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Developing creativity, motivation, and self-actualization with learning systems

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Abstract

Developing learning experiences that facilitate self-actualization and creativity is among the most important goals of our society in preparation for the future. To facilitate deep understanding of a new concept, to facilitate learning, learners must have the opportunity to develop multiple and flexible perspectives. The process of becoming an expert involves failure, as well as the ability to understand failure and the motivation to move onward. Meta-cognitive awareness and personal strategies can play a role in developing an individual's ability to persevere through failure, and combat other diluting influences. Awareness and reflective technologies can be instrumental in developing a meta-cognitive ability to make conscious and unconscious decisions about engagement that will ultimately enhance learning, expertise, creativity, and self-actualization. This paper will review diverse perspectives from psychology, engineering, education, and computer science to present opportunities to enhance creativity, motivation, and self-actualization in learning systems.
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Education has the dual power to cultivate and to stifle creativity. Recognition of its complex tasks in this domain is one of the most fruitful intellectual achievements of modern psychopedagogical research.

Edgar Faure (Learning to Be, Unesco, Paris 1972)

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1. Introduction

This paper starts off with a discussion of the synergies between the arguments of several leading experts on creativity, education and educational technology, and psychology with respect to creativity, motivation, and self-actualization. After establishing this basis, it extends a discussion of the role of personal ownership, imagination, and analogy in the development of "multiple points of view," an ability widely regarded as essential to learning and becoming expert. Hybrid human–computer systems and the concept of Meta-Creativity are then discussed, highlighting the opportunities they present to develop complementary psychological, cognitive, and computational strategies, enhancing both human and computer capabilities, particularly in creative and self-actualized pursuits. The next section addresses motivation and failure and how computers can be employed by designers, educators, and learners to welcome difficulty, failure, and challenge to develop experience and expertise. The paper then closes with a series of recent psychological findings, both positive and negative, on the topics of motivation, affect, optimal experience, creativity, procrastination, and interruption. These are seen as instrumental to the realization of learning systems that strive to foster self-actualization.

2. Self-actualization, learning and creativity: a synergistic cycle

Self-actualization, "the desire to become more and more what one is, to become everything that one is capable of becoming" (Goble, 1970), as stated in Abraham Maslow's theory of basic needs, is fundamentally equivalent to the goals for education, learning environments, and creativity, espoused by notable educators and psychologists: Teresa Amabile, Mihaly Csikszentmihalyi, Edgar Faure, Alan Kay, Seymour Papert, and Paul Torrance. These goals emphasize learning in relation to creativity, incubation, play, imagination, analogy, flexibility, optimal experience, joy, well-being, and adequate challenge. There is agreement not only that learning and creativity are essential to self-actualization, but also that self-awareness, intrinsic motivation, and self-actualization are fundamental to learning and creativity as well: there is a synergistic cycle. In the following paragraphs I will summarize relevant contributions of each of the aforementioned individuals.

Amabile has created a social psychology and computational model of creativity. Her structure includes three components within the individual: intrinsic motivation, domain-relevant knowledge, and creative skills, alongside a fourth environmental component encompassing the external setting, extrinsic motivation and rewards, social interactions, and time pressure. Although the definition of creativity is frequently debated there is some consensus that it deals with a "process" which results in a "novel" and "useful product," in the most general sense of these words. Amabile argues that, while a person is engaged in activity, the greater the individual's intrinsic motivation; facility with and access to domain-relevant knowledge; and creative skills; and the more the environment is supportive through resources, information, actualizing rewards, volunteering, freedom, and

opportunities, the more likely a product will be creative. Amabile's latest work has focused on achievement and its impact on affect, finding that personal achievement and setbacks are the greatest factors in predicting positive and negative experiences in the workplace (Amabile, 1983; Amabile and Mueller, 2002; Amabile, Hadley and Kramer, 2002; Amabile and Kramer, 2003).

Csikszentmihalyi has developed the psychology of optimal experience known as *flow*. He has also developed the systems perspective on creativity that emphasizes the environmental component of Amabile's model. Csikszentmihalyi's systems perspective asserts that creative work takes place in the context of established resources and disciplines, and the process of creative achievement is largely mediated by the social process of negotiation of the product's value with the disciplinary gatekeepers of the field. *Flow*—optimal experience—at least within the domain of learning and problem solving, maps onto Amabile's components of the individual (intrinsic motivation, domain-relevant knowledge, and creative skills) and elucidates them. *Flow* has the contributing elements of: matched challenges to skills, a merging of action and awareness, clear goals and feedback, intense concentration and absorption, feeling of control, a loss of self-consciousness, and a contortion of time. Csikszentmihalyi has studied how learning and creativity are facilitated by *flow* (Csikszentmihalyi, 1990, 1996).

Faure emphasizes discovery, experimentation, imagination, and creativity, and states that the tasks of education are to preserve individual originality, creativity, and ingenuity while preparing the individual for a place in real life. Faure sees this as an opportunity for the transmission of culture but warns against overwhelming learners with ready-made models. He argues for a more appropriate encouragement of individual gifts, aptitudes and personal forms of expression; at the same time, he believes that egotism should be forestalled by cultivating an outlook that celebrates individuals' specific traits within the context of collective creative activity. In response to Faure's presentation of these proposals, in his *Learning To Be: The World of Education Today and Tomorrow*, Rene Maheu, the Director-General of Unesco, agreed, emphasizing that education should be a lifelong process and one that is not only widely available but in fact a part of every individual's life. He went further to say that its aim should be both the improvement and realization of society and the individuals' potentialities (Faure et al., 1972).

Kay's motto, "The best way to predict the future is to invent it," is fulfilled in his technologies such as Dynabook, SmallTalk, and Squeak that facilitate learning. He believes that globally networked computers that are natural and easy-to-use will improve learning, but will only have this effect if the educational environment encourages participants to actively question the 'facts' and strive for new challenges. It is through these challenges and "knowledge ownership" that the "deep joy brought by learning itself" and the "new ways of thinking, that can enormously expand understanding" will be experienced (Kay, 1991).

Papert is the founder of Constructionism both as a theory of learning and a strategy for education. Constructionism is an approach to teaching and learning that emphasizes active knowledge construction (vs. passive knowledge) through experience, particularly through creating and experimenting. Papert studies the

way children develop and change intellectual structures and why some things can be learned without formal instruction, a process known as Piagetian learning, and other things cannot be learned, despite formal instruction. Papert believes that when children use their own intuition and use known concepts to extend their understanding of new experience, they learn best. He sees computers as particularly suited to the facilitation of this type of learning precisely because the computer assets can be matched and molded to the children's needs. He sees this occurring through relationships that are developed between the learner and the computer. These relationships can enhance people's sense of themselves as learners and their self-worth (Solomon, 1986). Papert's vision is one of self-actualization, enabling learners to become more and more what they are, understanding what they desire to become, and achieving everything they are capable of becoming (Goble, 1970).

Torrance, widely known as the ''Father of Creativity'' for his research over sixty years, developed the ''Torrance Tests of Creative Thinking.'' This test enabled him to dispute the use of IQ tests as a sole indicator of real intelligence; he showed that creativity levels can be scaled and personal creativity increased through practice. He advocated self-actualization at an early age as a preventative measure for the futility experienced by so many adults, ''It is my belief that every person should realize he can do some sort of original work that has some merit. If this realization were cultivated in childhood, we would not have so many adults with a sense of futility about doing something original'' (Torrance, 1965; Childs, 2003).

Amabile, Csikszentmihalyi, Faure, Kay, Papert, and Torrance champion the synergies of self-actualization, learning, and creativity and expand upon the elements each believes are most critical to attaining these goals. Amabile champions intrinsic motivation and achievement; Csikszentmihalyi, optimal experience and conducive environments; and Faure, discovery, experimentation, imagination, and increasing exposure to cultural influences. Kay invents learning technologies from the perspective that learning can generate deep joy and ownership of one's education and knowledge; Papert sees new relationships between technological entities and learners enhancing self-awareness and self-worth as well as yielding insights to Constructionist theories fundamental to sustained interest, ability, and adaptable cognitive structures; and Torrance believes in cultivating early experience and belief in personal creativity as a means for lifelong self-actualization. While there exists a synergistic cycle among self-actualization, learning, and creativity, the fact that we do not achieve excellence on a broad level in our current educational systems indicates that there are significant challenges to entering and sustaining this cycle. Some of these challenges and opportunities are discussed in the following sections.

3. Multiple points of view and imagination as learning strategies

When children ask their own questions and have the opportunity to seek out answers in many places in diverse ways, in a process of developing and exchanging different perspectives and constructing new findings to augment existing under-standings, Kay believes they have optimal learning experiences (Kay, 1991). This

belief is also espoused and to some extent operationalized by Ben Shneiderman in his essay, "Creating Creativity: User Interfaces for Supporting Innovation," and in his recent book, *Leonardo's Laptop*, in which he calls for technologies that facilitate users' abilities to: *collect* information easily from digital libraries and visualize data and processes; *relate* it to other information and consult with peers and mentors; *create* new information through free associating, exploring, composing, reviewing and replaying; and *disseminate* results broadly and easily (Shneiderman, 1999). Shneiderman and Kay's perspectives provide practical long-term guidance for developing learning systems and they are essential to facing the rapid changes taking place in the structure of society.

In an effort to prepare learners to be "healthy skeptics from an early age," Kay discusses the need for self-motivated flexible learning strategies. Kay describes Kevin Bruner's notions of developing multiple understandings of the world through doing, seeing, and manipulating symbols as fundamental to the efforts that "each of us [undertakes] to construct our own version of reality by main force, literally to make our-selves" (Kay, 1991). It is this self-directed "concept of knowledge ownership" and "personal franchise in the culture's knowledge base" that develops the self-actualized learner. Kay sees this process as the layering of cognitive bricks, which he calls "new technologies for thinking." Through these new technologies, these new understandings, individuals are able to explore more and more of the world. At the same time Kay acknowledges that the rate of change itself has rapidly increased, noting that much of what was learned by one generation may no longer apply to the next. Generations must therefore be capable of quickly adopting new paradigms (Kay, 1991). He underlines the difficulty of this task, noting that the philosopher of science Thomas Kuhn describes the institutional adoption of new paradigms as a 25-year process. While this 25-year timeframe may itself be changing, it is part of the process that Csikszentmihalyi describes as the function of the gatekeepers in his systems perspective on creativity (Csikszentmihalyi, 1996).

In considering the role of gatekeepers, it is productive not only to consider the institutional gatekeepers but also the gatekeepers within the individual. To some extent the existing cognitive bricks become gatekeepers. They are the individually amassed paradigms used to develop understanding and learning. Yet, at the same time, they are too often the rigidly held paradigms and perspectives that confound deep understanding and flexible thinking, and thwart development of new cognitive bricks. Papert is interested in the child's mind and the processes of shifting and evolving internal theories of the world, and why at times children fail to learn despite formal instruction. Researchers on learning have pursued these issues utilizing Papert's Constructionist theories to develop evolving experimental and perceptive learning environments. Papert himself developed the Logo programming language for this purpose. More recently, Eliot Soloway and others in the University of Michigan's Highly Interactive Research Group have developed ScienceWare, which includes components for data gathering, data visualizing, modeling, project planning for students, publishing, and project planning for teachers. In doing so they have implemented many of the strategies called for by Kay and Shneiderman. This software supports the learner's ability to build initial qualitative models and to

evolve them toward quantitative models as expertise is developed. The research group has formulated a rationale for learner-centered design that incorporates scaffolding to develop optimal challenges that promote sustained inquiry. They attribute this achievement in part to the role of the dynamic modeler of complex systems that expands a students access to new realms of science which were previously unavailable. This element of their software is an example of a "new technology for thinking"; it provides a new way of student understanding and learning, fosters the ownership of discovery and experimentation, and moves students toward self-actualization (Soloway).

James Adams in his books, *Conceptual Blockbusting* and *The Care and Feeding of Ideas*, tackles creative thinking strategies and aspects of meta-cognition, thinking about thinking. He discusses diverse methods by which individuals can increase the fluency and flexibility of idea generation and strategies for the development of personal paradigm shifts and changes (Adams, 1987; Adams, 1990). These books present some, now classic, problem-solving challenges such as the nine dots, the monk on the mountain, and the ping-pong-ball in a hole and discuss strategies for developing solutions including mental imagery, collaborative improvisation, great mentors, and many others, some of which are also presented in *Synectics* (Gordon, 1961) and *Lateral Thinking* (De Bono, 1990).

Significant research has been undertaken supporting many of the ideas discussed by Adams, Gordon, and DeBono (Sternberg, 1999). One particularly salient one is Kevin Dunbar's chapter on "How Scientists Really Reason" in *The Nature of Insight*, discussing the use of analogy finding in scientific laboratories. He discovered that analogies are most often used when experiments have failed. In these circumstances the application of analogies referencing previous experiments greatly reduces the time to develop a new solution. Analogies also significantly help develop greater understanding, especially in new members of a research group. Research groups that are heterogeneous, having different pools of knowledge to draw upon, make more fruitful analogies. And experts, capable of seeing the deep structural features of a domain, readily and frequently make productive analogies that in turn help them solve problems faster (Dunbar, 1995).

It is refreshing that Einstein, one of our deepest thinkers, believed that "Imagination is more important than knowledge." Einstein's own revelations of relativity were acquired in an imaginative exploration, riding a sunbeam. This is the case with many great scientific discoveries such as Kekule's discovery of the benzene-ring:

> I turned my chair to the fire and dozed. Again the atoms were gamboling before my eyes…. [My mental eye] could distinguish larger structures, of manifold conformation; long rows, sometimes more closely fitted together; all twining and twisting in snakelike motion. But look! What was that? One of the snakes had seized hold of its own tail, and the form whirled mockingly before my eyes. As if by a flash of lightning I awoke (Boden, 1994).

Edison, too, was known to cultivate dozing, sitting in punctuated equilibrium—balanced, leaning back in his chair with ball bearings in one hand above a cast iron

pan on the floor, awaiting their gravitational fate. With pen and paper in the other hand Edison was ready to record emergent ideas from his nether-land of consciousness. This elaborate effort was essentially an attempt to dream up or access possible worlds for invention and insight. The philosopher David Lewis believed in "possible worlds" and the notion that if you conceive of a world then it comes into existence (Lewis, 1973). This is an empowering notion. One can only imagine (or try to visit if one is ambitious) the worlds that were created when *Spy Magazine* asked several Nobel Laureates, "Where do butterflies go when it rains?" and Roald Hoffmann, winner of the 1981 Nobel Prize in chemistry replied: "Oh, they sit under big leaves, of course…. We know that under all kinds of leaves in the forests and trees and moss, especially under mushrooms, there is a lot of life that we don't normally acknowledge. Trolls, elves, things like that. And I'm sure the butterflies know that, too." In the same spirit and with a belief in the power of self-reflection to transform lives, Harvard psychology professor Brian Little enlists the projection of "possible selves" as a methodology for researching personal pursuits, self-efficacy, and well-being. Little uses "idio-tapes," a process of vocalized self-exploration in which participants share their mental images of the most important scenes of their past, present, and future, as accessed through an idiosyncratic, imaginary "videotape" (Little, 2004). Likewise, one of Jeffery Wildfogle's lessons in the Stanford course on Psychology for Peak Performance includes a "*retrospective* role-play conversation" reminiscing the *next* five years. Participants are encouraged to explain through improvisation their greatest accomplishments, the details contributing to how these accomplishments were attained, the ramifications, and the feelings experienced. This process is repeated with different conversational partners, allowing diverse "possible selves" to emerge. Participants can try futures on for size in new and different ways until they develop a strategy that fits at an internal level of personal well-being. "Marvin Minsky of MIT likes to say, you do not understand anything until you understand it in more than one way" (Kay, 1991).

Taking the preceding perspectives as a whole, imagination emerges as a productive activity facilitating learning, problem solving, and self-actualization. Adams, Gordon, and DeBono have developed strategies for developing imagination, meta-cognition and creative thinking skills. Many of these thinking strategies are productive in stimulating paradigm shifts. Soloway developed a learning application that facilitates productive paradigm shifts, strives for optimal challenge for sustained inquiry, and instantiates much of Shneiderman's agenda. Tools of this nature help develop knowledge ownership and self-efficacy. Kay sees the cognitive structures that such tools facilitate as cognitive bricks, "new technologies for thinking," that facilitate new ways of understanding. Dunbar presents a powerful and rapid way of developing new understanding through analogies. Analogies are powerful because they involve the process of flexible thinking about underlying mechanisms, structures, and relationships. Achieving new understanding in multiple ways is instrumental to developing expertise. Imagination, multiple understandings, and meta-cognition appear to be fundamental instruments of optimal learning.

4. Technology and meta-creativity: the potential of proactive systems

The relevance of the use of technology for creative problem solving and invention can only be adequately understood within the broader contextual areas of the diverse fields which contribute to research on creativity: psychology, sociology, neurology, cognitive science, and artificial intelligence. Bruce Buchanan's AAAI-2000 Presidential Address lays out a vision for "meta-creativity" as an approach to develop programs that *accumulate* past experiences and information, *reflect* on them, and *transfer* this information throughout the system, as a means for enhancing creative collaboration between machine and user (Buchanan, 2000). Especially in light of Kay, Soloway, and Shneiderman's educational efforts, Buchanan's approach has great potential for learning systems.

This process of using a superstructure for creative endeavors relies on strategies of meta-cognition. Meta-cognition is the process of thinking about thinking, understanding what is known and not known. It involves: connecting new information to former knowledge; deliberately selecting and monitoring thinking strategies; and evaluating these processes (Blakey and Spence, 1990). When asked if a computer can be creative, Minsky answered, "I plan to answer 'no' by showing that there is no such thing as 'creativity.' "His argument is that creativity is no different from other forms of thought and can therefore be achieved by computers. He believes that the processes that the most creative people engage in are achieved by two approaches, the manner in which they learn more and deeper skills, and the manner in which they learn to manage these skills. He speculates that behind their expertise they may often have developed advanced administrative skills that provide a better framework for utilizing and structuring their skills. It is due to this combination of this conscious or subconscious meta-cognitive manager, Minsky hypothesizes, that creative people are better learners, because they have better ways of choosing how and what to learn. He believes this in itself explains creativity. He goes so far as to say that even "if only once a child became involved (even unconsciously) in how to learn better, then that could lead to exponential learning growth" (Minsky, 1985).

The combination of humans and computers as a hybrid team, focused on a creative task, holds great promise. Herbert Simon, in his effort to understand the mechanism of human thought, studied games from the perspective of artificial intelligence and psychology. When IBM's Deep Blue beat Garry Kasparov, the reigning world chess champion, in 1997, "Simon was both pleased and disappointed. He was pleased that his famous 1957 prediction—that a computer program would beat the world champion within 10 years—was vindicated; as he was quick to point out, 30 years rather than 10 years represents a rather small error factor. He was also disappointed, however, that an approach based essentially upon brute force, rather than heuristic search, did the job" (Gobet, 2001). The recent finding that algorithms can at times be more creative than humans may have intrigued Simon. Jacob Goldenberg's, "Creative Sparks," research published in *Science* shows that a simple computerized routine, one that can easily be algorithmically implemented by humans, produces solutions consensually judged to be more creative than those achieved by human groups (Goldenberg et al., 1999). While this raises many

questions on the nature of creativity and human's perception of it, and on the current state of the relevant skills of computers and humans, the finding bolsters arguments for hybrid computer–human systems contributing to learning, creativity, and self-actualization. The computer and its algorithm were available to the human groups in Goldenberg's experiment, but they chose to ignore it. This leads to the obvious question of how to improve the human computer interaction and self-assessment of creativity to realize enhanced hybrid collaboration. Perhaps Garry Kasparov's call for the creation of a new contest, the hybrid computer–human chess championships, will spur research in this direction.

Being aware of one's own strengths and weaknesses is critical to accomplishment. Simon was insatiably curious. He entitled one of his talks at Carnegie Mellon Univeristy "The Cat Curiosity Couldn't Kill." He found as much pleasure in the search as in the solution (Gobet, 2001). Fostering this sense of intrinsic motivation, for the process rather than the solution, coupled with the ability to persist through doubt and failure along the way is what must be achieved in order to make significant strides toward enhancing learning. In this tremendous task, researchers and educators can again turn to Simon for some hope in the cumulative effect of his "concept of error." This concept explains how slight differences in the quality of moves, in two-person games, accumulate over the course of a game to lead to dramatically different outcomes (winning vs. loosing) (Gobet, 2001). This concept of error echoes Minsky's statement of the potential for exponential learning growth. At this stage in the development of learning systems, we may only need to achieve slight positive effects for the cumulative strategy to be profound.

5. Motivation and failure

Let us return for a moment to Papert's theories on Constructionism, his study of the way children develop and change their own intellectual structures, and his interest in why some things can be learned without formal instruction [Piagetian learning] while other things are not learned, despite formal instruction. When things are not learned there is often failure. Papert sees continual advancement of learning through repeated failures and successes in the debugging process. For Papert, debugging goes beyond a simple corrective technique and becomes a fundamental idea within Constructionism. Debugging is a process of construction, testing, and modifying (Papert, 1980). With similar vigor, the Constructionist agenda is taken to heart and championed by David Kelly, founder of IDEO, the late Rolf Faste, Director of the Stanford Product Design Program, and James Adams, at Stanford University in their course ME101:Visual and Ambidextrous Thinking. In this course, a philosophy similar to Papert's debugging philosophy is known as ETC – Express ideas, Test them, and Cycle between Express and Test iteratively. Through the iterative process of debugging or ETC, Constructionist methods strive for self-actualization. At Stanford there is also a saying that "spectacular failure is better than moderate success" (Faste, 1996). This is not an overtly masochistic agenda; rather, the message is that if you do not strive for spectacular success you will never

achieve it; if you achieve moderate success you have not strived far enough. Kay's version of this sentiment is that "difficulty should be sought out, as a spur to delving more deeply into an interesting area. An education system that tries to make everything easy and pleasurable will prevent much important learning from happening" (Kay, 1991). In Csikszentmihalyi's framework of creativity and optimal experience, this would be the notion of matching challenge with skill in service of *Flow*.

Through simulated Learning By Doing environments, it is possible to accelerate the pace of learning through exposure to difficult circumstances that may arise less frequently than in real world situations. This will inevitably accelerate the rate of failure and, if motivation is sustained, the rate of learning as well (Schank and Neaman, 2001). In their chapter on "Motivation and Failure in Educational Systems Design," Roger Schank and Adam Neaman, of the Institute for Learning Sciences at Northwestern University, use Michael Jordan's experience as an example to present the role of failure in becoming an expert:

> Failure is critical to learning. Experts are thus people who have failed many times. There is a wonderful Michael Jordan commercial for Nike. He is on screen shooting baskets and talking about all of his failures: I've missed more than 9000 shots in my career. I've lost more than 300 games. Twenty-six times I've been trusted to take the game-winning shot—and missed. I've failed over and over and over again in my life… And that is why I succeed (Schank and Neaman, 2001).

They acknowledge that fear of failure is a significant barrier to learning. They believe this can be addressed in several ways: minimizing discouragement by lessening humiliation; developing the understanding that consequences of failure will be minimal; and providing motivation that outweighs or distracts from the unpleasant aspects of failure. Schank and Neaman show they have been able to sustain the motivation of learners, who care about what they are doing, by providing them access to experts at the time of failure. Through questions, stories, anecdotes and additional experiences, learners are given the opportunity to "expend the effort to explain their failures." Learners are given the opportunity to achieve and become expert (Schank and Neaman, 2001).

Amabile's most recent research has focused on extreme positive and negative days in the workplace. Her findings are that personal achievement and setbacks are the single greatest factors in predicting positive and negative experiences (Amabile and Kramer, 2003). Personal accomplishments are the greatest predictors of best days and setbacks the greatest predictors of worst days. For many, a great proportion of all days are confounded by the technologies we work with, limiting our achievements. As part of his call for "Creating Creativity" (Collect, Relate, Create, and Donate), Schniederman has recently embarked upon a major assessment of the frustrations and costs associated with the predominant computer applications. His findings are appalling; an average of some 50% of time is wasted in standard computer use (Shneiderman, 1999; Light, 2002). Interuptions in the work environment also have a serious negative impact on productivity, creativity, and individual expertise. O'Conaill and Frohlich's research shows 41% of the time that

interruptions occurred in the workplace, individuals did not resume the work they were doing prior to the interruption (O'Conaill and Frohlich, 1995). Adequately addressing these social and human–computer interaction issues would go a long way toward enhancing achievement. Preliminary results from Amabile's workplace study found that self-efficacy is a strong correlate to achievement and that extreme affective experience (the top 5% of best days and bottom 5% of worst days) in teams is more likely when success and disaster are shared experiences. It is important to realize that the staying power of negative affect tends to outweigh the more transient experience of "positive affect." This is a phenomenon known as *negative asymmetry* (Giuseppe and Brass, 2004). Unfortunately for the purposes of motivating learners, this negative asymmetry means that negative affect experienced from failure will persist disproportionately to the "positive affect" experienced from success. Applying this research, educators and innovators will now have a better understaning of how to create motivating learning environments that celebrate achievement and provide sustaining inquiry opportunities at times of failure.

These experiences and findings describe some of the mechanisms that underlie the cycle of motivation, failure, and achievement. I want to emphasize an important element of Papert's explanation of self-empowered learning, the power of integrating technology with achievement to enhance the learning process. He believes that in the process of learning to program, a child's process of learning is transformed. The child becomes active and self-directed in her acquisition of knowledge and recognition of personal purpose. As soon as this experience enters a child's mind, her new knowledge is seen as a source of power and self-actualization (Papert, 1980).

6. Diluting influences and enhancers to learning: opportunities for meta-cognition

I will now discuss several psychological findings that present opportunities for the development of technologically enhanced meta-cognition. Beyond the direct effects of frustration on motivation and learning, there are other diluting influences such as time pressure and procrastination. Just as there are these lurking diluters, there are other circumstances and behaviors that enhance motivation and learning, such as creating analogies, volunteering, and experiencing "positive affect." While there are obviously numerous findings that could be discussed, this handful of examples has been selected for their direct relationship to creativity, achievement, and promotion of perseverance through failure, as well as their beneficial impacts on intrinsic motivation and well-being.

Amabile has shown that high time pressure has doubly negative impacts on creativity: first, it decreases people's creativity by 45%, and secondly, it deludes people into thinking they are more creative. The effect of this perception is a detrimental feedback loop encouraging high time pressure resulting in diminished creativity. Through intelligent-agent recognition of situation (time pressure, interruptions, procrastination, and calm leisure time) it may be possible to promote meta-cognitive strategies for creative pursuits. A system could help people shift their paradigm to correctly understand the implications and perhaps reverse the

detrimental misperception that time pressure is beneficial to creative pursuits. Such a system could strive to promote actions to help people protect their creative time, space, and collaborations. A proactive system could assist users in aligning their activities with their goals and to perceive these goals as objectives of a salient mission. With this mission-oriented outlook under extreme time pressure, Amabile has found individuals to achieve some of their highest levels of creativity (Amabile et al., 2002).

In a discussion of self-control and procrastination, Dan Ariely shows that people are willing to impose deadlines upon themselves in attempts to enhance performance. Often people have difficulty with self-control. Fortunately, people tend to recognize their own inability in this respect; unfortunately, they are not good at dealing with it. They often impose costly internal deadlines when compared to some forms of beneficial externally imposed deadlines (Ariely and Wertenbroch, 2002). In his study he asked students to set their own deadlines for handing in assignments, but told them that once they did so they would be held to them and penalized for missing them. The least costly approach would be for all deadlines to be on the last day of the class. Ariely's subjects realized that if they chose this option they would not have the self-control to meet it so they chose more costly deadlines spaced across the semester. There is an opportunity to develop intelligent-agents that can begin to understand the appropriate types of externally imposed deadlines. These intelligent-agents can assist in the realization of computing environments where individuals are buffered from the anguish of procrastination.

As noted earlier, analogies can play an important role in overcoming failure and moving on toward achievement. In scientific laboratories, Dunbar found that the most common and effective use of analogies occurred when experiments failed. In these cases analogies were used to relate the failure to the experience and knowledge amassed from other experiment (Dunbar, 1995). Perhaps the best-known serendipitous example of this is Archimedes's struggle with the purity of the king's crown. As he entered his bath he noticed the water rise. ''Eureka!'' Instantly he came up with the analogy that the crown could replace his body, realizing that the resulting change in the water level would be equivalent to the volume of the crown. Casting these findings of the impact of analogy on problem solving as a meta-cognitive strategy, we might cultivate eureka moments of discovery, promoting the slogan, ''When failure is achieved, celebrate and devise analogies!'' Buffering against negative affect, and proposing analogies or the search for analogies at the opportune moments could be constructive to perseverance, the development of multiple viewpoints, and deeper understanding. Kay sees the development of these juxtapositions as a primary goal of learning environments. He believes well conceived learning environments should be contentious and even disturbing, by focusing on contrasts and inconsistencies instead of absolutes. He argues for quality over quantity and the importance of will power and effort in the educational process (Kay, 1991).

Exploring further this notion of the importance of will and effort, there have been several studies of the effects of volunteering on well-being, creativity, and its interaction with affect and motivation. ''Volunteerism is more likely to enhance

individual well-being and be sustained over time if it (1) offers meaningful pursuit of personal goals, is coherent with the other commitments in one's daily life, and (2) is appropriately supported by organizational resources"(Little and Phillips, 2003). Amabile has shown volunteering to promote creativity, not surprisingly, by facilitating intrinsic motivation (Amabile and Mueller, 2002). Under certain conditions, when people volunteer for a task they will work much harder for free than if they are told after volunteering they will be paid a pittance for the work they do. This effect is known as the "Hidden Cost of Reward" (Lepper and Greene, 1978). Alice Isen has shown that people are more helpful, more willing to volunteer, after experiencing a mild "positive affect" inducement (such as a candy or comic); but the inducement must not be seen as payment. If technologies provide learners with the opportunities to volunteer, to apply their skills in supported meaningful ways, it is likely to enhance their well-being, intrinsic motivation, and creativity as well.

Isen has found that "positive affect" can have dramatic beneficial effects on the approach taken toward learning and problem solving. In numerous psychological experiments and investigations of neuropsychological models of cognition she has found overwhelming evidence that mild "positive affect" improves negotiation processes and outcomes; promotes generosity and social responsibility; leads to self-efficacy; increases motivation toward accomplishment; and facilitates openness and flexible manipulation of new information. She notes that it is only when a task is neither interesting nor important that people experiencing mild "positive affect" do not perform better than the control groups. It is remarkable and exciting that the earlier widely held view that "positive affect" "leads to oversimplification or superficial cognitive processing" has been refuted. Isen stops short of saying that "positive affect" causes creativity, noting that there may be a strong mutual correlate. Her research focus is on understanding the neuropsychological link between "positive affect" and creativity. She concludes with the statement that "'positive affect' is a source of human strength… promoting thinking that is not only efficient, but also careful, open-minded and thorough" (Isen, 2002). Learning technologies could monitor affect and consider "positive affect" inducement, particularly at times of great challenge. These systems could also facilitate the awareness of the benefits of "positive affect" as a meta-cognitive strategy that could persist in the learner beyond the interaction with the technology.

At times computer-aided instruction has been seen alternately as either a panacea or an oppressive implementation. Some suggest that the computer is programming the learner while others hold the vision that the learner, in programming and interacting with the computer, develops a personal mastery over a modern and powerful technology that puts her in intimate contact with some of the deepest ideas of modern science, mathematics, art, and intellectual model building (Papert, 1980). Through the synergistic relationship with the computer, the individual reaches an enhanced level of self-actualization.

Through a greater understanding of relevant psychological mechanisms, it will become possible to tailor technologies to facilitate the learning, creativity, and self-actualization goals of society. Already these findings have discussed—the

misperception of the erosive effect of time pressure on creativity, the benefits of external deadlines for mitigating procrastination, analogies as a strategy of working through failure, volunteering as a generous and invigorating activity, and "positive affect" as a human strength for optimal thinking—make it evident that there are tremendous opportunities to apply these findings toward the development of learning technologies that foster creativity, motivation and self-actualization.

7. Conclusion

This paper has discussed opportunities for reflective technologies to assist both in providing external structures and strategies, and in developing users' internal meta-cognitive strategies to sustain and facilitate learning, creativity, and self-actualization. The opportunity exists today to use our understanding of human psychology and abilities in artificial intelligence to create a synergistic hybrid human–computer learning system. Notable educators and psychologists agree that learning is enhanced when it is pursued as a creative and self-actualizing passion. Imagination, meta-cognitive awareness, and the development of multiple perspectives are fundamental to deep understanding. Because failure, over and over and over again, is a prerequisite to becoming an expert, so too are the abilities to persevere through failure.

Society, today and in the future, must produce the diverse skills, resources, and intellectual strategies to face its challenges, or fail. Connecting individuals, peers, and social groups as part of their own feedback loops with diverse technologies, at times more perceptive than they themselves, holds great potential for learning, personal growth, motivation, creativity, and life enhancement. If technologies play a role influencing individuals' behaviors or modifying environmental circumstances, a person who has identified desired behavior changes, in terms of commitments and results, stands to benefit substantially from synergistic interaction with these technologies. Together, they may realize self-actualization in the process.

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