Nurturing the Mind towards Adaptive Expertise

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A short time ago a colleague and I had been invited to develop a training program for newly graduated electrical engineers at a utility company. In conjunction with another contracting firm, these engineers were to go through three years of exposure to training, as well as, practical hands-on project experience culminating in the commissioning of electrical stations or substations. Commissioning is the fully functional operation of an electrical component in the national electric grid. Your electric service is dependent upon the successful operational commissioning of a given electrical system's component.

The training program, as initially anticipated and described to us by senior management would entail fundamentals and then proceed in complexity to be project-centered. Fundamentals were easy enough to understand, as was the concept of project centered. Fundamentals would focus on the knowledge, skills and/or tasks associated with or that act as a thread across or through all projects. Project centered was meant to mean that all examples, practice and application would be germane to those attributes and characteristics of engineering capital projects. "Complexity", however, as a term is both general and vague.

As training development specialists, we always look for degrees of exactitude in formulating training programs; particularly, one would think, in dealing with an exact science such as electrical engineering. Initially, complexity suggested a higher order of thought or additional concepts, principles or procedures that one would need to be learned in order to operate effectively on projects, or more "complex" projects. Obviously, one needs to understand that an interpretation of the word "complexity" held by a training development specialist differs from that of an engineer. Or, for that matter, almost any other discipline that one might encounter. It goes back to the old adage of never assume anything; have it spelled out in detail prior to venturing forward.

As it turned out, "complexity" referred not to additional concepts or principles to be learned, but rather the degree the state of completion, which the project currently was in. That is, there are numerous steps along a project time line that help discern the level of complexity. Within that time line is whether certain (electrical) line drawings have been completed, whether breakers and/or protection drawings of those lines have been completed and what systems with older or newer equipment is being requested to be changed or added to the system in question. Once electrical engineering concepts, principles and procedures have been learned, they remain static (no pun intended); there is nothing new to learn per se. Complexity arises based on the type, kind and age of systems to be exchanged or added to within an electrical system framework. Complexity arises based on what is being requested to be accomplished within a project. It arises when an electrical engineer looks at new drawings for the project and discerns that, "I've never seen a configuration quite like this before…"

Our program design for Fundamentals revolved around a framework of student centered training wherein trainees were presented the concepts and principles, provided varied examples, opportunities to practice and then onto the project(s) to apply what had been learned.

Recognizing that once Fundamentals had been achieved, it was paramount upon us to look beyond those finite sets of knowledge, skills and tasks and determine how to train to that "complexity" *as a higher order of learning*. Within that construct we began to see other parallels to living and learning as well.

We are not the first nor, certainly, will we be the last to raise this topic in a learning framework or as a societal construct, but perhaps we can add some additional clarity to the discussion and its importance.

As noted earlier, complexity had to do with the diversity of the project state, not the concepts, principles or tasks associated with electrical engineering or the project. What then did an SME (subject matter expert) do to address this complexity when faced with it? What mental processes allowed that SME to more effectively address the complexity better than another SME or novice engineer? What questions does an SME, now intuitively, ask herself when confronted with a unique or one-off situation. What mental models do they almost instantly formulate to address that uniqueness?

The literature is replete with papers discussing, and research showing, the construct of "Adaptive Expertise". In a 2014 paper on the review of Adaptive Expertise, Katerina Bohle Carbonell, Renée E. Stalmeijer, Karen D. Könings, Mien Segers, Jeroen and J.G. van Merriënboer[1] note that Hatano & Inagaki first coined the term in 1986 and contrasted it to "Routine Expertise". Hatano & Inagaki conceptualized that both types of expertise comprise the same extent of domain knowledge and the ability to perform flawless in familiar situations. However, the difference becomes apparent once confronted with an unfamiliar situation. While individuals with routine expertise struggle with the new demands, adaptive expertise allows for easily overcoming the novelty and quickly regaining a high level of performance thanks to a knowledge representation, which allows for flexibility (Schwartz, Bransford, & Sears, 2005). In contrast to routine expertise, individuals with adaptive expertise possess the knowledge of why and under which conditions certain methods have to be used or new methods have to be devised.

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[1] Educational Research Review 12 (2014) 14–29

Adaptive Expertise is a broad construct that encompasses a range of cognitive, motivational and personality-related components, as well as, habits of mind and disposition.[2] Hatano and Inagaki (1986) argue that some individuals, in solving a large number of problems, learn merely to perform a skill faster and more accurately, without constructing or enriching their conceptual knowledge. Such individuals are sometimes called expert, because their procedural skills are highly effective for solving everyday problems in a stable environment. While they are outstanding in speed, accuracy, and automaticity, they lack flexibility and adaptability to new problems. Rather than simply applying their knowledge to solve a task expeditiously, some experts see a task as an opportunity (or as requiring them) to depart from the routine and expand their expertise.[3]

Research points to characteristic features of an adaptive expert which encompass: a) mastery of the field/domain, b) efficiency, c) knowledge transfer d) metacognition, e) a propensity to view the novel/unique/new situation as an opportunity to solve or create a solution (innovation/creativity) and, f) self-efficacy. Embedded in these characteristics is the sense, belief or understanding of the need for life-long learning. If, as research suggests, it takes at least ten (10) years to master a disciple[4] (domain), then one can reasonably construe it will take longer to reach routine expertise, let alone adaptive expertise. More on this later.

Let's take a step back for a moment and look at how education is in the midst of a transitional period. As Charles M. Reigeluth[5] points out in his current book, "Reinventing Schools", "Our current paradigm of schooling is often called the "factory model" and was developed for the Industrial Age, from about 1830 to 1960, when factory work had replaced farm work as the most common means for earning an income in the U.S." The underlying characteristic of this model was instruction, whether reading, writing and arithmetic, and discipline where everyone followed the same rules and procedures for success. But with the advent of computers and globalization of industry, we embark onto the information highway where manual factory work is rapidly being replaced by robotics and information processing. Charles Reigeluth captures the essence of the Information Age with these subtitles in his book:

- Standardization to Customization
- Uniformity to Diversity
- Adversarial to Collaborative Relationships

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[2] Characterizing Adaptive Expertise in Science Teaching, Valerie M. Crawford, Mark Schlager, Yukie Toyama, Margaret Riel, & Phil Vahey SRI International, Paper presented at the American Educational Research Association Annual Conference, April 11–15, 2005, Montreal, Canada.

[3] Ibid P.6

[4] Anderson, J. R. (1982). Acquisition of a cognitive skill. Psychological Review, 89, 369-406. Ericsson, K. A., & Charness, N. (1994). Expert performance: Its structure and acquisition. American Psychologist 49(8), 725-747.

[5] Charles M. Reigeluth and Jennifer R. Karnopp, "Reinventing Schools" Roman & Littlefied Education Press, 2013

- Bureaucracy to Teams
- Autocratic to Shared Leadership
- Centralized Control to Autonomy with Accountability
- Compliance to Initiative
- Professional Service to Self Service and,
- Compartmentalization to Holism

Further, he points out how the educational needs of students have been influenced by these key characteristics of the Information Age into an environment which is focused on:

- Knowledge work
- Complexity
- Systemic thinking
- Diversity of skills
- Collaboration and,
- Initiative

We see these trends rapidly occurring in the Armed Forces as well. From the early 20th century and even into the early 21st century individuals wishing to join the U.S. Army needed only be of age (17) and have a minimum of a GED certificate; not even a high school diploma. Now, even a GED may not get you into the Army; most higher paying jobs in the Army require technical skills attained through extensive training inside or outside the Army through a Technical College or having a Bachelor's degree. If you hope to be an officer, "Most officer programs require a college degree, and are very competitive. Many officers have Master's or higher degrees"[6]

At a minimum, the proceeding suggests students and adults in this Information Age are going to need skills that readily transcend the core functions within the Industrial Age. Just a few of these traits include: complex, initiative, systemic and holistic. Certainly, industrial age schooling presented concepts such as complex and initiative but seldom, if ever, until the late 20th century brought out systemic and holistic. Teaching of patterns and interrelationships between disparate thoughts and functions was practically unheard of, but information processing caused those relationships to become more apparent. In an Information Age they are becoming a necessity to see, understand and implement functionally, almost daily.

The Information Age has begun to transcend formal education as anyone can go online and learn extensively about anything. Schools and Colleges/Universities are no longer the sole repositories of learning, innovation and insight into any area. They do offer formalized methods and mechanisms to expound upon one's desired realm of interest however. What the Information Age is offering is an avalanche of information, circumstances and possibilities to be analyzed, synthesized and digested continuously. The 24 hour news cycle has become the 24 hour life cycle of

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[6] Military.com "Eligibility rules for the Armed Forces"

input awaiting personal decisions for today to likely needing change for tomorrow. Being adaptive to ever changing circumstances and input appears to be the emerging framework of and for the Information Age generation.

In his book, "5 Minds for the Future"[7], Howard Gardner lists the following needed mind types:

- Discipline
- Synthesis
- Creative
- Respectful and,
- Ethical

He describes the "Disciplined mind" as having mastered at least one way of thinking – a distinctive mode of cognition that characterizes a specific scholarly discipline, craft or profession. The disciplined mind also knows to work steadily over time to improve skill and understanding.

- The "Synthesizing mind" takes information from disparate sources, understands and evaluates that information objectively, and puts it together in ways that make sense to the synthesizer and to other persons.

- The "Creating mind" breaks new ground. It puts forth new ideas, poses unfamiliar questions, conjures up fresh ways of thinking, arrives at unexpected answers.

- Recognizing that nowadays one can no longer remain within one's shell or one's home territory, the "respectful mind" notes and welcomes differences between human individuals and between human groups, tries to understand these "others" and seeks to work effectively with them.

- Proceeding on a level more abstract than the respectful mind, the "ethical mind" ponders the nature of one's work and the needs and desires of the society in which on lives. The mind conceptualizes how workers can serve purposes beyond self-interest and how citizens can work unselfishly to improve the lot of all.

The future individual operational constructs both Gardner and Reigeluth espouse can be found within the framework of an adaptive expert. As noted earlier, the literature, particularly within the realm of the sciences, is focusing on the characteristics of an adaptive expert and how best to train towards that expertise. These characteristics raise some interesting parameters. That is, if we begin reverse engineering those characteristics on a timeline, we find they are not attained in short order but extended over many, many years; which suggests the necessity to

[7] Howard E. Gardner, 5 Minds for the Future, Harvard Business Press 2008

view attaining these attributes in a holistic integrated fashion. More on that in a minute.

In a delineation of what constitutes an adaptive expertise, we have at least two divergent, yet wholly interrelated, measures: mastery and self-efficacy. Mastery as to how long one takes to attain a level of expert performance (10+ years), and, self-efficacy as to how one perceives learning and the ingrown disposition to see it as opportunity.

Self-motivation stems from students' beliefs about learning, such as self-efficacy beliefs about having the personal capability to learn and outcome expectations about personal consequences of learning (Bandura, 1997)[8]. Students who feel self-efficacious about learning to divide fractions and expect to use this knowledge to pass a college entrance exam are more motivated to learn in a self-regulated fashion ("heutagogy" specific to the self-determined learner). Intrinsic interest refers to the students' valuing of the task skill for its own merits, and learning goal orientation refers to valuing the process of learning for its own merits. Students who find the subject matter of history, for example, interesting and enjoy increasing their mastery of it are more motivated to learn in a self-regulated fashion.[9]

Students who set specific proximal goals are more likely to self-observe their performance in theses areas, more likely to achieve in the target area, and will display higher levels of self-efficacy than students who do not set goals (Bandura & Schunk, 1981)[10]. Other studies have revealed that experts display significantly higher levels of self-regulatory processes during practice efforts than novices (Cleary & Zimmerman, 2000).[11] Experts plan learning efforts using powerful strategies and self-observe their effects, such as a visual organizer for filling in key information (Zimmerman & Risemberg, 1997). They self-evaluate their performance against their personal goals rather than other learners' performance, and they make strategy (or method) attributions instead of ability attributions. This leads to greater personal satisfaction with their learning progress and further efforts to improve their performance. Together these self-reactions enhance various self-motivational beliefs of experts, such as self-efficacy, outcome expectations, learning goal orientation, and intrinsic interest.[12]

Research shows that self-regulatory processes are teachable and can lead to increases in students' motivation and achievement (Schunk & Zimmerman, 1998).[13]

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[8] Bandura, A. (1997). Self-efficacy: The exercise of control. New York: W.H. Freeman.

[9] Barry J. Zimmerman, Becoming a Self-Regulated Learner: An Overview, THEORY INTO PRACTICE, Volume 41, Number 2, Spring 2002 Copyright © 2002 College of Education, The Ohio State University

[10] Bandura, A., & Schunk, D.H. (1981). Cultivating competence, self-efficacy, and intrinsic interest through proximal self-motivation. Journal of Personality and Social Psychology, 41, p.586-598.

[11] Barry J. Zimmerman, Becoming a Self-Regulated Learner: An Overview, THEORY INTO PRACTICE, Volume 41, Number 2, Spring 2002 Copyright © 2002 College of Education, The Ohio State University

[12] Ibid

[13] Ibid

If, generally speaking, we view expertise as a desirable goal for others, or ourselves, irrespective of what field or endeavor that may be in, how do we begin to attain it? Research is clearly showing that self-regulation leading to expertise is derived, in large part, from self-efficacy. What we now have is the understanding to necessitate the beginning of teaching these principles of self-efficacy early in a child's life in order to affect their disposition to learning, not from a performance standpoint, but toward mastery of fields or domains. This, of course, does not preclude teaching to these attributes later in life either, but they are more effective when children's minds are more prone to accept them. Equally, parental attitudes in the early stages of child development in this sphere are essential to laying a strong foundation for self-actualization. Teachers and schools are then in an integrated framework as the guardians and promulgators of those beliefs.

We need to inculcate a sense of an inter-relational context into teacher education where we equalize the necessity to teach subject matter (cognitive domain), with the affective domain proscription for learner centric achievement and mastery.

Three primary conclusions for engineering course and curriculum design were derived from a 2010 research study conducted by Vanasupa, Stolk and Harding.[14] In it they stated, "…1) the complex interrelationships among different aspects of human development cannot be ignored. Students' thoughts, feelings, and behaviors are all influenced by their past experiences and ecological factors such as the learning goals and constraints, the peer and instructor interactions in the classroom, and the learning climate. Therefore, self-determination and self-regulation theory suggest that holistically addressing these experiences in the classroom can leverage students' total development as learners. 2) students' perceptions of autonomy, relevance, and value in the learning environment are required for both intrinsic motivation and lifelong learning skill building. While there are many factors at play, meeting students' needs in these areas can fuel the their development of several critical constructs and ultimately their learning achievement. 3) by gaining a more complete understanding of how students perceive their course experiences, faculty can design learning environments that provide for choice, and adopt instructional practices that support student control, leading to the stronger growth of the *will* and *skill* for learning throughout one's professional life.

Once again, these research-based insights were derived from college age students (bachelor's degrees and above) where their self-efficacy and self-regulation constructs had already been well formulated. But, the results clearly demonstrate that the factors leading to adaptive expertise need to be included not only in

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[14] International Journal of Engineering Education, Vol. 26, No. 4, pp. 914-929, 2010 printed in England, "Application of Self-Determination and Self-Regulation Theories to Course Design: Planting the Seeds for Adaptive Expertise" - Linda Vanasupa1 Jonathan Stolk [2]and Trevor Harding [1] 1) *Material's Engineering Department, California Polytechnic State University. San Luis Obispo. CA 2) Olin College of Engineering. Needham, MA*

courses, but the curriculum holistically. Moreover, that the factors of self-efficacy and self-regulation need to become inherent in all curricula from the earliest grades.

Adaptation is paramount to the survival of any species. Adaptive expertise is a requisite trait to survival, both for life's pursuit and one's chosen domain, in the Information Age.
