The Science of Learning and Implications for Navy Learning Policy

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ABSTRACT

One goal of the Navy's Revolution in Training is to apply the "Science of Learning" to improve the performance of the Warfighter. The Science of Learning is often spoken of as if it is a "thing" that can be purchased off-the-shelf, but in reality it is a body of knowledge about learning that has been derived by application of the scientific method. The scientific method has been used for over two hundred years to derive empirical data about the way people learn, the way they remember, and the way their performance can be improved through the application of sound learning principles. Leaders can apply the Science of Learning to improve human performance in day-to-day Navy operations by using empirical data to make learning decisions rather than relying solely upon expert "opinions."

Like any area of science, the Science of Learning has its own experts. Just as the National Aeronautics and Space Administration looks to experts to help them design rockets and review the work of others, experts in human learning can help policy-makers develop Science of Learning policy. Although it is unreasonable to expect every leader in the Navy to be a "learning scientist," each leader can be taught the basic principles of the Science of Learning, and the context in which it should be applied in the decision-making process. However, to make this a reality it will be necessary to implement the organizational structures to insure that the Science of Learning is a key consideration in Navy operations. If this is not done, then there will likely be misapplication and misinterpretation of Science of Learning principles with potentially serious consequences. A human performance decision support system could be developed and implemented by the Navy to ensure solid decision-making by leaders about learning and performance issues.

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INTRODUCTION

An important goal of the Navy's "*Revolution in Training*" described in the Executive Review of Navy Training is to apply the *"Science of Learning"* to improve the performance of the workforce and the Warfighter (United States Navy, 2001). The report made five recommendations to help "*revolutionize*" Navy training. These were: 1) Adopt a Navy Learning System, 2) Establish a Human Performance System, 3) Align Training, 3) Establish a Lifelong Learning Continuum, and 5) Emphasize Human Performance in Acquisition.

However, the recommendations of the report were generally not based upon the Science of Learning as much as "expert" opinion and best practice, and were more of a prescription for the reorganization of the Navy training and education system than the actual implementation of the Science of Learning into the Navy training and education process. While Navy training reorganization is an essential component of the Revolution in Training, it does not inherently guarantee that the Science of Learning will be an important part of that revolution. In the opinion of some of the most respected educational experts,

> Too much of the structure of educational technology is built upon the sand of relativism, rather than the rock of science. When winds of new paradigms blow and the sands of old paradigms shift; then the structure of educational technology slides toward the sea of pseudo-science and mythology. (Merrill, Drake, Lacy, Pratt, & the ID_2 Research Group, 1996, p. 7)

The purpose of this paper is to better explain the "Science of Learning", its relationship to *science* and the *scientific method*, to point out common errors in the application of Science, and to identify the policy and planning issues that must be aggressively addressed before the Science of Learning can actually be implemented in the U.S. Navy. Part of an effective implementation plan must be the creation of the infrastructure necessary to ensure that sound policies and procedures that instantiate Science of Learning principles are followed at every level in the Navy.

What is the Science of Learning?

The Science of Learning is not a "thing" that can be bought "off-the-shelf." While there are many commercial educational programs that one can buy off-the-shelf, there is generally no direct connection between these programs and any particular Science of Learning principle. The Science of Learning is the body of knowledge derived through scientific research about the way that people learn, the factors that affect learning, and the way in which technology can be used to facilitate learning. It is widely held in the training and education community that the Science of Learning can be used to plan, develop, and deliver effective and affordable instruction to improve Navy Workforce and Warfighter expertise (United States Navy, 2001).

Like any body of knowledge, it often takes a domain expert to make sense of it. Nevertheless, the knowledge that constitutes the Science of Learning can be delivered as guidelines and tools to help the Navy training and education community deliver more learner-centered and relevant instructional products. Unfortunately, our observation is that the Science of Learning is often confused with the act of creating instructional products and the infrastructure supporting the distribution of learning content.

The Science of Learning is not the Instructional Systems Design (ISD) process nor is it the Navy Integrated Learning Environment (ILE), although it is desirable that both should be based upon the Science of Learning. Recently, the authors had the opportunity to review the open literature concerning the design of web-based instructional content (Hamel, Ryan-Jones, & Hays, 2000) and the quality of that content (Hays, Ryan-Jones, & Stout, 2003). Our observation from reviewing this literature from a Science of Learning perspective is that there is only very weak support for the processes that are widely used throughout government and industry to develop computer-based instructional content. The process of ISD is at best an art that is mediated primarily by the predispositions of the instructional developer and considerations about the cost of the content being developed.

Where did term "Science of Learning" originate?

Knowledge about learning has been around as long as people have been trained or educated. Skinner (1954) was one of the first researchers to use the phrase "science of learning." His opinion was that the principles of learning discovered through science could be applied to improve the methods used in the art of teaching. However, to effectively apply the science of learning, it is important to develop a world-view that allows one to think "scientifically." Before discussing some of the specific things that should be done to implement the Science of Learning in the Navy, let us look at the way science and a "scientific world view" helps us gain and apply knowledge.

SCIENCE AND THE SCIENTIFIC METHOD

People have wondered about their place in the universe for at least as long as there has been language. People have sought to understand themselves and the world around them by applying various approaches to the examination of the environment and their internal states. Science has been the most successful of these approaches. As Francis Bacon, widely regarded as one of the earliest proponents of the scientific method, puts it, "The lame in the path outstrip the swift who wander from it" (Beverage, 1957, p. 3).

Slavin (2002) points out that the "No Child left Behind" legislation recently enacted by Congress mentions "scientifically-based research" no less than 110 times. The text of the legislation defines research as "rigorous systematic and objective procedures to obtain valid knowledge" (United States Congress, 2001). Only by applying the principles of science, and the scientific method can we efficiently and knowledgably develop new and effective educational approaches and policies. As with the public education system, it is important for the Navy to base its education and training decisions upon empirical data, and not solely upon personal opinion even if it is considered to be expert in nature.

What is Science?

The word *science* is derived from the Latin *scire*, meaning to know, and inherently deals with knowledge. Science is defined in the dictionary (Webster's New Collegiate Dictionary, 1977) as:

1. Possession of knowledge as distinguished from ignorance or misunderstanding.
2. Knowledge covering general truths or the operation of general laws especially as obtained and tested through scientific method.

It has only been since the Seventeenth Century that the scientific method, as we know it today, has played a major role in the search for knowledge. In earlier times, other methods were used to test the truth of our conceptions of reality. "*Scientia* in the classical world meant reasoned disclosure of something for the sake of the disclosure itself. Up to the Seventeenth Century such disclosures consisted largely of classifications of things that were qualitatively different, but after Galileo it became the search for nature's quantitative laws" (Smith, 1982, 1989, p. 83).

The Scientific Method

The scientific method is a systematic and iterative process that continuously improves upon the explanations that are derived using the process. Figure 1 is a simplified diagram of the scientific method. The scientific method can be divided into four stages or

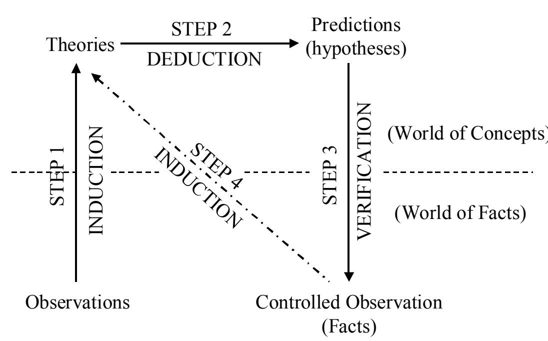

Figure 1. A Simplified View of the Scientific Method (Adapted from: Graham, 1977 and Wallace, 1971)

steps. Step 1 begins with *observations* of events in the world. If these events are observed by more than one person or often enough, the scientist can use *induction* or the process of establishing general principles from specific systematic observations to develop *empirical generalizations* about the observed events. Empirical generalizations, in turn, are items of information that can be synthesized into a *theory* or "an interconnected system of ideas composed of abstract concepts and rules for relating these concepts to the observed facts" (Graham, 1977, p. 8).

In Step 2, a theory may be used to suggest further relationships or predictions about conditions in or rules of the real world through the method of *logical deduction*. Forming this deduction into a *hypothesis*, the scientist can then, through the process of *verification* (Step 3), test the relationship of the hypothesis to reality by making new, controlled observations. This testing should result in new information that leads to a decision to accept or reject the tested hypothesis.
Finally, in Step 4, the results of the controlled observations are used to inductively confirm, modify, or reject the theory. This may lead to the development of new hypotheses that can be further tested as the cycle continues.

The scientific method should be considered to be the intellectual model for many other systematic and iterative processes, such as the ISD or materiel acquisition process. However, just trying to apply a process like ISD, does not mean one is being "scientific." Science and the scientific method are also a way of thinking about and approaching the real world. The scientific method includes specific techniques to help avoid many of the mistakes that all humans tend to make, whether they are scientists or not.

Possible Foibles in Science

The dictionary defines a *foible* as "an odd feature or mild failing or weakness in a person's character" (Webster's New Collegiate Dictionary, 1977). We often make mistakes because we have predispositions to think in certain ways. Scientists can and do make mistakes like anyone else, and they can unconsciously be influenced by others or by circumstances. Wilson (1952) and Babbie (1975) discuss some of the mistakes or foibles that can lead scientists to make unwarranted conclusions or recommendations. Many of these foibles are interrelated and can combine to lead to even larger mistakes on the part of a scientist.

1. *Inaccurate Observation*. Mistakes can be made during measurement, data collection, and data analysis. Scientific procedures are specifically designed to reduce these kinds of errors. Although they are not 100% effective, "the care with which scientific observations are made is an important norm of science" (Babbie, 1975, p. 14).
2. *Overgeneralization*. This occurs when the scientist proposes broad patterns of effect on the basis of relatively few observations (Babbie, 1975, p. 15). Overgeneralization can take two forms. First, the results of a study can be mistakenly applied to a population that is different from the population that was tested. For example, the results of a study whose subjects were male may inappropriately be applied to females. Secondly, conclusions can be drawn that are not supported by the data. Perhaps the chief safeguard against overgeneralization is the replication of the study, sometimes under slightly varied conditions.
3. *Selective Observation*. Scientists can yield to the temptation to focus on observations that correspond with the pattern they have previously concluded to exist and ignore their contradictory observations (Babbie, 1975, pp. 15-16). This is sometimes found in the literature reviews that are used to justify the need for an experiment. One clue that can be used to evaluate whether selective observation is a possibility on the part of a scientist is the presence of a bibliography containing only the author's own references.
4. *Deducing Unobserved Information*. Scientists are sometimes tempted to explain away ambiguous or contradictory observations on the basis of their preconceived notions about the data rather than what they observe in the data (Babbie, 1975, pp. 16-17). This can sometimes lead to selective data collection on the part of the scientist until the preconceived notion is "supported."
5. *Illogical Reasoning*. Sometimes scientists fail to apply clear logic or use illogical reasoning (Babbie, 1975, pp. 17-18). One example is the common confusion between necessary and sufficient conditions. For example, just because a victim of a certain disease always loses weight does not mean that anyone losing weight has a given disease (Wilson, 1952, p. 34). Confusion can also occur when two events are falsely related as cause and effect when both are actually the result of a third factor. This can result in treating the symptoms and not the cause (Wilson, 1952, p. 34). Another example is explaining contradictory data with the trite

phrase "the exception that proves the rule." Illogical reasoning can be avoided by applying a system of logic consciously and explicitly to the problem being studied. For example, probability theory can sometimes explain "exceptions" in the findings.

6. *Premature Closure of Inquiry*. Scientists want to be "successful." Sometimes this desire, combined with some of the other possible foibles of science, can lead a scientist to "positive declarations of success" before the scientist has fully explored the area of interest (Babbie, 1975, p. 18).
7. *Ego Involvement in Understanding*. As human beings, scientists can sometimes succumb to their egotistical defensiveness regarding their own ideas and conclusions. Like others, scientists may not like to have their own ideas challenged by others. But, a full commitment to the norms, rules, and methods of science can help the scientist to recognize their own errors in logic (Babbie, 1975, p. 19).

Some Misapplications of the Science of Learning

The Science of Learning is often misapplied in the real world. Two very common misapplications that the authors have observed deal with web-based instruction. The first example is the proposed "two sigma" improvement in web-based learning over classroom learning, and the second is prescriptions for the design of learning objects. It is widely believed in the training and education community that the conversion of a course from a traditional classroom format to a self-paced, web-based format can lead to a two standard deviation improvement in learning from the instruction. When one looks more closely at the source of this belief, one finds that is derived from study of Bloom (1984) in which he compared traditional classroom instruction for children to one-on-one tutoring. However, one-on-one tutoring by a teacher is very different than self-paced, web-based training. Formal evaluations of the prior classroom format to the new web-based format that are properly designed and executed do not tend support two standard deviation improvements in learning.

In the world of web-base training, the construction of learning objects has been proposed as a way to dramatically reduced the cost of instruction by reusing or repurposing existing content when new content is developed. One common learning object model is the Reusable Learning Object (RLO) model originally developed in the civilian sector. In this model, an RLO is made up of several Reusable Information Objects (RIOs). RIOs are usually constructed around enabling learning objectives that foster attainment of the terminal objective of a lesson. The authors have seen several guides for development of RLOs that state each RLO should be made up of seven plus or minus two RIOs. Closer examination of this rule shows it to be based on a paper by Miller (1956). In this paper, Miller identified some of the properties of short-term memory. Specifically, if someone is read a list of things such as numbers or nonsense syllables, and then asked to repeat what was heard, a typical individual can only hold about seven plus or minus two separate items in short-term memory. This has nothing to do with the number of enabling objectives that should be included in a lesson. By definition, the objective of instruction is to help the student get the information into his or her long-term memory. The number of enabling objectives is determined by the requirements of the task to be learned, not the amount of separate items that can be held in short-term memory.

Both of these misapplications point out the need for caution in applying the Science of Learning to training and education. We often think that instructors and instructional developers know everything there is to know about learning. This is really not the case. Teachers and instructional developers are best thought of as practitioners and not as scientists, and as such their actions are often based upon unscientific approaches to the problem. However, there are some guidelines that both the scientists and practitioners can use to improve the development and evaluation of training and educational products.

Rules and Principles of the Scientific Method

One way to guard against the foibles and misapplications discussed above is to utilize proven methods that prevent or reduce the likelihood of making these mistakes. Wilson (1952), Beveridge (1957), and Valiela (2001) provide some basic rules of the scientific method to which a scientific investigator must be committed to insure scientific integrity.

1. *Good Observation*. Scientists continuously search for better ways to observe the world. Controlled observation is the only way that we can be assured that our hypotheses concerning the causal effects of one variable (e.g., practice) on another (e.g., learning) is supported (Valiela, 2001, p. 6). What the

scientist chooses to observe is usually dictated by his or her scientific orientation, or paradigm. This orientation inherently makes the scientist selective in what is studied. "It is necessary to limit what is to be observed to a portion of the universe small enough to be encompassed" (Wilson, 1952, p. 22). Beyond this, an observer's own characteristics also affect the phenomena observed. Physicists recognized in the early twentieth century that the act of observation altered the process under study. Behavioral researchers have more recently realized that there is no such thing as a "detached observer," since scientists are affected by their own biases (Rosenthal, 1966) regarding the phenomenon under study. Some of these biases can be overcome by the public nature of scientific observation.

2. *The Public Nature of Observation*. Scientific observations should be public in the sense that their studies can be repeated, or replicated by other trained scientists. "The essence of any satisfactory experiment is that it should be reproducible" (Beveridge, 1957, p. 23). Replication is the major means of increasing our confidence in the results of any single investigation. "A scientific observer is never afraid to allow others to view the phenomena in which he is interested. He should welcome checks and repetitions of his work as adding to their certainty" (Wilson, 1952, p. 23).
3. *The Need to Theorize Logically*. Theories about the knowledge domain must logically and consistently account for the things a scientist has observed. "We require that the actual facts be reported, that we are told how the facts were obtained, and that the reasoning used to reach a conclusion from the facts shown be explicit" (Valiela, 2001, p. 5). Changing the basic assumptions of a theory can change a scientist's explanation of the same data. For example, an increase in the observed suicide rate among a certain group could be explained as a result of its members' lack of self-concept. This psychological theory focuses on the individual. An alternate explanation of the same data, from a social perspective, might locate the causal factors for increased suicide rate in the breakdown of the supporting societal mechanisms.
4. *Testing of Theory by Observable Consequences*. Scientists test theories by using them to predict certain outcomes and then determining whether the outcomes can be verified by observation. There is no requirement that the outcomes produce physical effects. Any effect, even those that occur in the human mind can be used to test a theory as long as these effects change something that is observable. For example, even though we cannot locate a specific new thought in someone's brain, one can infer that learning has occurred if an individual is able to demonstrate a new skill or item of knowledge.

Practical Application of the Science of Learning

Science is more than the methods and the data they generate. Science is also a way of thinking and of making decisions. Part of implementation of the Science of Learning is learning how to make sense of the body of knowledge and the products that are purportedly based on that knowledge. There are some basic rules that anyone can use to think more "scientifically" and to evaluate products that are based upon scientific studies (Beveridge, 1957).

1. *Maintain a healthy level of skepticism*. Don't believe everything you hear even though it may be based upon a published study. For example, demand evidence that demonstrates the effectiveness of instructional approaches and require demonstrations of instructional products that will justify their claims.
2. *Consult original sources (e.g., publications) whenever possible*. Don't trust someone else's summary, interpretation, or explanation of a research effort. Read it yourself and make your own interpretations of the results of the study.
3. *Don't jump to conclusions.* Decisions are sometimes made on the basis of opinions or insufficient data. If the results of a study sound too good to be true, it probably is.
4. *Always be ready to abandon or modify our hypothesis*. Hypotheses are only as good as the data that support them, and they should be abandoned as soon as they are shown to be inconsistent with the data that were collected to support them.
5. *Do not draw general conclusions from one experiment*. Experimental results are only valid for the precise conditions under which

the study was conducted. For example, a study of an instructional technique effective in a study of K-6 children may not be effective in middle-aged adults.

6. *Apply Occam's Razor.* This is the maxim of parsimony that was first stated by William of Occam in the 14th century. Simply stated, given alternative explanations for some phenomena, the simple explanation is usually to be preferred over the more complex explanation.

IMPLEMENTNG THE SCIENCE OF LEARNING

How can the Navy help ensure that the principles and methods of the Science of Learning are applied to improve the performance of the Navy Workforce and Warfighters? Navy policy makers must realize that implementing the Science of Learning in the Navy means more than just talking about it or using it as a slogan. It is an active and ongoing process. There are really two steps necessary to implement the Science of Learning *de novo* in an organization such as the Navy. The first step is to create an environment that values and promotes science and scientific thinking. The second step is to create tools and guidelines and make them available to the nonscientist practitioner who actually utilizes the Science of Learning information to make day-to-day decisions about training, education, and performance issues.

Guidelines to Implement the Science of Learning

The Navy isn't the first Federal government entity to build a science-based program. Other government agencies have had experience in building programs and the Navy can benefit from this experience (Shavelson & Towne, 2002). Some of the factors that are believed to be important in program development include the following:

1. *Establish a Science of Learning Implementation Group*. The Science of Learning is not something that can be bought off of the shelf. It is difficult to understand and just as difficult to implement. Successful implementation will require the establishment of a custodial group under a Command that has a charter to foster learning within the Navy.
2. *Staff the Group with Personnel Skilled in Science, Leadership and Management*. Competent personnel are necessary to implement the Science of Learning in the Navy. Leaders and managers of the relevant Science of Learning staff components should be recognized as having the proper credentials and experience in the field. These credentials should demonstrate a high degree of professional training in learning and scientific methodology, and with a proven track record professional publication of this expertise.
3. *Create Formal Structures to Guide Agenda, Inform Funding Decisions and Monitor Work.* Control is a key component for implementing a science-based program. It is best supported by a formal system of governance outside of the group that is chartered to be the steward of the Science of Learning. Governance boards are a very common management structure, and oversight tool for science-based organizations. These boards are a way to independently develop the proper culture, and foster interactions with the stakeholders.
4. *Establish a Peer Review System.* Peer review is a widely accepted practice to assess the quality of science-based work, and to provide the mechanism for self-regulating the nature of the work. This system insulates the work and workers from outside political pressure to conduct specific studies, to find specific results, and to task specific individuals or centers.
5. *Insulate the Implementation Group from Political Interference.* This is very difficult to do in the military environment. But, it fosters the scientific culture, protects the process, and prevents misdirection of scientific study to the latest fads.
6. *Address Short-, Medium-, and Long Term Issues.* It is important to balance the common and sometimes misguided strategy of seeking the "low-hanging fruit" against the often more important long-term needs of the Navy. Money is often the driving force in the decision-making process which foster the low-hanging fruit strategy, but the long-term effects of this strategy are often unknown and may be counter productive.
7. *Adequately Fund the Program.* Implementing the Science of Learning in the Navy may be an expensive and long-term process, but it will likely fail if funding is not available to make it work. Funding shortfalls

may lead to shortcuts that are not supported by the Science of Learning.

NAVY SCIENCE OF LEARNING POLICY

Implementing the Science of Learning in the Navy requires a high-level leadership commitment and day-to-day operational commitment to the Revolution in Training. If the vision is that the Science of Learning is important to the future of the Navy, then Navy training and education policy decisions should be informed by scientifically derived data rather than opinions, fads, or politics. While there is little doubt that politics, short-term gain and funding will always be important considerations, it is just as important to ensure they are mediated by the Science of Learning, and in themselves are not solely guiding the implementation policies and procedures.

Science of Learning Guiding Principles

The authors believe that the Navy Science of Learning vision should consider the following guiding principles:

1. *Learning is the foundation of Navy expertise*. The jobs that modern Navy personnel must complete are very complex and technology-dependent. Training and education that is job-relevant and effective can help ensure that the workforce and the Warfighters have the necessary skills and knowledge to achieve their missions.
2. *Learning is the outcome and instruction is the process*. People often confuse the terms instruction and learning. Only if instruction is properly designed to include the required learning objectives and the instructional methods to guide and evaluate learning can we be sure that Navy personnel have learned what is required by their jobs.
3. *Instruction is only as effective as the policies and procedures that support it*. Instruction does not occur in a vacuum. It is embedded in structures such as the Navy schools and the ILE. Instruction is often influenced by outside policies, such as reducing the number of instructors or increasing the number of students. If policies conflict with sound instructional approaches, it is likely that the instruction will be less effective.
4. *Quality of learning is an important component of return on investment*. Instructional plans and programs are increasingly required to show return on investment (ROI). Too often ROI is "quantified" in terms of dollar savings on travel, infrastructure, or personnel. Although these are important, they are irrelevant if the learners do not obtain effective instruction that enables them to successfully complete their missions. The evaluation of instructional or training effectiveness should be the first step in any ROI study.
5. *Knowing what to teach is as important as knowing how to teach*. The best instructional methods are for nothing if the content of the instruction does not support the requirements of the job. Too often job and task analysis is given fewer developmental resources and effort than the design and development of actual instructional products. It is essential that leaders, managers, and instructional developers target the needs of the job prior to making any instructional design decisions.
6. *Knowing how to perform the job does not guarantee knowing how to teach it*. Navy instructional developers rely on subject matter experts (SMEs) to help them understand the requirements of jobs and to help them ensure that course content is correct. SMEs are not trained to be instructors or instructional developers. In fact, many experts have "forgotten" why they do things in certain ways because their skills have been learned so well as to be "automatic." The role of SMEs, although essential, should not be overextended to areas in which they do not have expertise.
7. *Consult experts in the Science of Learning to make Science of Learning policy*. One does not ask an electrician to repair plumbing. Likewise, persons without training and expertise in the Science of Learning should not be consulted to make learning policy decisions. Navy leaders need a cadre of trusted experts in the Science of Learning.

Science of Learning Functional Architecture

Figure 2 shows a possible functional architecture for implementing the Science of Learning in the Navy.

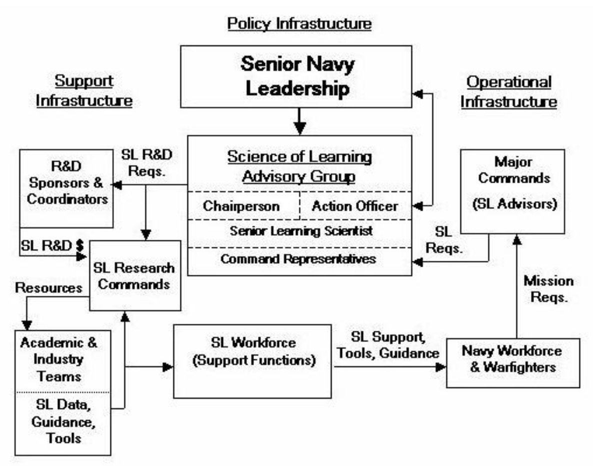

Figure 2. Possible Functional Architecture for Implementing the Science of Learning

The figure shows three major functional infrastructure requirements: policy, operations, and support. The policy infrastructure establishes and enforces Navy policies. Senior Navy Leaders make Science of Learning policy with the aid of a Science of Learning Advisory Group. This Group includes:

- A Chairperson, who organizes and coordinates meetings
- An Action Officer, who is the main link with Senior Navy Leadership
- A Senior Learning Scientist, who serves as the Group's main advisor on learning issues, and
- Representatives from Major Navy Commands.

The operational infrastructure is where the Navy does most of its work. It consists of the Navy Warfighters and the general workforce. Navy personnel have jobs to do and their missions have specific requirements. These requirements are communicated to their major commands and a determination is made whether a given requirement involves the Science of Learning. The Science of Learning Advisors assist in this determination. If mission requirements involve Science of Learning issues, they are communicated to the Science of Learning Advisory Group through the Command's Representative. These requirements are prioritized by the Group and forwarded to the Support Infrastructure.

The Support Infrastructure consists of organizations that include:

- Research and Development sponsors and coordinators
- Navy Science of Learning Research and Development Commands, and
- Academic and industry teams that conduct Science of Learning Research and Development under the guidance of Navy Research and Development Commands.

Once the Science of Learning Advisory Group has communicated Science of Learning research and development requirements to the research and development sponsor and coordinators, they provide the research and development funding to the Science of Learning Research and Development Commands so they can develop programs to address these requirements. Research teams from academia and industry are funded and monitored to develop Science of Learning data, guidance, and tools.

After Science of Learning products are evaluated and approved by the Science of Learning Research and Development Commands, they can be provided to the Navy through a Science of Learning support infrastructure. This Science of Learning support infrastructure can help the Navy Workforce and Warfighters improve their operational capabilities by helping them apply the principles of the Science of Learning.

CONCLUSIONS

While there is much talk about the need for the Science of Learning in Navy training and education, the Science of Learning as a functioning entity has yet to be fully implemented in the Navy. The actual implementation of the Science of Learning will require substantive changes in Navy policy, and the creation of a Science of Learning infrastructure to facilitate this implementation. This can only happen if individuals at the highest levels of Navy leadership are willing to commit to changes in the way Navy training and education policy is created and implemented.

Some individuals believe that they or their organization "owns" the Science of Learning. This is a very dangerous misconception. No one can "own" the Science of Learning, but Navy leaders can be "stewards" of the Science of Learning. This means that they must:

- Establish a Science of Learning support infrastructure that promotes the Science of Learning throughout the Navy and assists Navy organizations in its implementation.

- Consciously decide to make instructional policy decisions on the basis of data, not opinions, fads, short-term goals, or political expediency.
- Seek out individuals who have documented expertise and experience in the Science of Learning and place them in important positions within the Science of Learning support infrastructure.
- Listen to the advice of these experts rather than marketers or sycophants.
- Demand scientifically designed evaluations of all instructional products to ensure that the Navy is getting what it pays for.

If Navy leaders begin to follow these principles, the Science of Learning can help the Navy ensure that its personnel receive high quality training and education. This, in turn, will help them achieve success in their assigned missions.

REFERENCES

Babbie, E. R. (1975). *The practice of social research*. Belmont, CA: Wadsworth Publishing Company.

Beveridge, W. I. B. (1957). *The art of scientific investigation* (3rd ed.). New York: Vintage Books.

Bloom, B. S. (1984). The two sigma problem: The search for methods of group instruction as effective as one-to-one tutoring. *Educational researcher, 13*, 4-16.

Graham, K. R. (1977). *Psychological research: Controlled interpersonal interaction.* Belmont, CA: Wadsworth Publishing Company, Inc.

Hamel, C. J., Ryan-Jones, D. L., & Hays, R. T. (2000). Guidelines for evaluation of internet-based instruction. *Proceedings of the Interservice/Industry Training Simulation and Education Conference*, 537-543. Orlando, FL: National Training Systems Association.

Hays, R. T., Ryan-Jones, D. L, & Stout, R. (2003). Raising the bar for instructional quality. *Proceedings of the Interservice/Industry Training, Simulation, and Education Conference*. Orlando, FL.

Merrill, D. A., Drake, L., Lacy, M. J., Pratt, J., & the ID_2 Research Group. (1996). Reclaiming instructional design. *Educational Technology, 36*(5), 5-7.

Miller, G. A. (1956). The magical number seven, plus or minus two: Some limits on our capacity for processing information, *Psychological Review, 63*, 81-97.

Rosenthal, R. (1966). *Experimenter effects in behavioral research*. New York: Appleton-Century-Crofts.

Skinner, B. F. (1954). The science of learning and the art of teaching. Reprinted in Rosenblith, J.F., Allinsmith, W., & Williams, J. P. (1962). *The causes of behavior* (1st ed.). Boston: Allyn & Bacon, Inc.

Shavelson, R. J., & Towne, L. T. (2002). Scientific Research in Education. Washington, DC: Committee on Scientific Principles for Education Research, National Academies Press, 127-157.

Slavin, R. E. (2002). Evidence-based educational policies: Transforming educational practice and research. *Educational Researcher, 31*(7), 15-21.

Smith, H. (1982/1989). *Beyond the post-modern mind* (rev. ed.). New York: The Crossroads Publishing Co.

United States Congress. (2001). *No Child Left Behind Act of 2001*. Washington, DC: Author.

United States Navy. (2001). Revolution in training: Executive Review of Navy Training (Final Report). Washington, DC: Author.

Valiela, I. (2001). *Doing science: Design, analysis, and communication of scientific research*. New York: Oxford University Press.

Wallace, W. (1971). *The logic of science in sociology*. Chicago: Aldine-Atherton.

Webster's new collegiate dictionary. (1977). Springfield, MA: G. &. C. Merriam Company.

Wilson, E. B., Jr. (1952). *An introduction to scientific research*. New York: McGraw-Hill Book company, Inc.