provide a multifaceted perspective by introducing the thoughts of a newly minted Ph.D. in technology strategy and entrepreneurship, Dr. Robert Tierney from the University of Twente, Netherlands. The Special Issue editors, Prof. Steven T. Walsh and Dr. Yorgos Marinakis, also provide insights into the MoT pedagogy field and display how the authors in this Special Issue progress the field. We initiate with a brief discussion of the advent of importance in MoT.

The importance of Management of Technology (MoT) has been recognized since the earliest days of economic research (Smith, 1776; Ricardo and Li, 1819), yet appreciation of the importance of education on technology management has lagged. Some suggest that this lag is the result of managerial discomfort with technology and lack of understanding of its importance in the strategic process of the firm, region, as well as in national and global economy (Christensen, 2008). Yet the importance of technology in management and the economy was sealed when, in the 20th century, two business cycle economists (Schumpeter and Swedberg, 1942; Kondratief, 1937) demonstrated the central role of technology in creating disproportionate economic growth. The fastest growing regions were those that led in technology commercialization. When another economist (Solow, 1956) won the Nobel Prize for demonstrating that the Gross Domestic Product (GDP) was modified by technology as a multiplier of capital and labor, MoT became an important policy matter for most governments and firms. No longer was technology taken as a given. Technology management was now deemed exceptionally important.

Research into the strategic role of technology became important (Mansfield, 1968) and at this time authors generally stated that technology needed to be directed by the strategic effort of the firm (Ansoff and Stewart, 1967). Some years later, Friar and Horwitch (1985) suggested a more dynamic interaction between technology and strategy in which each had primal input of the other. Much later, articles on MoT education began to appear (Yanez et al., 2010). Finally, education in general has changed with the times, from traditional practice, to video learning, to on-line processes, "edutainment," and finally, to providing an educational process that "addicts" students to lifelong learning (Cooper et al., 2015). We now introduce the field of MoT.

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0040-1625/

We first discuss Prof. Mani's insights. Prof. Mani has managed technology-based organizations since the 1960s. He epitomizes the technologist's embrace of managerial roles that abound in industry, academia and policy makers. He is both an academic scholar as well as a reflective practitioner when it comes to the field of Management of Technology (MoT). He has teamed with MoT researchers to advance the field (Walsh et al., 2014). He noted that many exceptional engineers are placed in leadership positions without an MoT education. This is one of the reasons why, over the years, many of the Indian Institutes of Technology (IIT) developed MoT concentrations.

Prof. Mani noted that technologists, when thrust into more managerial roles, could not rely on their technical educational background to assist them (Kim, 2015). He stated

"Vision is the single most important characteristic for the successful growth of a technical based organization. This was best illustrated to me by the example of William Lawrence Bragg of Cavendish laboratory, when he decided to pursue a new line of research in biophysics, instead of continuing on the previously established path of Ernest Rutherford in the area of radioactivity. This led to one of the most important work, that of unraveling the structure of DNA by Francis Crick and James Watson. He also stated that several other characteristics are also essential for healthy growth of an organization. They are, in my view and experience, (a) understanding the strength's, weakness and stamina, (b) external visibility of the organization or group, (c) clarity of functions of every team member at all levels, (d) accepting mistakes openly and taking corrective actions (e) open door policy."

These are all things that MoT programs teach today, with pedagogy activities in scenarios (Wright et al., 2015), cases (Marinakis et al., 2014; Walsh et al., in press), simulations (Linton, 2015) and entrepreneurial action (Harms, 2015). Prof. Mani also stated that an academic organization has to identify and choose areas of strength instead of spreading too thin or becoming too narrow. For instance at Harish-Chandra Research Institute, Allahabad, India we chose string theory, high energy phenomenology, some areas of condensed matter Physics Astronomy and number theory to focus on. Later Quantum information theory was also added. This strategic focus with a directed choice paid good dividends, making it an internationally visible research center.

This insight resonates with a major contemporary strategic perspective on how to develop exceptional organizations (Walsh and Linton, 2011; Hamel and Prahalad, 1990). Yet the competency based organization comes with a price — meritocracy. Dr. Mani further stated that periodic meetings with the members were critical in ensuring transparency in the roles of each member. They were beneficial to impress upon the entire organization the importance of each person's contribution to create a supportive and productive environment. Equally essential is to create an atmosphere where it is possible to accept mistakes — this needs an understanding and a collective effort to take corrective steps whenever possible. Finally an open door policy is absolutely necessary in order to keep accurate and effective information flow. Too often, rumor, misrepresentation cause considerable dissipative energy of the organization. Prompt responsive feedback has proven to increase the faith and trust of the entire staff toward the organization allowing the team to feel ownership.

If a competency based organization is to thrive, financial rewards and profits have to be equitable. This is one of the reasons why finance was integrated into many MoT programs (Kassicieh et al., 2015). Prof. Berg is a progenitor of the MoT field. He has been, as he stated "involved in the system of technological innovation since my first position as a researcher with Westinghouse Electric after my PhD in the physical sciences. I was a practitioner for almost 2 decades as a researcher, technical strategist, research director, etc. before I got involved to heavily focus on the theories of technological management. This came about after Westinghouse sent me for a couple of months' extensive program for executives at Carnegie Mellon University in Pittsburgh. The program covered many of the basics for general management: strategy, finance, marketing, human resources, etc. The ex-dean of the Graduate School of Industrial Administration (GSIA), who ran the program, (became) the new president of Carnegie Mellon University asked me to critique his course in the program. The course (I worked on in particular) was "Strategic Planning." I thought and said the course was useful, new to me but lacked involvement with a connection to the role of technology. He asked me to teach (this) course. After talking to the academic leaders in the field and preparing a course after reading extensively in the literature I did so to the graduate program. So my comments are based on this history of teaching, being a researcher in the field with many PhD students and colleagues world-wide."

Prof. Berg further states that Management of Technology includes all the segments of management: finance, marketing, economics, organization, etc. But it also requires an understanding of the technological aspects including research and development and governmental policy. So it is too broad for any simple minded approach. Indeed, in his pedagogy, Prof. Berg focuses on issues that he thinks are fundamental. He discusses this subject with the following statement.

Dr. Berg states that "the focus I give is to combine theory and practice in what I cover in my course. Out of this, in recent years, a research and pedagogical focus on the role of technology in the Service Sector of the economy has also arisen which had been neglected by the academic community even though over 80% of the US economy is in the service sector. In more recent years my research concentration has been on the issue of emerging technologies and whether the theories already developed for MoT apply to this segment. My conclusion is they do! The key issues that are vital are that analysis from theory or from empirical evidence are the limits of any technology in a technological parameter versus time/or investment in R&D plot and the market limitation in market penetration plot versus time. The strategic understanding and theory and analysis persist. So the topics that I use cover historical technological developments, theory, and practice and that I think are fundamental to understand and incorporate. They are:

1) 'The Cobb–Douglas function illustrating the tradeoff of capital and labor in production and why technological innovation creates products and processes that have never existed. And most fundamentally the difference between ideas and patents and innovation and market utilization (and that) ideas are not innovation. At this stage I highlight the time interval between conception (Idea) and innovation (market entry).
2) I cover many models of the process of innovation: Marquis Model (Marquis, 1969), Funnel Model (Clark and Wheelwright, 1995), Twiss Model (Twiss, 1980), Abernathy and Utterback Model (Abernathy and Utterback, 1978), Tushman and Moore Model (Tushman and Moore, 1988), and several Financial Models associated with the product–life cycle (Segerstrom et al., 1990)."'

Prof. Berg stated that his pedagogy has changed over the years to include: history, new issues, cases, and especially the systems approach where I demonstrate all the managerial aspects and their involvement in the process of technological innovation. So I try to focus on the fundamentals of understanding and the theory backing those fundamentals with the utilization of real cases and anecdotes from my personal experience to highlight the fundamentals. So the summary of my overall emphasis, which I think is applicable today, is on the "Global Strategic Management of Technological Innovation from a 'Systems' point of view."

Dr. Tierney is the youngest of the professionals that we invited to provide an introduction to the field of Management of Technology. He stated that "for the past 30 years many management of technology professors have embraced a clinical approach or hands on real world corporate and entrepreneurial experiential learning. I utilize simulations, case studies and theory based teaching. Indeed, this Special Issue has simulation based MoT educational tools (Linton, 2015), MoT manufacturing and service product based cases on some of today's hottest subjects including nanotechnology (Walsh et al., in press), and electric vehicle infrastructure (Mayboom, 2015). Today you must not only develop

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outstanding course but they must be linked with others to develop great MoT programs."

He further stated that

"Today enveloped concepts like Lean startup built lead user research (Von Hippel, 1986) and the science of muddling through (Lindblom, 1959) are a big hit in the students' educational experiences. Further theory has gone from trying to find universal truths like the sequential product versus process innovation theory proposed by Abernathy and Utterback (Abernathy and Utterback, 1978) to a more democratized thought where researchers have found that product versus product innovation is category dependent (Barras, 1986; Linton and Walsh, 2008). There are a large number of new constructs like third generation road mapping techniques (Tierney et al., 2013) where students experience specific knowledge for differing innovation, technology and product categories rather than universal theories. The subject is most effectively taught with a more "Hands on" clinical approach."

Similarly he stated that today's generation of lifelong learners demand that we continue to be educated and pass that education on to our students to enrich their classroom almost addicting experience (Cooper et al., 2015). Finally he noted that the "21st century world" is more complicated, more international, more technology driven and more involved. Today teachers are expected to do more with less. They often are bound by decreasing program requirements, students that often feel that their futures are not as bright as the previous generation and we must not only teach our students more but get them hooked on lifelong education (Cooper et al., 2015). Indeed we as teachers are challenged to assist in the development of T professionals, preparing our students for a life where they might embrace three or more professional careers during their work life.

Prof. Walsh and Dr. Marinakis honored the experience, time and effort that these professionals and our authors put into Management of Technology (MoT) pedagogy. In this Special Issue we provide a number of efforts that overview trends in MoT pedagogy, that suggest new areas for program development, and that provide course development efforts including an original case that will provide an exceptional segment for your classes. The Special Issue has 8 efforts plus this Introduction.

After this Introduction, we start this Special Issue with a discussion of the current trends from Prof. Kim in his effort, "The Current Transition in Management of Technology Education: The Case of Korea" (Kim, 2015). Prof. Kim's emphasis is in MoT in Korea due to the country's industrialization process and its contribution to Korea's economic growth. He highlights Korea's significant changes in MoT education since 2008. He focuses on changing innovation characteristics from process to product, from high-tech to high-touch, from productivity to creativity, from manufacturing to service, and toward increased entrepreneurial venture creation. He provides a dual focus on innovation and entrepreneurship, and also addresses multidisciplinary problem solving. He also advocates a balance between theory and practice as dual principles that MoT education programs will be based on.

Prof. Harms provides some new thoughts on MoT based entrepreneurship, along the lines of Professors Kim (Kim, 2015) and Mani (Walsh et al., 2014). He also provides new thoughts on education as Dr. Tierney had suggested, with self-regulated learning. Dr. Harms analyzes 194 students in 41 groups in his work entitled "Self-regulated learning, team learning and project performance in Entrepreneurship Education: Learning in a Lean Startup environment" (Harms, 2015).

Professors Walsh, Marinakis and Berg provide a course element that addresses many of the issues mentioned by Prof. Mani (Vision), Prof. Berg (fundamentals) and Dr. Tierney (progressive teaching). "Systems Equipment Division at Ferrofluidics" (Walsh et al., in press) is a teaching case focused on the first nanotechnology based firm in the world. It is a case that speaks to entrepreneurial action based on entrepreneurial team competency, and to entrepreneurial action based on the lack of applicable competency. It is grounded on the fundamentals of MoT pedagogy and makes use of many works that the progenitors of management of technology have developed over the past 50 years. It can be used in technology entrepreneurship classes, strategy, commercial development and technology project management classes.

MoT education has progressed, as all masters and Ph.D. education have changed, in the 21st century. Today there is more participatory learning. In the Special Issue we present an innovation simulation, "Teaching Innovation to Technologists (non-business people) and Non-Technologists (Business People): Scotch Whisky as an Exemplar of Process Changing Product," (Linton, 2015) as an alternative to traditional lectures. Many lifelong learners want more hands on, more participatory, more game like learning experiences. This is just such an element that many professors might be looking for in their courses.

Scenario Analysis is one of tools that MoT educators provide, yet it is one of the most difficult concepts to teach. The effort "Teaching scenario analysis: an action learning pedagogy" (Wright et al., 2015) provides an outline of the pedagogical underpinning based on an action learning for scenario analysis. The scenarios are portrayed not as narratives, but as vehicles for exploration of the causes.

MoT pedagogy has become more focused on society and services. Our sixth effort, "Infrastructure as a social catalyst: Electric Vehicle station planning and Development" (Mayboom, 2015) focuses on both. It also specifically looks at government policy, emerging technologies and the service sector. The author describes the importance of infrastructure and the service sector. Here, as in all services, the key to the product (electric vehicles) becoming viable is infrastructure (Linton and Walsh, 2003). The paper provides a professor with a technology policy for their pedagogical efforts.

The next offering in the Special Issue focuses on the integration of Finance with MoT pedagogy. "Financial Analysis in Management of Technology Programs: Links in a Clinical Approach" (Kassicieh et al., 2015) provides a view into the issue of integrating traditional field finance to the needs of MoT pedagogy. These authors show how one program has produced a tighter link between MoT and finance and how this tighter link might help other MoT programs worldwide.

The final contribution is a critical analysis of a book that can be used in an introductory course on MoT in order to increase interest in bachelors or masters level MoT pedagogy. The work "A critical analysis "Abundance: The Future is is better than you think" can be used as a MoT text book (Cooper et al., 2015). This reviews the use of a bestselling business book in order to entice interest in the field for lifelong learners. The book stresses 21st century problems and how technology based innovations and policy and its management can create not a future as optimistic as our past but one that suggests a brighter future. Many of our masters' students are provided a picture of a world that is harsher than the ones their parents were born into and this book provides at least one scenario where there is a plethora of opportunity.

This Special Issue on MoT pedagogy traces the fundamentals that initiated the importance of MoT education. It provides an initial direction for 21st century MoT pedagogy programmatic themes. It provides support in developing important courses in a MoT program and finally provides a number of case studies, simulations, scenarios and background for important topics in MoT.

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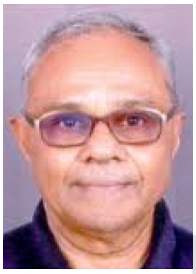
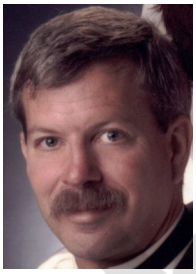
Daniel Berg is a distinguished research professor in the College of Engineering at the University of Miami in Coral Gables, Florida. He is a professor emeritus from Rensselaer Polytechnic Institute where he was an Institute professor of science and technology, provost and president. Prior he was the Mellon Dean of Science and provost at Carnegie-Mellon University. His earlier career in industry was at Westinghouse in Pittsburgh, Pennsylvania where he became technical director of Westinghouse. His undergraduate education was at the City College of New York followed by a PhD at Yale University in Physical Chemistry.



H.S. Mani is an accomplished manager, director researcher and teacher. He has held many positions including Professor I.I.T. Kanpur, Director Harish-Chandra Research Institute, Raja Ramanna fellow, Institute of Mathematical Sciences, Visiting Scientist S.N.Bose National Centre for Basic Sciences and many others. He has earned many awards including; D.A.E. C.V.Raman lectureship from the Indian Physics Association, M.N.Saha award by UGC-Hari Om Ashram, Best teacher's award I.I.T. Kanpur 2007 and National Science Academy Teachers award 2013.

Yorgos "George" Marinakis is a registered U.S. patent attorney and a member of the National Association of Patent Practitioners. He is admitted to the New Mexico and Massachusetts State Bars. He has a B.A. in mathematics from San Jose State University; a Ph.D. in the biological sciences, a J.D. and an MBA from the University of New Mexico; and is a management Ph.D. candidate at the University of Twente. He has worked for Lockheed Missiles and Space Company, Lockheed Martin Technical Operations, and Fidelity Management and Research Company. He currently has a patent law practice and is a partner in a design firm.



Dr. Robert Tierney graduated from the University of Twente Nikos in the field of technology innovation. He was a student hire at Sandia National Laboratory. He has a biology degree and a Management of Technology and Innovation masters from the University of New Mexico. He has had 5 ISI ranked journal publications in the last three years.

Dr. Steven Walsh Steve is a distinguished professor at UNM where he also holds the Regents professor at UNM's Anderson School of Management. He also is the Institute professor for entrepreneurial renewal of industry at the University of Twente. He has many business service awards including the lifetime achievement award for commercialization of Micro and Nano technology firms from MANCEF. He has also been named as a Tech All Star from the State of New Mexico Economic Development Department and has been recognized by Albuquerque the magazine as a leader in service to the economic community. He is a serial entrepreneur that has helped attract millions of dollars in venture capital to these firms.

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