Learning for Seapower

Cognitive skills for the post-industrial era[1]

by Mie Augier & Maj Sean F.X. Barrett

"We must also create a supporting culture of lifelong learning, enabled by a value proposition for education that is clearly understood as absolutely essential for professional advancement. In short, naval education must be weaponized for the entire spectrum of conflict that our Nation will certainly face in the Cognitive Age."

—Education for Seapower [2]

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PME and learning to meet the demands of the cognitive/judgment era are essential to our warfighting capabilities and cultivating judgment in our future leaders. Among the important topics the *Education for Seapower* (E4S) study emphasizes is the recognition that we have moved beyond the industrial era and need to rethink how we can improve our PME institutions to emphasize the development of thinking and judgment. Gen David Berger's *Commandant's Planning Guidance* (CPG) also highlights this necessity:

> We must change the Training and Education Continuum from an industrial age model ... At present, our entire system for formal schools management reinforces the industrial age model and therefore needs to be changed.[3]

Lee Shulman, former president of the Carnegie Foundation for the Advancement of Teaching, writes that acquiring technical skills and expertise is far from enough for developing good judgment and integrity. Rather, we must seek a balance between the intellectual, the technical, and the moral.[4] This is essential to enabling warfighters to think, decide, and act with integrity and character. Furthermore, Shulman underscores an important theme of the post-industrial age environment: Leaders cannot simply be experts in one domain; rather, they must be capable of applying knowledge to new and potentially unforeseen situations. This requires a different approach to learning and education, and it is our hope that this article may help explicate some of the important aspects and dimensions of learning and education relevant to current and future times.

As we do so, it is important that we think through the implications for PME. In a previous article, "Leadership for Seapower", (*MCG*, Dec19), we focused on the differences in the themes of the different eras and the corresponding skills demanded of our future strategic leaders. E4S focuses primarily on the organizations, governance, and policy for naval education, making it important to outline some of the organizational, managerial, and learning dimensions and their implications for what it means to move "beyond the industrial era." In this article, we identify some of the relevant dimensions and foundations of how the changing strategic environment and shift in eras influence the roles of leaders, the skills they need, and how they need to be educated to develop and maintain an "intellectual preparedness" to meet these new demands.[5]

"I have noticed over the past several years that there is an increasing dissonance between what we are doing with regard to training and education, and what we need to be doing

based on the evolving operating environment. Specifically, many of our schools and training venues are firmly based on the 'lecture, memorize facts, regurgitate facts on command' model of industrial age training and education."

—CPG[6]

Some Trends and Discontinuities Relevant to Education and Learning for Seapower

Several major trends and changes in the post-industrial era have resulted in paradigmatic shifts or "discontinuities" in how we organize, how we manage and lead, the types of problems we encounter, and the skills that might be useful in such an environment.[7] Table 1 (on next page) notes some of the key themes differentiating the industrial and post-industrial eras. One major difference, as the CPG notes, concerns how we teach. The conventional industrial era approach to pedagogy is rooted in the belief of the simple transfer of knowledge: educators deliver content, and students receive it and eventually transfer it back to the educator (e.g., exams to be graded). While this is adequate to meet the demands of the industrial era, this form of pedagogy has very little to do with learning in any educational sense, for education involves far more than simply memorization. This has become particularly evident in the post-industrial era, where skills such as holistic problem-solving, imagination, initiative, and critical thinking are so important.[8] Over time, some (interrelated and overlapping) trends that have developed include the following:

- The shift toward increasingly ill-structured and wicked problems necessitates broad and holistic problem-solving skills, rather than functional/narrower skills.[9] Additionally, because of the pace of change, we need to educate people who are able to think through, frame, and solve problems that may not yet exist—and not just equip them with tools to solve specific, already-identified ones. Thus, agility in thinking and the ability to synthesize information from a wide range of sources are essential.
- The important dimensions of warfighter knowledge are no longer based on specific functional areas, physical work, or along institutional boundaries (e.g., the importance of jointness and collaboration with the interagency and industry). Instead, the most important dimensions of warfighter knowledge are cognitive skills and attitudes.
- An increasing emphasis on thinking, not just tools, is essential. Learning how to ask the right questions is more important than being able to regurgitate the right answer. Teaching and learning cognitive skills to build mental agility, broaden minds, and inculcate an appetite for lifelong learning requires a corresponding shift in how we educate.

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Given the importance of these changes, some basic, fundamental questions might be useful to explore, including:

- What skills and attitudes are most important in the cognitive/judgment era, and are we educating and organizing to instill them? How?
- What do we know about learning and thinking that can help us develop these skills?
- What does cognitive/judgment era learning look like in practice, and how can we incorporate and embed it into our PME institutions and curricula?
- How do we get there? For example, what do we currently teach, how do we teach it, and what kind of learning approaches might be useful?[10]

We do not even begin to provide a complete answer to these questions in this paper, but we hope to sketch out some relevant aspects.

"The lack of value that today's warfare tribes have placed on education in the recent past does not equate with the actual value of that education … The value of continuous education for the naval professional is, in the language of the 21st century, the development of critical thinking."

—E4S[11]

Some Cornerstones of Learning in the Post-Industrial Age: Developing Agile Minds for Lifelong Learning

As we become further removed from the industrial era, we must consider the (often interrelated) skills, attitudes, and cognitive abilities that are important for both intuitive and systemic decision making in the cognitive/judgment era and examine what we know about educating for them so that we might improve our warfighters in these areas. Undergirding this approach is the importance of a growth mindset. A growth mindset refers to the belief that intelligence is malleable and improvable—a belief that has positive effects on academic performance and motivation.[12] Students are motivated to exert more effort, which promotes "deep" learning and more transferrable knowledge, when they believe intelligence is changeable and not

Major Era/Paradigm	Industrial Era	Beyond Industrial Era
Central Themes	• Planning, efficiency, productivity • Capital and labor as scarce resources • Optimizing processes and production	• Problem solving skills, holistic understanding • Thinking, judgment, and attention as scarce resources • Decisive action under ambiguity and uncertainty
Characteristics of Larger Environment and Problems Confronted	• Well structured, familiar, repetitive • Stable and predictable environment	• Complicated, interactively complex, wicked, unknown • Changing/dynamic environment
Organizing to Create and Capture Advantages	• Hierarchy, routines, standardization derived from experience/past success • Authority • Extrinsic motivation • Processes become self-referential (creating more work for managers) • Measuring codifiable daily tasks	• Flexibility, teams, decentralized organizational structures • Adaptive and agile organizations; team of teams
Role of Managers/Leaders	• Control, measure, specify processes, analyze, quantify (in pursuit of known, static objectives) • Avoid negative outcomes	• Lead, motivate, "we-leadership" • Inspire imagination, initiative, and trust • Understand people, organizations, and the environment • Generate new possibilities
Skills and Attitudes Useful for Managers/ Leaders	• Analysis, specialists • Ability to use and apply tools to analytic problems • Apply knowledge based on experience to known problems • Fixed intelligence mindset enough	• Critical thinking, curiosity, intuition, integrity, imagination, holistic and multidisciplinary understanding and problem solving, civil awareness, active open-mindedness, general skills, insight, broad minds • Apply knowledge to new situations and different domains; cognitive flexibility • Proficient with tools but prepared to drop them • Growth mindset needed • Intellectual preparedness and ability for lifelong learning
Learning Types and Environments to Support Generation of Useful Skills	• Instructional learning; memorize and repeat • "Kind" or "fast" learning environments	• Transformational and active learning • Analogies • "Slow" learning useful • "Wicked" learning environment

Table 1. Trends relevant to how we educate and learn.

fixed and that their performance is attributable to effort rather than ability.[13] Neuroscience research even suggests that those with a growth mindset are more receptive to corrective feedback and are not afraid of making mistakes in the first instance.[14] While by no means an exhaustive list, we attempt to integrate literature from various fields, including cognitive science, organization studies, strategic management theory, education, and other areas to help understand some of the learning dimensions and foundations relevant to PME.

Critical thinking and thinking critically. Critical thinking has long been recognized as a topic important to PME institutions.[15] Key panels (e.g., the Skelton Panel on Military Education) and commissions have examined its place in PME in the past, spurring reorganizations to educate better thinkers. Individuals engaged at seemingly all levels of our military institutions and organizations are very aware of the importance of nurturing and leveraging thinking.[16] One of the most important and visible legacies of critical thinking in the history of PME institutions is Gen Alfred Gray's emphasis on critical thinking and judgment. In providing his commander's intent to the CG, Marine Corps Combat Development Com-

mand, concerning the development of a concept for PME, which was a key step in the general transformation of the Marine Corps toward embracing maneuver warfare, Gen Gray explained:

> My intent in PME is to teach military judgment rather than knowledge. Knowledge is, of course, important for developing judgment, but should be taught in the context of teaching military judgment not as material to be memorized. I want Marine NCOs and officers who know how to think about and in war, who know how to conceptualize an engagement, a battle, and a campaign and then execute the concept.[17]

As critical thinking (and thinking about critical thinking) has risen in prominence and importance, a lot of literature has emerged, but some are obviously more useful than others. In fact, LtGen Paul K. Van Riper offers explicit warnings about approaches to critical thinking that reduce it to following analytical procedures (e.g., systems analysis) that do not consider interactively complex systems holistically and instead attempt to break them down into component parts.[18] Gen Van Riper opts to employ the term "thinking critically" instead of "critical thinking" so that students do not confuse the need to ask pertinent questions and frame arguments with more limited analytical techniques. He posits that preparation, study, and broad experience are necessary, although not guarantees, to thinking critically.

Another useful way of cultivating critical thinking is to emphasize "deep" or "slow" learning and the ability to make connections and understand the forces shaping a situation. Exposure to new challenges and self-directed problem-solving enhances such cognitive flexibility.[19] Students must first be taught *how* to think, not *what* to think about. Introducing broad concepts that facilitate making abstract connections and encourage holistic problem-solving is more conducive to lasting learning than is information specific to a particular class or task.

The post-industrial era requires more flexible and agile capabilities and skills, as well as the ability to understand and frame problems. Knowledge can become a double-edged sword that makes us blind to new possibilities as we focus more narrowly on a specific area of expertise. Educating warfighters and leaders who are able to make decisions in situations they have never previously imagined, let alone encountered, requires cultivating broad interdisciplinary and holistic problem-solving skills, as well as the ability to think across domains and approaches. Relying on tools created to help us understand well-structured problems is no longer sufficient, most especially in the domain of war.[21] Furthermore, even as advances in technology have led some to view technology as a "silver bullet" solution to much broader problems and have increased enthusiasm for science, technology, engineering, and mathematics (STEM) education, we would be wise not to ignore the importance of problem-solving skills and critical thinking in STEM fields, too. The National Academies, for example, recently issued a report encouraging the adoption of more integrative approaches by including communication skills, problem-solving, teamwork skills, and ethical decision making with STEM in higher education.[22]

Holistic problem solving and the importance of generalist skills. "The challenges of the twenty first century require holistic approaches to the changing character of conflict."

—E4S[20]

Thus, in the context of PME and discussions of larger operational, strategic, and administrative problems, we must remain aware of such issues and try to mix people with different skills and backgrounds together to help facilitate understanding across disciplines and MOSs, which is conducive to better understanding such problems.[23] Additionally, research on cognitive flexibility (or, the ability to rapidly identify the type of problem at hand, match it with the appropriate type of cognitive processing, and apply knowledge to new situations and in different domains) notes that "experts" trade such flexibility for narrow skills that foster cognitive *inflexibility*.[24]

While training in rote fundamentals that facilitate muscle memory and quicken reaction time is imperative in a military context, simply teaching this crude form of execution, or being able to regurgitate knowledge, becomes a problem when it is the basis of training and education. The changing strategic environment and the growing need for us to be able to adapt—which usually involves combining many different types of knowledge and thinking about them differently—necessitate being able to understand and develop broad concepts. This can be facilitated by teaching metaheuristics, which enhance the transferability of knowledge and skills to new task situations.[25] Learning through analogies can also foster cognitive flexibility. Faced with a novel problem, decision makers must be able to think about a familiar type of problem they have seen in the past, reflect on the similarities (and differences), and translate and adapt the analogy to the novel situation.[26] Boyd identified the need to create "a higher and broader more general concept to represent reality" in order to diminish uncertainty and the related disorder.[27] Doing so requires finding "some common qualities, attributes, or operations to link isolated facts, perceptions, ideas, impressions, interactions, observations, etc. together

... preparation, study, and broad experience are necessary, although not guarantees, to thinking critically.

Knowledge does not keep better than fish. **(The Aims of Education and Other Essays, *Alfred North Whitehead.*)** ***(Photo by LCpl Karis Mattingly.)***

as possible concepts to represent the real world."[28] Developing these skills also helps cultivate *anticipatory skills* such as sensing the forces shaping situations.

Inspiring imagination to inform judgment. Renowned for his intellectual achievements and originality, Albert Einstein famously noted,

> Imagination is more important than knowledge. For knowledge is limited, whereas imagination embraces the entire world, stimulating progress, giving birth to evolution.[29]

As important as knowledge is, it is also mostly static. In order to be useful for post-industrial-era learning and problem-solving, knowledge needs imagination, insight, intuition, and improvisation to change, expand, and enrich our understanding of things.

Alfred North Whitehead similarly discussed the importance of imagination in the context of education and in generating ideas, freshness, and growth in knowledge, which he deemed essential for both the institutions of, and intellectual foundations for, learning. Knowledge itself, he said, "does not keep any better than fish."[30] Imagination—and the "atmosphere of excitement" that arises from it—transforms knowledge.[31] In fact, imagination is so central to education that without it, institutions of learning (i.e., universities) have little reason for existence: "A university is imaginative or it is nothing—at least nothing useful."[32] Imagination and passion for learning is central to the view of learning and education as a lifelong process (as opposed to a destination) and is essential for both learners and educators alike.[33]

Fostering a learning environment that cultivates and improves attitudes and skills such as imagination and curiosity to inform judgment is by no means an exact science, but we nevertheless discuss a few possibilities:

- Encourage active open-mindedness. The most useful interactions between teammates occur when they treat their own forecasts and ideas as hypotheses in need of testing and actively solicit feedback to prove them false rather than try to convince others that they are correct. This entails seeking new information and contrary opinions, even across disciplines, and actively updating beliefs.[34]
- Foster creativity. As domain expertise increases, so does "cognitive entrenchment," which undermines problem-solving and adaptation capabilities, as well as creative idea generation.[35] Entrenchment becomes more costly when greater flexibility is needed. Focusing attention outside of one's domain of expertise is one way to mitigate this problem.[36]
- Learn to disagree (even with yourself). An effective problem-solving culture maintains a balance between respecting standard practice and pushing in the opposite direction—so-called "ambidextrous thought." This entails identifying the dominant culture (e.g., individualism or conformity) and then pushing against it.[37] Similarly, encouraging learners to pose questions for others and even of themselves facilitates learning for transfer.[38]
- Practice problem (re)formulation, (re)conceptualization, and diagnosis. As Nobel laureate Herbert A. Simon notes, "Problem formulating is itself a problem solving task."[39] While how we frame, formulate, and conceptualize a problem is crucial for how we pursue its possible solutions, we often spend far too little time on the diagnosis. Presenting students with well-formulated problems and well-specified tools leaves little room for thinking. However, presenting elements of wicked/ill-structured problems can lead to problem reformulation and reconceptualization that can cultivate the ability to understand the forces shaping problems.

A learning environment that features active learning and cultivates imagination and curiosity is one that is conducive to the quest for lifelong learning and for developing and improving "intellectual preparedness." Attitude is ultimately the first mover for PME. Boyd explains,

> So much of it is attitude. If a guy has a real good attitude (wants to win), he doesn't necessarily have to be a real good pilot initially, you can teach him to be.[40]

Implications for PME Organizations

Any changes to PME curricula and instructional methodologies should be informed by the fact that learning that is more challenging, slower, and frustrating in the near term oftentimes yields better results in the long term.[41] Struggling, not repetition, enhances subsequent learning. Officers selected for PME have largely succeeded the entirety of their careers, so they might

prove resistant to this sobering reality. These challenges are compounded by the fact that students may feel they learn less in an active learning environment even though they actually learn more,[42] and professors who facilitate "deep" learning also often receive lower evaluations from students, despite more readily preparing them for the long term, because their courses are more difficult and frustrating.[43] Active learning simply requires an increased cognitive effort.

As a result, any changes will undoubtedly take a lot of time and effort and encounter a lot of resistance, which will only be exacerbated by the number of different parties with equities in PME. Progress is never easy, but it should be guided by the notion that education and learning require long-term investments in people, our most important strategic asset. Training and educating for specific knowledge and immediate "payback" undermine this effort. Instead, we must strive to equip our people to be able to adapt to the unforeseen.

Notes

1. We are grateful to MajGen William F. Mullen and Mr. Robert Kozloski for comments on an earlier version and/or helpful conversations on the topic. Any remaining errors were produced without help.

2. *Education for Seapower,* (Washington, DC: Department of the Navy, December 2018), 2.

3. Gen David H. Berger, *Commandant's Planning Guidance: 38th Commandant of the Marine Corps*, (Washington, DC: Headquarters Marine Corps, July 2019), 13.

4. Lee S. Shulman, "Signature Pedagogies in the Professions," *Daedalus,* (Cambridge, MA: Summer 2005).

5. In his *Year 3 Strategic Vision, Goals, and Implementation Guidance*, Secretary of the Navy Richard V. Spencer identifies "prioritizing learning as a strategic advantage" as one of his six strategic goals. In FY20, he wants the Department of the Navy to "accelerate the implementation of Education for Sea Power initiatives to advance an institutional culture of learning, innovation, and intellectual preparedness … as the core of our sea power advantage." Secretary of the Navy, *Year 3 Strategic Vision, Goals, and Implementation Guidance: Fiscal Years 2020–2023,* (Washington, DC: 2019), 2. Additionally, and although we mention it briefly here, discussing some of the different ways of learning and approaches to education that might be useful in the post-industrial age (and how we might correspondingly need to change our PME institutions) deserves its own paper and is beyond the scope of this one.

6. *Commandant's Planning Guidance*, 16.

7. Kuhn introduced the notion of paradigms; Drucker later established the notion of discontinuities in societal changes. See Thomas S. Kuhn, *The Structure of Scientific Revolutions*, (University of Chicago Press: 1962) and Peter F. Drucker, *The Age of Discontinuity: Guidelines to Our Changing Society*, (New York, NY: Harper & Row, 1969).

8. The fact that our PME has focused on teaching tools for already-identified problems instead of teaching thinking probably goes some way towards explaining why we were content to live in a "vacuum, one of strategy-free actions." See, for example, James N. Mattis, "Remarks By Secretary Mattis at the U.S. Naval War College Commencement, Newport, Rhode Island," DOD, (June 2018), available at https://www.defense.gov.

9. For example, in its meta-analysis of PME reform, *E4S* highlights a previous study by the Center for Naval Analyses that recommends, "The Navy should expand PME to broaden officers' knowledge of the Navy beyond their own communities," 50.

10. This question takes on added importance given the plethora of studies (see, for example, *E4S*) from a wide variety of sources that have been conducted over the previous decades but have not seemed to successfully nudge PME institutions far enough beyond the industrial age paradigm. There is also another layer of questioning concerning how technology can help in education. We do not delve into it here, but we do note that it is important that we do not try to substitute the need for learning with technology, or mistakenly think they are one and the same. Nobel laureate Herbert A. Simon cautions:

> Notice that if you proceed in this way, technology is the tool but it is not the driver. What we must avoid above all is designing technologically sophisticated hammers and then wandering around to find nails that we can hit with them. That is a great temptation for all of us who are involved with computer technology; for computers can do really fascinating things when they are not being stubborn; and we would like to see how we can use those potentialities in education. But I submit that we are not going to succeed in that unless we really turn the problem the other way around and first specify the kinds of things students ought to be doing: what are the cost-effective and time-effective ways by which students can proceed to learn. We need to carry out the analysis that is required to understand what they have to do—what activities will produce the learning—and then ask ourselves how the technology can help us do that.

See Herbert A. Simon, "What We Know about Learning," *Journal of Engineering Education*, (Washington, DC: American Society for Engineering Education, October 1998), 346.

11. *Education for Seapower*, 32.

12. Betsy Ng, "The Neuroscience of Growth Mindset and Intrinsic Motivation," *Brain Sciences*, (January 2018), available at https://www.ncbi.nlm.nih.gov.

13. Committee on Defining Deeper Learning and 21st Century Skills, *Education for Life and Work: Developing Transferable Knowledge and Skills in the 21st Century*, (Washington, DC: The National Academies Press, 2012).

14. "The Neuroscience of Growth Mindset and Intrinsic Motivation."

15. Critical thinking's longer legacy traces back to at least Socrates.

16. For examples, see *Education for Seapower*; the *Commandant's Planning Guidance*; and Robert H. Scales, "Too Busy To Learn," *Army History*, (Summer 2010). *War on the Rocks* maintains a series of articles, "Educating the Force," focusing specifically on PME. This can be located at https://warontherocks.com.

17. Gen Alfred M. Gray Jr., "General Alfred M. Gray's Training and Education Letter on Professional Military Education," in *The Legacy of Belleau Wood: 100 Years of Making Marines and Winning Battles; An Anthology*, edited by Paul Westermeyer, (Quantico, VA: History Division, United States Marine Corps, 2018).

18. Paul K. Van Riper, "The Identification and Education of U.S. Army Strategic Thinkers," in *Exploring Strategic Thinking: Insights to Assess, Develop, and Retain Army Strategic Thinkers*, edited by Heather M.K. Wolters, Anna P. Grome, and Ryan M. Hinds, (Ft. Belvoir, VA: United States Army Research Institute for the Behavioral and Social Sciences, 2013).

19. David Epstein, *Range: Why Generalists Triumph in a Specialized World*, (New York, NY: Riverhead Books, 2019), 45. In contrast, being

taught how to follow procedures in the application of particular formulae does not.

20. *Education for Seapower*, 37.

21. Herbert A. Simon even found this approach lacking in the context of seemingly well-structured engineering problems. For example, in explaining the tenets of the Carnegie Plan and how Carnegie went about "professionalizing" teaching and learning, he explained:

> The idea of the Carnegie Plan was that the emphasis in engineering education should not be placed on knowledge, but should focus attention on the learning processes and the problem solving processes of the students. The goal of training students was to enable them to execute skills; they had to acquire those skills; and the most essential skills were the broad skills that we call problem solving.

See "What We Know about Learning," 343. Elsewhere, Simon argues that focusing solely on knowledge presents a false dichotomy, noting that "two-bladed scissors are still the most effective kind. In addition to the large body of knowledge that is represented in semantically rich systems, there have to be processes for operating on that knowledge to solve problems and answer questions." See Herbert A. Simon, "Problem Solving and Education," in *Issues in Teaching and Research*, edited by D.T. Tuma and F. Reif, (Hillsdale, NJ: Lawrence Erlbaum Associates, 1980), 85.

22. The 2018 *Financial Times* Skills Gap survey reveals that top employers actually identify these "soft skills" as the most important skills in MBA graduates. See Patricia Nilsson, "What Top Employers Want from MBA Graduates: The FT's 2018 Skills Gap Survey Reveals What Lies Ahead in the Jobs Market," *Financial Times*, (London, UK: September 2018). The Department of the Navy's new Chief Learning Officer notes the importance of the liberal arts, too:

> People say these days, lots of people, that the liberal arts are not practical enough. That people need to be trained for their first job. And that the liberal arts, however nice or lofty or idealistic, can't train the workforce we need for the coming century. This idea of education is horribly misguided. Because at the end of the day, what I think this world needs is more people who are capable of truly critical thought, of truly critical rigorous analysis. People who are creative and can think outside of the box. People who have what Eugene O'Neill called 'the touch of a poet.' A little bit of that creative and rebellious spirit that brings change to our world. In short, I think the most practical education one can have is an education that does not prepare your [*sic*] for your first job, but that prepares you for the next 60 years of your life.

See John R. Kroger, "Inaugural Address," *Reed College President's Office*, (Portland, OR: September 2012).

23. Unfortunately, many institutions have disciplinary walls or school boundaries that are quite solid, and people often prefer to interact with those who think like themselves, even though they can probably learn more interacting with those who think most *unlike* themselves.

24. This definition combines those provided by Daniella Laureiro-Martínez and Stefano Brusoni, "Cognitive Flexibility and Adaptive Decision-Making: Evidence from a Laboratory Study of Expert Decision Makers," *Strategic Management Journal*, (Chicago, IL: Strategic Management Society, April 2018), 1032: and Epstein in *Range*. Also, cognitive flexibility enables superior decision making and helps organizations overcome strategic inertia, thus underscoring its importance to the development of effective strategic leaders.

25. "Problem Solving and Education"; and Fernand Gobert, "Chunking Models of Expertise: Implications for Education," *Applied Cognitive Psychology,* (Society for Applied Research in Memory and Cognition, 2005).

26. Jeannette Wing advocates for teaching a similar skill—what she refers to as "computational thinking." According to Wing, "Computation thinking is using abstraction and decomposition when attacking a large complex task or designing a large complex system … It is choosing an appropriate representation for a problem or modeling the relevant aspects of a problem to make it tractable." See Jeannette M. Wing, "Computational Thinking: It Represents a Universally Applicable Attitude and Skill Set Everyone, Not Just Computer Scientists, Would Be Eager to Learn and Use," *Communications of the ACM,* (New York, NY: March 2006).

27. John R. Boyd, "Destruction and Creation," *John Boyd*, (September 1976), available at https://www.colonelboyd.com.

28. Ibid.

29. Albert Einstein, *Einstein: On Cosmic Religion and Other Opinions & Aphorisms* (New York, NY: Covici-Friede, 1931).

30. Alfred North Whitehead, *The Aims of Education and Other Essays*, (New York, NY: The Free Press, 1929), 98.

31. Ibid., 93.

32. Ibid., 96.

33. Ibid., 97. Whitehead further explains,

> Imagination is a contagious disease. It cannot be measured by the yard, or weighed by the pound, and then delivered to the students by members of the faculty. It can only be communicated by a faculty whose members themselves wear their learning with imagination … More than two thousand years ago the ancients symbolised learning by a torch passing from hand to hand down the generations. That lighted torch is the imagination of which I speak.

34. *Range*.

35. Professor Erik Dane defines cognitive entrenchment as "a high level of stability in one's domain schemas." See Erik Dane, "Reconsidering the Trade-Off between Expertise and Flexibility: A Cognitive Entrenchment Perspective," *The Academy of Management Review*, (Briarcliff Manor, NY: October 2010), 579.

36. Professor Andrew Hargadon explains, "Having one foot outside your world means you can be less beholden to the people, ideas, and objects that would otherwise bind, and blind, you. Bridging multiple worlds, in essence, makes you less susceptible to the pressures of conforming in any one because you have somewhere else to go." See Andrew Hargadon, *How Breakthroughs Happen: The Surprising Truth About How Companies Innovate,* (Boston, MA: Harvard Business School Press, 2003), 77.

37. *Range.*

38. *Education for Life and Work*.

39. Herbert A. Simon, *Problem Formulation and Alternative Generation in the Decision Making Process*, Technical Report AIP 43, (Arlington, VA: Office of Naval Research, 1988), 7.

40. John Boyd Corona Ace Oral History Interview, K239.0512-1066, (Montgomery, AL: USAF Historical Research Agency: January 1977), 55.

41. *Range.*

42. Louis Deslauriers, Logan S. McCarty, Kelly Miller, Kristina Callaghan, and Greg Kestin, "Measuring Actual Learning versus Feeling of Learning in Response to Being Actively Engaged in the Classroom," *Proceedings of the National Academy of Sciences of the United States of America*, (Washington, DC: August 2019),

43. See also *Range.*