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Engineers Are Entrepreneurs and Innovators*

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This paper is a scholar-practitioner synthesis that suggests that, while all engineers are somewhat entrepreneurial, there are academic and professional roadblocks and enabling pathways to entrepreneurial activity. The paper suggests a framework to perceive wider dimensions and systemic relationships that build entrepreneurial wholeness, beginning in the formative education process then throughout an engineering career. The paper's thesis is that a functionally entrepreneurial engineer is not a single tool (EE, ChE, CE, ME, etc.) but is multi-disciplinary, like a Swiss Army knife or Leatherman multi-tool. Some background, a multi-skill framework and some examples are provided. The conclusion calls for correction of technological illiteracy in America, a phenomenon that threatens entrepreneurial engineers.

INTRODUCTION

I HAVE YET TO MEET an engineer who is not entrepreneurial. Regretfully, too many engineers' entrepreneurial and innovative skills are applied as if using just one tool in a tool-box, or with narrow vision, like looking at the world through toilet-paper tubes. This paper is a scholar-practitioner synthesis that suggests that, while one engineering eye may need to narrowly focus through the tube of technical and project constraints, the other eye can perceive wider dimensions and systemic relationships that build entrepreneurial wholeness, beginning in the formative education process and then continuing throughout an engineering career. This paper's thesis is that a functionally entrepreneurial engineer is not a single tool (EE, ChE, CE, ME, etc.) but is multi-disciplinary, like a Swiss Army knife or Leatherman multi-tool. Some background, a multi-skill framework and some examples are provided. The conclusion calls for correction of technological illiteracy in America, a phenomenon that threatens entrepreneurial engineers.

My qualifications for making these claims started out from mentoring by entrepreneurial engineers in the defense industry who helped me, as a high-school student, to learn how to manage, design, manufacture and sell simple products through the Junior Achievement program. The next step was a B.S.E.E. degree leading to career number one in the nuclear submarine Navy. I added nuclear-Navy mechanical and nuclear engineering learning, then served a full career in the complexity of reactors, propulsion and sensor systems, torpedoes, Tomahawk cruise missiles and five years in command at sea of a nuclear missile submarine. This experience synthesized theory with practice in many dimensions. Career number two was ten years of academic study in adult education and human and organization systems applied in defense conversion economic development in New England including start-up and operation of a new commercial ocean-going vessel shipyard [1]. Career three is helping science-technology ventures to grow and develop in Eastern Idaho (see www.eastidaho.org and The Idaho Technology Corridor). Life-long learning, lots of innovation and a minimum of couch-potato TV watching.

The entrepreneurship theory-practice literature base that informs my learning can be drawn from references at:

- Sirolli Institute, http://www.sirolli.com/, which advocates a personal or neighborhood/rural type of enterprise facilitation and is a great place for beginning entrepreneurs to start;
- Ewing Marion Kauffman Foundation, http://www.entreworld.org/, and organizations they sponsor along with other not-for-profits that facilitate learning for developing entrepreneurs;
- Council for Entrepreneurial Development, www.cednc.org, which serves high-impact companies in the greater Research Triangle Region of North Carolina not only to start but to do 'intrapreneurial' or skunk-works type innovation within an existing business; and
- Leader to Leader Institute, http://www.pfdf.org/, formerly the Drucker Foundation, which provides guidance for entrepreneurial leaders in the public and not-for-profit sector, careers that many engineers will have in academia, government and think-tanks.

Translating entrepreneurial theory into practice is complicated; however, one can learn from other

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engineers who helped build American industry. Some are chronicled in books such as *The Power of Boldness* [2]. Applications of *intra*preneurial or skunk-works thinking within inertia-filled corporations, the Navy, and even universities, are recorded in books such as *Reinventing Government: How the Entrepreneurial Spirit Is Transforming the Public Sector* [3] and Gifford Pinchot's *Intrapreneuring* [4].

BUILDING AN ENTREPRENEURIAL MODEL

Engineers are entrepreneurial when not excessively bound by formal problem-solving rules and not afraid to question pre-determined 'right' answers. Graduates of good engineering schools learn and demonstrate many classic entrepreneurial strengths. Engineers are driven to achieve results with high standards of excellence; always striving to do things better; thinking 'outside of the box;' being smart, capable and decisive; and being problem-solvers who love new challenges and believe nothing is impossible [5]. A narrow science and engineering curriculum that fails to expose students to hands-on entrepreneurial experience may leave other classic strengths to be learned and developed in the future, such as being: visionary and pioneering; great at seeing possibilities where others don't; willing to search for new opportunities and challenges; passionate and energetic; proactive and future-focused; driven by a sense of urgency; confident about risk-taking; and determined to create wealth for themselves and others and make a difference. It is the burden of engineering faculty to add multiple degrees of entrepreneurial freedom in thinking and acting while holding students accountable for technical, environmental and social excellence.

The invitation to submit papers to the *International Journal of Engineering Education* sought a response to the observation: 'In the wake of the downward trend of the world economy, organizations all around the globe are looking for innovations to bring about the next wave of prosperity.' Therefore, the remainder of this paper will focus on a framework to achieve the capstone entrepreneur goal: *to create wealth for themselves and others and make a difference*. This is a leadership imperative. The ultimate entrepreneurial engineer will not be able to do it all by themselves; however, s/he will significantly contribute by wrestling with critical questions that have mental, spiritual and physical dimensions: 'What is prosperity?' 'What is my mission, the reason I was put here on earth?'

Fig. 1. The enterprise trinity.

Scholar-practitioner Ernesto Sirolli advocates a simple enterprise model that helps in understanding and implementing entrepreneurship. He names this model The Enterprise Trinity and describes how it works in his book, *Ripples on the Zambezi* [6].

Sirolli suggests that for enterprise success three critical entrepreneurship skills and passions are required within or supporting the enterprise management system:

- the skill, passion and discipline to design and produce a product or service;
- the skill, passion and discipline to market and sell the product or service; and
- the skill, passion and discipline to achieve financial management of the enterprise.

Sirolli's work in multiple cultures and countries reveals that: the personalities of individuals who possess these three skills and passions are different; that entrepreneurial persons possess one or two of these skill sets; however, that no one person is sufficiently competent or passionate at all three sets. Sirolli concludes that it is impossible for a lone individual to successfully run an enterprise of any complexity. The lesson is that entrepreneurial activity is a team sport. Sirolli's model also implies that at least one of the persons with skill and passion also possesses a skill, passion and discipline for synergistic enterprise management: the leadership, functional integration, and/or coaching role. My experience in the Navy, manufacturing, science and technically oriented enterprise development and operation confirms that Dr. Sirolli is correct. How can engineering theory-practice education adopt or adapt some of the principles in the basic entrepreneurial model to help facilitate improvements in prosperity?

IMPLICATIONS FOR ENGINEERING-RELATED ENTREPRENEURSHIP EDUCATION AND PRACTICE

Product and service

Engineers are strongly oriented toward physical and intellectual products and/or services. These products form one of the three cornerstones of an entrepreneurial enterprise model. Accordingly, engineering education can celebrate and build on the current product-service theory and practice in most curricula. Challenges to engineering education stream from the explosion in scientific and technical knowledge that is increasing exponentially. How

can education keep up with both detailed and dynamic complexity in materials, nanotechnology, and signals processing, along with changes in mathematics and computational capacity, engineering connections to environmental and life sciences, etc? Magazines such as MIT's *Technology Review* raise awareness of fresh concepts each month. No university has the resources to do it all, but what is the foundational knowledge that an engineer needs to help create new and improved products and services? I cannot answer this question; however, I can ask that, within the foundational learning that theoretical and applied engineering science provides, graduates be exposed to a sufficiently broad applied knowledge base to be ready to take on entrepreneurial work after graduation.

The applied knowledge base I imply is a synthesis of what we know (memorized, learning and problem-solving techniques), what we can actually do (mind–hand skills and competencies) and those habits of our hearts that underpin our disciplines and routines (communications and working relationships with others). The engineers I want to hire and to work with as colleagues have 'know-how' summarized in the table below. These Rudyard Kipling's six honest serving men are also pointers for life-long learning we must all adopt to remain employed and productive.

Marketing and sales

My personal experience with many scientists and engineers is that their passion is most often product oriented, and is somewhat oriented toward marketing, such as telling the story about what they are doing, and less oriented toward selling. Marketing and sales skills and competencies are people oriented. They deal with customers and suppliers. They emerge from the tools of adult education teaching and learning, and psychology principles such as motivation and persuasion. Marketing is recognizing or developing and then meeting human wants and needs. Selling is convincing a prospective customer to use the product or service and to pay for it. Product and service development, manufacturing or delivery is joined at the hip with marketing and sales. The twofold goal of profitable entrepreneurial marketing and sales is to attract new customers by promising superior value and to keep and grow current customers by delivering satisfaction.

Table 1. Elements of an entrepreneurial engineer's knowledge and skills base [7].

- Know-how: tested, proven procedures to get things done
- Know-who: those individuals who possess appropriate experience or resources
- Know-what: the ability to discern and pick out key patterns and relevant action
- Know-why: an understanding of an experience's larger context or vision and/or the applicable base of theory or principle
- Know-when: a connecting sense of rhythm, timing and realism
- Know-where: a sense of three-dimensional physical and virtual space in which things get done

Is marketing only business related, or is marketing also important engineering learning? How does marketing connect with engineering education? Engineering students learn to market, advertise, and sell their ideas if only to engineering faculty and to their peers when course mini-research projects, class multi-disciplinary projects in team implementation, senior theses, or other innovation is required in the curriculum. Grades may be the price. Business marketing lexicon, along with other entrepreneurial concepts such as return on investment, can be introduced in this process. Undergraduates can be introduced to grant-writing requirements for programs such as Small Business Innovation Research or can team with graduate students or faculty who are preparing grant proposals. Grant-writing is a marketing and sales activity aimed at the funding customer.

The best entrepreneurial engineering marketing and sales education occurs, I believe, when engineering and business undergraduates team up to design and practice technical-business assessments of existing and emerging firms. Student peer teaching/learning quickly converges on basic concepts and terminology when driven by self-directed adult learning motivation. Curriculum concepts could be drawn from concurrent development practice or programs such as: Stanford University's Dual MBA/MSE Program; MIT-Sloan Leaders for Manufacturing; the International Design Business Management with Helsinki School of Economics and Business Administration (HSEBA) and Helsinki University of Technology (HUT); or Rhode Island School of Design's Design Marketing Collaborative. When engineering students must explain scientific and technical concepts to marketing students and vice-versa, so that coherent comparative and competitive analysis and synthesis can occur, great multi-disciplinary learning occurs. Presentation skills are honed when mock investors, roles played by other students, local business leaders or Small Business Development Center staffs, listen and feed back to the presenters. In these processes, students learn: to market and sell themselves, a prelude to job search; to separate abstract or minutia concepts from things more important; and to communicate effectively.

Financial

Most engineers I know have been well taught to plan and manage resources for a project. Many are less passionate and disciplined about the detailed bean-counting that relates project elements to project financial budgets, activity-based cost accounting structure or overall enterprise cash-flow and profitability models. Perhaps this is too much to teach an undergraduate engineer. But if we send young engineers out without at least a cheat-sheet checklist of financial principles and

critical questions, how can they link the value of technological innovation and discipline they are prepared to add to overall enterprise performance?

I suggest two approaches to teaching some financial passion and discipline to engineers. The first is to include learning about engineering economics into senior or class-team projects. In my shipbuilding industry, an excellent learning tool is *Marine Engineering Economics and Cost Analysis* [8], a book that looks at the broad industry from the perspectives of shipbuilding, repair, lifecycle vessel operations, and salvage, etc. The book includes data-disks with realistic information for capital investment or repair decisions, freight-rates vs. vessel characteristics and other connections between engineering and enterprise. Project software and its resource-assignment tools force project designer-managers to convert the narrative budgets for materials, equipment, labor, etc., to the hard cash budgets that roll up into the weekly cash flow requirements and overall project costs. Running projects as war-gaming scenarios with what-if contingencies imposed by faculty or assigned students can help the learning. For example, if, in day three of a compressed project scenario, the expected progress payment doesn't show up, then what?

The second approach is to include some learning about emerging performance measurements that relate financial data, once only displayed as spreadsheet figures, to measures that directly relate to enterprise strategy. These emerging measures applied in enterprise such as manufacturing [9] get at delivery performance, customer service, process time, quality, flexibility, etc., to provide fast feedback to engineers and operators and foster improvement instead of simply monitoring. Managerial accounting can convert these measures to financial data for higher-level decision-making and external reporting requirements.

PUTTING IT ALL TOGETHER: ENGINEERS AS SWISS ARMY KNIVES OR LEATHERMAN TOOLS

Engineers must have skills, passion and discipline in one or more of the three basic entrepreneurial enterprise functions: the product; its marketing and sales; and financial management. A scholar-practitioner learning model could produce a person who can pass the exam in the classroom, do useful things in the enterprise, and make money. The engineering curriculum can be strengthened with: a laundry-list of entrepreneur characteristics and some freedom to begin to act entrepreneurially; an applied six-part knowledge base; terms and practice in design-marketing-sales relationships; principles and practice in engineering economics and cost analysis; and project management. These features probably exist to some degree in most engineering schools with some teaming with business schools. They can be packaged and emphasized as examples of what a multi-disciplinary engineer needs to enter and succeed in the entrepreneurial enterprise environment. But entrepreneurial engineers are not enough. More Americans must understand and value what engineers do.

Engineering education faces a big challenge outside the engineering classroom if the profession is to vitally influence entrepreneurial enterprise leaders in the US to achieve the capstone goal: to create wealth for themselves and others and make a difference. The challenge comes from a major weakness in America: the public lack of understanding about technology. This lack restricts a major driving force for effective marketing of engineering intellectual and physical products and services. The National Academy of Engineering report, *Technically Speaking: Why All Americans Need to Know More About Technology* [10], defines technology as the entire system of people and organizations, knowledge, processes, and devices that go into creating and operating technological artifacts, as well as the artifacts themselves. The report suggests that technological literacy is the key tool of the educated consumer to buy what scientists and engineers do. Technological literacy encompasses three interdependent dimensions—knowledge, ways of thinking and acting, and capabilities. Like literacy in reading, mathematics or the arts, technological literacy is to provide people with the tools to participate intelligently and thoughtfully in the world around them.

If entrepreneurial engineers whose knowledge is based on engineering education, and their cousins the scientists, cannot influence technical awareness and thinking throughout the campus, then the education system will continue to produce technologically illiterate Americans. Other countries and their corporations will continue to buy top-quality engineering education from the US but will develop the wealth from entrepreneurial action based in their own countries. While a distribution of engineering excellence throughout the world is a good thing, it makes no sense to allow US standards to atrophy. With these thoughts in mind, I hope that engineering educators will become more entrepreneurial themselves, and help revitalize engineering enterprise in America.

CONCLUSION

This paper is a scholar-practitioner synthesis that suggests that, while all engineers are somewhat entrepreneurial, there are academic and professional roadblocks and enabling pathways to entrepreneurial activity. The paper suggests a framework to perceive wider dimensions and systemic relationships that build entrepreneurial wholeness, beginning in the formative education process then throughout an engineering career. The paper's

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REFERENCES

1. L. Gebhardt and R. Jarvis, Concurrent development of the SENESCO shipyard, *Journal of Ship Production*, **17**(1) (2001), pp. 40–45.
2. E. Blount (ed.), *The Power of Boldness—Ten Master Builders of American Industry Tell Their Success Stories*, American Academy of Arts and Sciences, Washington, DC (1996).
3. D. Osborne and T. Gaebler, *Reinventing Government: How the Entrepreneurial Spirit Is Transforming the Public Sector*, New York, Penguin Group (1993).
4. G. Pinchot, *Intrapreneuring*, Harper & Row, New York (1985).
5. K. Catlin and J. Matthews, *Leading at the Speed of Growth—Journey from Entrepreneur to CEO*, Kauffman Center for Entrepreneurial Leadership, Cleveland (2001).
6. E. Sirolli, *Ripples from the Zambezi*, New Society Publishers, Gabriola Island, BC (1999).
7. D. R. Keough, *Getting Started with Knowledge Management*, Excalibur Technologies, Vienna, VA (1998).
8. E. C. Hunt and B. S. Butman, *Marine Engineering Economics and Cost Analysis*, Cornell Maritime Press, Centerville, MD (1995), p. 350.
9. B. H. Maskell, *Performance Measurement for World Class Manufacturing*, Productivity Press, Portland, OR (1991), p. 408.
10. G. Pearson and T. Young, *Technically Speaking—Why All Americans Need to Know More About Technology*, Committee on Technological Literacy, National Academy of Engineering & National Research Council, Washington, DC (2002), p. 156.

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