

Thought Question: Could we develop pedagogical processes that teach people to develop and fully use their innovative thinking traits?

Research Article: *Thoughts on improving innovation: What are the characteristics of innovation and how do we cultivate them?*

Subject Area: Innovation

Authors: Poirier, V., Schwartz, H., Eddy, D., Berman, R., Chacour, S., Wynne J., Cavanaugh, W., Martin, D., Byrne, R., & Sanberg, P.,

Date: 2017

Abstract

Innovation is the “introduction of something new and different that is brought into our society”. This paper explores how education could help people develop habits of mind associated with innovation as well as better use their innate innovative traits. The authors investigated the innovation process, characteristics of innovative people, and the influence of innovative environments on creative thinking. Their stated goal is to determine an effective educational process to improve innovative thinking as well as to develop measures that assess the effectiveness of that educational process.

Enjoy the article! **And remember...**an educational process may be able to improve the ability of individuals to fully use their innovative traits.

Keywords: Innovation; creativity; entrepreneurship; motivation; abstract thinking

THOUGHTS ON IMPROVING INNOVATION: WHAT ARE THE CHARACTERISTICS OF INNOVATION AND HOW DO WE CULTIVATE THEM?

Victor Poirier¹, Lyle H. Schwartz¹, David Eddy¹, Richard Berman^{1,2}, Selim Chacour¹,
James J. Wynne^{1,3}, William Cavanaugh¹, Dean F. Martin^{1,4}, Robert Byrne^{1,5}, and Paul R. Sanberg^{1,6}

¹Institute for Advanced Discovery & Innovation, USF Research & Innovation, Tampa, FL, USA

²College of Global Sustainability, University of South Florida, Tampa, FL, USA

³IBM Research Headquarters, Yorktown Heights, NY, USA

⁴Department of Chemistry, University of South Florida, Tampa, FL, USA

⁵College of Marine Science, University of South Florida, St. Petersburg, FL, USA

⁶Morsani College of Medicine, University of South Florida, Tampa, FL, USA

This paper will review current thinking about innovation and identify key innovative traits as initial steps in exploring the feasibility of teaching innovative thinking. While education may not be able to create innovative traits in individuals, education may improve the ability of individuals to utilize the traits they already possess. Therefore, we begin by defining innovation and identifying the characteristics, traits, and thought processes of innovative individuals or groups of individuals and the environments that they exist in using the existing literature and personal experience. This information will help formulate a process to educate individuals to better utilize their innovative traits. If we can envision a curve depicting the utilization of traits, where on the left of the curve we would place individuals with a low utilization, on the right of the curve would be individuals with a very high utilization rate, and in the middle a distribution between the two extremes, our goal would be to develop an educational process whereby we could show individuals how to fully utilize the traits they have, awaken traits that are dormant, and, in so doing, shift the distribution toward fuller utilization. With greater utilization of innovative traits, we could then expect to increase the number of innovations that individuals or groups of individuals contribute to our society.

Key words: Innovation; Creativity; Entrepreneurship; Abstract thinking; Motivation

INTRODUCTION

While the innovative process is critical, relatively little is known about how we can cultivate innovative thinking. Given the centrality of innovation to current educational and business efforts, this is a crucial gap to fill. This paper starts with what we do know about innovation, exploring the current views on innovation, articulating the innovation process,

and identifying the characteristics associated with innovative individuals. Although it is unlikely that education can create an innovative trait in an individual, education may very well be able to improve the ability of individuals to utilize the innovative traits they possess. Therefore, we place particular emphasis on the characteristics, traits, and thought processes of innovative individuals or groups of individuals and

Accepted November 30, 2016.

Address correspondence to Victor Poirier, USF Research & Innovation, University of South Florida, 3702 Spectrum Blvd., Suite 165, Tampa, FL 33612-9445

the environments in which they exist. These characteristics, gathered from the existing literature as well as from personal experience, can then be used as the foundation for an educational process to educate individuals to better utilize the innovative traits that they possess and to awaken those that are dormant. With improved utilization, individuals could improve their innovative thinking and increase the quality and number of innovations they create.

What Is Innovation?

Innovation has many different definitions, but, in its most simplistic form, “it is the introduction of something new and different that is brought into our society” (1), specifically “something different that has impact” (2). Innovation, which is created from inspiration and creativity, is not limited to the areas of science or engineering but can be viewed as a universal concept. For instance, an individual studying the arts should be exposed to the concepts of innovation. We should instill in this nascent artist the desire and drive to innovate, to create something beyond what exists, and to develop new art, thus providing the roadmap to excel in his or her domain. Innovative thinking is critical to everyday lives, regardless of individual interests and passions, because it provides societal value (3). In addition to occurring in a variety of domains, innovation may and often does occur at the interface of different disciplines and requires collaboration among individuals from different backgrounds and experiences.

While innovation is critical to improvements in how we live, how we benefit from the changes that occur, and how we can enjoy life more fully, innovation is not all positive. The literature is replete with what we might call negative innovation (4,5). The technological unemployment that is created from a technological advancement or innovation, as extensively covered by MIT’s David Autor (6), is one clear example. Oftentimes, it is more complex still, encompassing both sides of the dichotomy.

Innovation can come into being as a new idea, creative process, or, as is in most cases, the evolutionary improvements on existing products, processes, or concepts (2). It improves an object, device, or concept, or creates a novel process that could be used to solve a problem. A particular innovation can be one

or all of these things. Positive innovation is viewed as an ongoing improvement of an existing product or an extension of an existing understanding. It is not limited to the development of a new and novel single product. It can be a process of adding bits and pieces to an existing product or process, an addition that improves what was there in the first place (7).

Innovation is the extension of understanding to reach new technical options and arenas. Innovation includes the strategies and technical supporting structures as well as standards and norms that allow applications, certitude of impact, and entrepreneurship. Positive innovation must provide societal value and have impact in the present or near future; it must be better than what exists, and an innovation cannot be trivial (3). The process of innovation, which we will discuss next, requires seeing what others don’t see or can’t see.

THE PROCESS OF INNOVATION

The elements of the process to move an inspiration to public acceptance can be described as follows: Inspiration—Creativity—Motivation—Entrepreneurship—Innovation. We have arrived at this process by analyzing the definition of innovation as stated in the prior paragraph and breaking it down into logical components. The beginning of the process is usually associated with a fragmented inspiration that, in time, is further developed by joining with other fragmented thoughts to finally arrive at a complete creative inspiration. At this point, the motivated entrepreneur must bring the developed creative thought forward to determine if it has societal acceptance, is better than what exists, and has value and impacts society in the near term as well as in the long term. However, this process is not always orderly, as the motivation to accomplish something great can take precedence over inspiration in initiating the innovation process.

In the innovation process, an inspiration or a creative thought cannot stand on its own. Inspiration is subordinated to innovation, as innovation requires significant societal value and can stand the test of time. The innovation must prove that it is novel and genuinely new and is valued sufficiently to allow the process of entrepreneurship to begin to add it to the culture of our society. Innovation is rarely created by one individual who has an inspiration;

it often requires multiple individuals who provide novel incremental insights, adding bits and pieces to improve the original idea (3). Each individual involved must possess the skill and the will in order to sustain the processes of innovation and maximize the likelihood of success. Alternately, inspiration can be evoked spontaneously or appear after a period of time in response to an unsolved problem or condition.

Inspiration can be characterized as the process of being mentally stimulated to do something creative. According to Thrash and Elliot, inspiration involves being inspired by something and acting on that inspiration, and it has three main motivational qualities: evocation, transcendence, and approach motivation (8). In regards to evocation, Kaufman, building on Thrash and Elliot, posits that “inspiration is *evoked* spontaneously and without intention by something—whether it’s an idea that comes from within, an inspiring person such as a role model, or a divine revelation” (9). He also noted that inspiration requires transcendence, or the ability to rise above mundane and often-selfish concerns, in order to achieve “a moment of clarity and awareness of new possibilities” (9). Finally, “inspiration involves *approach motivation*, in which the individual strives to transmit, express, or actualize a new idea or vision” (9).

In addition to being more open to new experiences and more absorbed and engaged in their tasks, inspired people are more intrinsically motivated and less extrinsically motivated (9). They are often driven by the inner satisfaction of doing good, accomplishing something to benefit society (10). This type of motivated inspiration is a critical energizing force behind successful innovation. In contrast, extrinsically motivated individuals are often driven by their egos to receive public praise and to benefit themselves (10). Intrinsic motivation, then, is one of the most important keys to success and is present whenever there is a clear vision, realizable goals, and a strong belief in one’s ability (11).

Since motivation emanates from within the individual, it is important to bolster that inner power by immersing oneself in an environment with similarly motivated individuals, as motivation and positive attitude are contagious (11). Motivation can also be strengthened in individuals through the process of education (11). Goal setting is an important aspect

to successful motivation provided that goals are set at a manageable level. By dividing major goals into smaller goals, it is easier to motivate oneself when it appears that the goal is more feasible and attainable. Persistence is a trait that improves motivation, as it forces individuals to finish what they have started. Finally, individuals need to train themselves to read about subjects in which they have an interest to maintain their enthusiasm and ambition as they set and accomplish goals (11).

Contrary to the view that inspiration is purely mystical or divine, inspiration is best viewed as an interaction between one’s current knowledge and the information one receives from the world, which can increase the likelihood of experiencing inspiration. For example, individuals who prepare for an inspirational experience by having a positive attitude, an open mind, and an approach-oriented attitude will be more likely to experience and be mindful of inspiration (9).

Finally, innovation requires public acceptance, which can be and often is achieved through the process of entrepreneurship. The entrepreneur is an individual who is willing to take risks to achieve a goal, to take an innovation to the public. They are pioneers, leaders, inventors, and business professionals who are motivated and driven to make an innovation successful.

Characteristics of Innovation

Noted author Steven Johnson listed six key characteristics of innovation (7) that resonate with the authors’ experiences. The first is the importance of timing, which is crucial in the process of translating inspiration to innovation. The history of cultural progress, including technological and scientific advances, is a story of one door leading to another door, as we explore one room at a time. Unfortunately, breakout ideas that are 50 years ahead of their time almost always end up being short-term failures because they are ahead of their time. The idea was right, but the environment was not ready to receive and support it.

Johnson’s second point addresses the key question: Where do good ideas come from? Ideas are not created as a single event; they are more like a swarm. Ideas are akin to a specific constellation of

thousands of neurons, firing in sync for the first time in the brain, resulting in the creation of an idea that pops into consciousness. He proposes that a new idea is a network of cells exploring the adjacent possible connections that they can make in the mind. What matters in the mind is not just the number of neurons but the myriad connections that have formed among them. The question here is how can a person push their brain to those more creative networks?

Johnson also points out that to make the mind more innovative, it needs to be placed inside environments that share that same network signature: networks of ideas or people that mimic the neural network of a mind exploring the boundaries. Although ideas occur inside minds, these minds are connected to external networks that shape the flow of information and inspiration out of which great ideas are fashioned. Just as we have neural networks in our heads that push us to new levels of innovative thinking, we have social networks that help us to push the current boundaries of innovative thinking. What is clear is that great ideas and improvements can occur when individuals with varying backgrounds discuss their thoughts and ideas freely, allowing them to formulate different ways of looking at a complex problem and establishing connections to the boundaries of other technologies and other environments.

Johnson goes on to discuss a third characteristic of innovation: Ideas or inspirations rarely produce immediate innovative thoughts and require time to develop. These ideas and inspirations lack key components, which may be supplied by other individuals. The idea or inspiration requires that it be immersed in a network or environment conducive to developing innovative thoughts. Partial ideas can connect with other ideas to establish a complete thought. Timing is key, as ideas need to be stored in the subconscious until connections are made to fill in the gaps. To think of something that other individuals have not thought of or make a connection not made by others requires patience and insight. Incubation in either network (neural or social) is necessary to overcome the initial limitations of innovative thinking. How do individuals continually remain open to multiple perspectives and persist beyond the obvious initial answers or assumptions? It's a combination of timing, patience, and persistence.

The fourth feature he describes involves idea generation. Thoughts, ideas, hunches, or inspirations that occur in the brain may be generated by the random firing of neurons via small synaptic gaps. These random firings can connect to adjacent sites and can form more complete ideas and thought processes. These new ideas and thought processes can then further combine with other partial thoughts after being immersed in a network of others whose brains have been shaped by different disciplines. Partial thoughts can then cross boundaries to other compatible thoughts to fill missing gaps in key ideas, leading to innovation.

Inspirations obtained from dreams have solved many significant problems, as pointed out by Johnson. The authors also attest to personal experience of this phenomenon. Robert Thatcher, a neuroscientist from the University of South Florida, suggests the counter-intuitive notion that the more disorganized your brain is, the smarter you are (12). But how does one get a particular set of clusters of neurons to fire at the right time? Johnson points out that history has shown that one must separate oneself from everyday interactions. One way is to go for a long walk in solitude and let the brain freely open up the subconscious; another is to experience the power of vacation, immersed in an environment that allows one to think freely, unencumbered by everyday activities.

Clearly, there is significant benefit to allowing the free cross-fertilization of ideas and inspirations. Ryan, Deci, and Edward pointed out in their Self-Determination Theory that people can be motivated because they value an activity or because there is strong external coercion and challenges. No single phenomenon reflects the positive potential of human nature as much as intrinsic motivation, the inherent tendency to seek out novelty and challenges. They suggest that social environments can facilitate or forestall intrinsic motivation by supporting versus thwarting people's innate psychological needs (13). Unfortunately, this concept has risks, as new ideas and concepts can be stolen by competitors. Johnson suggests that what is needed is an organizational program that allows cross-fertilization to permit partial thoughts, hunches, etc. to disperse and recombine—a continuous brainstorming session that is active throughout the day and yet is protected from outside sources.

Johnson's fifth point was that of error or the series of missteps in the development of an innovative process. Error is an important aspect, as it forces you to explore the "why" and the "how," to get out of one's comfort zone and look for alternative paths. Psychology professor Charlan Nemeth conducted research that led her to suggest a paradoxical truth about innovation: "Good ideas are more likely to emerge from environments that contain a certain amount of noise and error" (14). We should not forget that error is what made humans possible in the first place. She pointed out that, without noise or error, evolution would stagnate, an endless series of perfect copies that are incapable of change. Indeed, it is possible to say that human progress is simply a huge chain of innovations, i.e., making things better, going back all the way to the basics, such as fire, farming, and animal husbandry.

Johnson's sixth and final point was that of exaptation, or the development of an idea or tool in one field that can be adapted to flourish in another. For example, he points out that a match you lit to illuminate a dark room turns out to have a completely different use when you now open a doorway and discover a room with a pile of logs and a fireplace in it. A tool that helps you see in one context ends up helping you keep warm in another. That's the essence of exaptation. The importance of this concept is that creativity can flourish when collisions occur from different fields sharing the same space. Employees who primarily shared information with people in their own divisions were less productive from an innovation point of view compared to employees who maintained active links to a more diverse group. Johnson also pointed out the importance of facilitating the environment where people can be exposed to a variety of new ideas and encouraged to piece them together in new ways. This can greatly assist the likelihood of innovation. An iconic example would be Johannes Gutenberg, who took bits and pieces from different fields and merged them together to form an innovative device that changed society: the Gutenberg printing press. He did not conceive an entirely new technology; he took the technology of moveable type, ink, and paper from the Chinese and the press itself from wine makers, modifying and improving this borrowed technology and creating a new innovation to solve an unrelated problem.

THE CHARACTERISTICS OF INNOVATIVE INDIVIDUALS

Now that we have reviewed what innovation is, how the innovative process works, and the key characteristics of innovation, we turn to the individual. If we are to understand what innovation is and how it can be improved, we must look at the characteristics that innovative minds possess and how these can be developed and enriched. That is, we must consider how we can "nudge" individuals to use and improve their innovative powers (15).

It is not clear that we can create an innovative mind in an individual who does not possess at least some basic characteristics of innovation. It is not our intention, therefore, to try to create it; rather, it is our intention to try to improve what already exists. Can we—by removing blinders, by waking up dormant characteristics, by eliminating the fear of failure and other barriers, and by exposing individuals to the power of innovation—expand the number of individuals in our society who fully utilize these characteristics and contribute to the innovative process? If, for example, individuals can be taught to view failure as a learning tool to improve, that would facilitate looking at alternative avenues to accomplish the desired outcome. Failure would then be just one more barrier to reflect upon and to learn from, just one segment of the innovative process.

When we think about the entire adult population in the United States, we can assume a broad variation of experience in cultural background and educational level as well as significant differences in environmental exposure. In this large adult population, we can expect to observe that some people do not have the ability to inspire or innovate while others do. If we evaluate this group of individuals to determine their innovative ability, we would expect a large variation, which would lead us to create a fictitious curve to illustrate a distribution of individuals that utilize innovative traits. Individuals with a low utilization, indicated by a low level of innovative thinking, would be on the left of the curve, while individuals with a high utilization rate would be on the right. The vertical axis would simply indicate the total number of individuals in each segment. The shape of the curve between the two extremes is of little importance at this point, as we do not intend to radically change

the shape of the curve but are simply trying to move individuals that are on the left of the curve to the middle or the right of the curve, shifting the existing curve to the right. By utilizing an educational process, can we shift the curve to the right? Can we educate individuals to more fully utilize the traits they do possess and to awaken those that are dormant? If so, with improved utilization, individuals could enhance their innovative thinking and increase the number of innovations they contribute to society.

The first step in this process would be to identify the characteristics, traits, and thought processes innovative individuals possess that set them apart. What distinguishes these individuals from others? How do these individuals interact in groups to cross-fertilize concepts and thoughts, to add bits and pieces to partial ideas in order to create the complete innovation? Common themes and characteristics have been identified in creative individuals by several authors, including Harvard professor Howard Gardner in his book *Creating Minds* (16). He pointed out that the creative individuals he has studied—Sigmund Freud, Albert Einstein, Pablo Picasso, Igor Stravinsky, T.S. Eliot, Martha Graham, and Mahatma Gandhi—came from locales removed from centers of excellence. The creative minds of his subjects emerged at different times, depending on the domains in which they resided, and took an average of ten years before they reached dominance in their domains. At that point in their lives, these “creators” (as he deems them) tended to migrate towards centers of excellence where they could associate with peers of similar backgrounds to take advantage of cross-fertilization.

Gardner’s creators also recognized the importance of bringing their accomplishments to others and of rebelling against control. They had sufficient strength and skill to allow differences of opinion as well as differences from past thinking. During their lifetimes, the creators experienced periods of comfort that quickly changed to periods of severe isolation, especially during a period of a major discovery. During these times of isolation, creators needed special relationships with one or more supportive individuals.

In addition to this general profile, there are 14 characteristics that innovative individuals often possess; it is our position that these characteristics can be fostered and developed through innovative education.

Cognitive factors

Abstract Thinking and Problem Solving

One of the key characteristics that many (but not all) innovative individuals possess is the ability to think abstractly. This involves seeing patterns beyond the obvious and using patterns or a variety of ideas or clues to solve larger problems. In contrast, concrete reasoning involves looking at things on the surface and using this information to solve problems in their most literal sense (17). Concrete thinkers reason in terms of facts, events, and specific examples, whereas abstract thinkers move away from these specific things and reason in terms of generalizations, ideas, and deeper meanings.

If abstract thinking can lead to improvements in innovative thoughts, we should be able to use educational techniques to improve the process of abstract thinking in individuals who rarely use these innate traits. By increasing the utilization of abstract thinking in individuals, we can increase the driving force to improvements in innovation and the innovative thinking process. As abstract thinkers can think “outside of the box,” this thinking process will be very beneficial in problem solving by asking pointed questions that no one else has, questions that can lead to solutions (18).

This ability to question is key because, when we try to innovate, we need to establish what we want to accomplish; that is, we need to clearly identify the problem that we wish to solve or the condition that we wish to improve. The abstract thinker has the ability to dissect a problem to establish the underlying condition producing the symptoms of the problem. Identifying the underlying condition is of paramount importance to solving the problem and requires that the proper questions be asked—often others don’t ask or can’t ask questions that can only be developed through the process of abstract thinking, where the abstract thinker can play a significant role.

In addition to abstract thinking skills, innovators often have superior problem-solving skills. For example, being able to break down a problem into multiple, smaller, actionable problems is beneficial to the innovator in several ways. Smaller problems that are practical and have solutions that can be executed aids considerably in the task of solving the overall problem. Concentrating on smaller problems and

solving one problem at a time also increases confidence and can present a clearer view of the overall problem.

Incubation is another key problem-solving strategy of innovators. They are often awake and quietly lying in bed, thinking about a problem while searching for a solution, when, all of a sudden, a solution appears in a clear and precise manner, a subconscious solution that may have been forming for some time travels to the conscious level. Among the authors, several keep pencil and paper by the bed to take notes before the solutions disappear.

Knowledge: Depth and Breadth

The concept of knowledge is a complex one, as both depth and breadth are connected to innovation (16). Innovation often comes more easily to individuals who are very knowledgeable in their chosen fields, those with a deep understanding of the basic principles of one or more disciplines. However, innovators can also be characterized by a breadth of knowledge, and those individuals can often work well outside their original fields of study. These individuals are often innovation leaders who create change by surrounding themselves with competent experts who can provide depth of expertise in a given area.

The Desire to Fill Gaps

Innovative individuals seem always to be searching for information to fill gaps in the development of innovative thoughts, continuously looking for and saving bits and pieces of seemingly random information to see if, when joined with other bits and pieces, they can complete prior, partially developed thoughts (7).

Motivational factors

Motivation: Extrinsic vs. Intrinsic

Motivation could be described as a combination of internal and external factors that stimulate desire and energy in people to be continually interested and committed to a job, role, or effort to attain a goal (11). It is the driving force to get things done. Research has shown that innovative individuals are more intrinsically motivated since they are driven by the inner satisfaction of doing something good for society or the desire to solve a difficult problem (13).

Bringing innovation to our society is facilitated by motivated individuals. If individuals understand the differences between extrinsic and intrinsic rewards and are encouraged to act on their inner desires, innovation should follow.

Extrinsic and intrinsic motivation do not have a dichotomous relationship; rather, they exist on a continuum. According to Ryan and Deci, there are multiple types of motivations, such as external, introjected, internalized, and identified, depending on how their basic needs are satisfied relative to competence, autonomy, and relatedness (13). Understanding different types of motivation is key to promoting innovative efforts.

Additionally, no matter the source of the motivation, individuals can improve motivation by employing various strategies. For example, individuals who break down goals into smaller tasks may experience more frequent accomplishments, which can boost inspiration, setting off a productive and creative cycle.

Creativity

Being creative is fundamental to invention, innovation, and entrepreneurship. Creativity is the ability to think about the world in new ways, to think from a clear, open perspective, and to be unencumbered by existing knowledge. Howard Gardner described various characteristics of creative individuals. He noted that creative individuals tend to spend a large amount of time thinking about what it was that they wanted to accomplish; tend to leverage whatever strengths they have and not worry about what they don't do well, as they can always get help from others; and are ambitious even though they don't always succeed. In fact, when creative people fail, they use that failure as a learning experience and build on failure to get better and better (16). He also defined a creative individual as someone who solves problems, fashions products, and/or defines new questions that might be initially novel but, ultimately, are accepted in a setting. Beyond the individual, Gardner argues that creativity is an interactive process in which three elements participate: individual talent, field, and domain/discipline (16).

Individuals can and do demonstrate innate creativity and imagination even at very young ages. This can

be seen by observing pre-school children who develop imaginary friends. These individuals create in their minds a complete life-like friend with whom they can play, eat, interact, and talk. They use their innate traits of creativity and imagination to create a world that they are comfortable with. Children who create these companions have very strong imaginations and very high levels of creativity, both of which they can further develop as they enter adulthood (19).

Curiosity

Innovators recognize that desirable discoveries sometimes happen by accident and understand the role that good fortune and luck can play in the innovation process (3). They have an intense curiosity to see how machines work, how objects are created, how concepts are created, and why processes are what they are. The “how” is usually the driving force rather than the “what.” People who are curious take advantage of spontaneous moments, which helps the innovator overcome the fear of asking a “bad” question. They are motivated to ask: “How did this happen?” Serendipitous moments are important in developing innovation because they force the innovator to pay attention to what the data are telling them and train them to refrain from reading into it something that it is not. Innovators keep an open mind and look at the possible benefits that could emerge from an observed accident and, often, can’t help wondering what would happen in the event that a slight modification to the basic premise took place.

Risk Taking: No Fear of Failure

While innovators are not necessarily risk takers in the same way as entrepreneurs, they do take risks. Innovators approach their endeavors as challenges, with failure serving as an opportunity for learning. This reduces the focus on risk and the perception of risk. Being wrong, on its own, doesn’t unlock new doors, but it does force the innovator to look for them (7).

Positive Attitude

A positive attitude is key for innovators, as their outlook on life allows them to be receptive to new possibilities and opportunities. In addition, because innovators often go against the status quo, there may

be naysayers who insist that a proposed innovation may be unnecessary or impossible. In the face of opposition, innovators maintain a positive attitude, knowing that their ideas have merit even when others don’t agree. Their positivity not only keeps them moving forward but frequently serves to motivate the entire innovation team.

Grit: Persistence and Passion

Grit, that combination of persistence and passion identified by Angela Duckworth (20), is a key characteristic among innovators. The discipline to complete what they have started is often a mark of an innovative individual. Persistence is of the utmost importance, as the innovator must not give up or be devastated by failure. Choosing what not to follow or being convinced to stop a particular task, project, or strategy is also important. When at a crossroads, the authors have found that clear and concise analysis to re-establish new directions should be undertaken, with sufficient flexibility to look at alternative paths to achieve the goal. Innovative individuals generally possess intense passion (10), compelling desire, and enthusiasm to make a change or to create something new. It is a strong driving force. These individuals believe strongly in examining existing structures, concepts, or knowledge to improve what already exists. Their passion drives a desire for excellence. Successful innovators are able to finish a project, seeing it through from ideation to completion. They don’t allow distractions to derail them, and they don’t bring a project to completion prematurely.

Dissatisfaction

Innovators are dissatisfied with what exists and are always looking at what can be improved (3). For example, an individual interested in architecture cannot prevent himself from looking at floor plans for new construction to see if they are correct or lacking in some aspect. For future use, they analyze and store, in their memories or in their notes, information on what they consider good and bad. They are constantly looking at everything in sight, analyzing what they see and mentally looking at what can be improved, asking themselves why things have been done in a certain manner and how they might have been done differently.

It Takes a Village

Open-mindedness

Innovators are receptive to new information and ideas. They are also skeptical of preconceived ideas, preferring to maintain an open mind and consider limitless possibilities. This ability often gives them an advantage because they can solve problems using lateral thinking to come up with innovative ways to tackle an issue instead of getting bogged down in circular vertical thinking.

Cross-Fertilization

The ability to bring a new skill set to a field can yield a different perspective on a situation (21). People with a broad knowledge in diverse areas working in association can solve complex problems where individuals cannot. Although being well versed in one or more disciplines is helpful, it is not a necessary requirement.

Beyond the individual, organizations can play a major role in moving innovations forward and bringing them to fruition by fostering environments that encourage people to take risks. Working with other motivated individuals in environments that are motivating provides the ideal situation to optimize cross-fertilization of ideas and concepts, resulting in outcomes far superior to what would be realized from one individual's thought process (16).

Salesmanship: Art of Communication

Salesmanship is defined here as the ability to transfer information in a concise and convincing manner with the goal of achieving acceptance of the transferred message. Innovators need to possess the ability to present their ideas and concepts in a clear and precise fashion. To manifest their innovations, they may require financial backing and must be able to convince potential investors to support their vision. They also need to attract individuals to form a team that can assist in the development of the innovation. The same skills in salesmanship may be needed to convince their peers in the scientific community.

Vision and Timing

An innovator can benefit from being a visionary (10). The ability to look into the future to determine what avenues to follow and what to undertake can

lead to clear thinking and help determine how one can improve what exists today. Innovators must possess the courage to step into the darkness, to learn, and to understand. Because of their vision, innovators have an excellent sense of timing, seeming to understand exactly when the environment is ripe for innovation. They are always scanning the horizon, watching for shifts and trends that signal opportunities for intervention and change.

The utilization of all of these innovative traits varies in importance, depending on the domain in which the innovator is immersed. Innovators can also have any combination of these traits, but some of the traits and characteristics may be thought of as being more conducive to innovation than others. The innovator who utilizes abstract thinking, is very motivated, understands the importance of cross-fertilization, is inspired and persistent in trying to achieve goals, is very curious and creative, tends to be dissatisfied with the present situation, and is usually well educated in at least one discipline will likely have the more successful path.

CHARACTERISTICS OF INNOVATIVE ENVIRONMENTS

Innovative new ideas, as well as incremental new advances, are achieved by groups and by individuals (10). These individuals or groups can be influenced by the environments in which they exist, and they, in turn, can influence their environments. We speak often of Thomas Edison as a great inventor but infrequently of Menlo Park and the variety of minds and skills that were brought together to achieve the actual innovative process. Perhaps in this current era, in which so much innovation comes from the university community, we forget the influence that Edison had in establishing the Naval Research Laboratory and how that lab and the National Bureau of Standards set the stage for research and development during World War II, facilitating not only the Manhattan Project, but also countless innovative new products that influenced how war was fought, as well as how the injured were treated. Some industries, such as Bell Labs and US Steel, had already learned the lessons of Menlo Park before the war, but dozens followed in the post-war years, giving life and substance to the great industries we recognize as Xerox, 3M,

IBM, Apple, Google, and so many others. Similarly, those lessons had impacts on the federal government and led to the great laboratory systems of Department of Energy, Department of Defense, National Institutes of Health, and National Aeronautics and Space Administration, as well as many lesser-sized government laboratories in other departments and agencies.

Bement, Dutta, and Patil, in addition to noting the importance of the organization, observed that physical spaces for free open and informal discussions can lead to improvements in innovation (3). Facility ergonomics are important to maximize the cross-pollination of the inventive capacity of an organization: offices, labs, common sharing areas, large gathering areas for open technical reviews, and poster sessions (3).

Johnson also indicated that physical spaces work hand in hand with organizational inspiration to build information networks that allow hunches to persist, disperse, and recombine, creating an environment where brainstorming is something that is constantly running in the background throughout the organization (7).

In order to maximize the ability to collaborate effectively and foster improvement in innovation, Bement et al. identify four key aspects. The first is proximity, which ensures that multi-disciplinary people are close to each other. The second is independence, as individuals need to be independent if they are to collaborate. The third is open areas for freeform discussions and experimentations. And the fourth is privacy, for most innovative thinking happens during private downtime (3).

Within the great laboratories and collaborative innovation environments, there are many common themes, but there are also many differing tactics to create an environment rich with opportunity for innovation. Group effort requires both inspiration and management. Institutions, such as the ones mentioned above, identify strategic areas of corporate (or governmental) interest; bring the elements, people, facilities, and work environment together; search for and encourage areas of potential opportunity; organize paths to progress; and exploit innovations when revealed. In order to make this process successful, companies and other entities must set the stage for success.

NEXT STEPS

Having considered the innovation process, the traits of innovative individuals, and the importance of innovative environments, we must now consider how to use this information to create an efficient and effective educational process to concretely improve innovation outcomes.

We believe that we do not need to try to create innovative characteristics; rather, we simply need to show individuals how to cultivate innovative thought by: 1) fully utilizing the traits they already possess, 2) awakening dormant traits, and 3) understanding the importance of contextual factors, or the innovation environment. In doing so, we would “shift the curve to the right,” allowing individuals to improve their innovative thinking and increase the quality and number of innovations they create.

Looking ahead to that task, we must consider what educators can do to help individuals identify and improve their innovative characteristics and how they can help those individuals collaborate successfully by providing an effective innovation environment. In order to take this next step, we will need to consider the following key questions:

- What are the most effective pedagogical methods to teach the habits of mind associated with creativity and innovation?
- What resources—human, material, and organizational—can be assembled to provide the best foundation for understanding innovative thinking?
- How can the development and execution of innovative thought be best assessed?
- In what situations do individual and collective innovations complement or conflict with each other? How can both types of innovation—individual and collective—be best supported?
- How can we create effective innovation environments for our student innovators?
- How do we address various levels of knowledge and ability regarding innovation among student populations?
- What pedagogical techniques and classroom policies can be employed to promote innovative thinking?
- What study design and instruments would be appropriate to implement and employ for the

collection and analysis of data on creative and innovative thinking?

In addition to a consideration of these crucial questions, we must also consider potential roadblocks or resistance. For instance, there may be resistance from students and faculty given that innovative thinking is often thought to be an inborn and unchangeable trait. Some students and faculty may also be resistant to the idea that innovation, which they may view as a spontaneous and unstructured outburst of creative thought, can be taught in an organized and purposeful way. Moreover, the nature of such a course would require a high level of student involvement and independence as well as the ability to confront failure and grapple with ill-defined problems, all of which may place some students well outside their comfort zones.

A careful consideration of these key questions and potential roadblocks will be crucial in moving forward—beyond the identification of innovative traits—to the development of an educational process with the appropriate metrics to assess its effectiveness. To that end, members of the Institute for Advanced Discovery & Innovation at the University of South Florida, including the authors, are part of an experimental training program in innovation and anticipate future publications to report on the results of these efforts.

ACKNOWLEDGMENTS

The authors would like to acknowledge the valuable support provided by Dr. Kimberly Macuare, Dr. Sarah Kiefer, and Dr. Michael Cross.

REFERENCES

1. Webster's college dictionary. New York (NY): Random House; 1991.
2. Anthony SD. The little black book of innovation: how it works, how to do it. Boston (MA): Harvard Business Review Press; 2012.
3. Bement A Jr, Dutta D, Patil L. Educate to innovate: factors that influence innovation: based on input from innovators and stakeholders. Washington (DC): National Academies Press; 2015 [accessed 2016 Sep 15]. http://www.nap.edu/catalog.php?recoed_id=21698.
4. Sveiby K, Gripenberg P, Segercrantz B, Eriksson A, Aminoff A. Unintended and undesirable consequences of innovation. XX ISPIIM The Future of Innovation; 2009 Jun 21-24; Vienna. <http://www.sveiby.com/articles/UnintendedconsequencesISPIIMfinal.pdf>.
5. Soete L. Is innovation always good? In: Fagerberg J, Martin BR, Anderson ES, editors. Innovation studies: evolution and future challenges. New York (NY): Oxford University Press; 2013. p. 134-144.
6. Autor D. Polanyi's paradox and the shape of employment growth. National Bureau of Economic Research; Sep 2014 [accessed 2016 Oct 15]; NBER Working Paper No. 20485. <http://www.nber.org/papers/w20485>.
7. Johnson S. Where good ideas come from: the natural history of innovation. New York (NY): Penguin Group; 2010.
8. Thrash TM, Elliot AJ. Inspiration as a psychological construct. *J Pers Soc Psychol.* 84(4):871-89; 2003.
9. Kaufman SB. Why inspiration matters. *Harvard Business Review* [2011 Nov 8; 2016 Oct 15]. <https://hbr.org/2011/11/why-inspiration-matters>.
10. Csikszentmihalyi M. Creativity: flow and the psychology of discovery and invention. New York (NY): Harper Perennial; 1996.
11. Sasson R. What is motivation and how to strengthen it. *SuccessConsciousness*. [accessed 2016 Oct 15]. http://www.successconsciousness.com/strengthen_motivation.htm.
12. Thatcher RW, North DM, Biver CJ. Intelligence and EEG phase reset: a two compartmental model of phase shift and lock. *Neuroimage.* 42:1639-1653; 2008.
13. Ryan RM, Deci EL. Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *Am Psychol.* 55(1):68-78; 2000.
14. Nemeth C. Dissent as divine cognition, attitudes, and judgement. *Soc Cogn.* 13(3):273- 91; 1995.
15. Halpern D. Inside the nudge unit. London (UK): Ebury Publishing; 2015.
16. Gardner H. Creating minds: an anatomy of creativity. New York (NY): Basic Books; 2011.
17. Moshman D. Cognitive development beyond

- childhood. *Educational Psychology Papers and publications*; 1998 [accessed 2016 Oct 15]; Paper 48. <http://digitalcommons.unl.edu/edpsychpapers/48/>.
18. Baskin JS. Northwestern's non-linear approach to innovation. *Forbes*. [2015 May 7; 2016 Oct 15]. <http://www.forbes.com/sites/jonathansalembaskin/2015/05/07/northwesterns-non-linear-approach-to-innovation>.
 19. Pearson BL, Russ SW, Cain Spannagel SA. Pretend play and positive psychology: natural companions. *J Pos Psychol*. 3(2):110-119; 2008.
 20. Duckworth A. *Grit: the power of passion and perseverance*. New York (NY): Scribner; 2016
 21. Smith K. *Innovation in public education: problems and opportunities*. New Schools Venture Fund. [2009 Aug 27; 2016 Oct 15]. <http://www.newschools.org/files/innovation-in-education.pdf>.