Interdisciplinary Competence

The Key to Exceptional Performance

Carol J. McIlwain, Ph.D.

Interdisciplinary research ... integrates information, data, techniques, tools, perspectives, concepts, and/or theories from two or more disciplines or bodies of specialized knowledge to advance fundamental understanding or to solve problems whose solutions are beyond the scope of a single discipline or area of research practice.

—From "Facilitating Interdisciplinary Research" by the National Academy of Sciences, National Academy of Engineering, and Institute of Medicine of the National Academies, 2005.

Various disciplinary approaches exist for integrating knowledge. Research demonstrates that knowledge integration is improved with interdisciplinary and transdisciplinary approaches to problem solving. Integrated and interdisciplinary teams achieve better problem-solving skills by leveraging common knowledge. Results from academic institutions and a 3M Company study support the development

McIlwain *is a Defense Senior Intelligence Leader and the director of acquisition and contracts at the Office of Naval Intelligence. She spent more than 33 years with the Navy serving in program management and engineering fields. Her awards include two Joint Civilian Service Commendation awards, two Global War of Terrorism awards, NATO medal, Naval Air Warfare Center Innovation Award for Program Management, and the Daniel S. McCauley Professional Achievement Award for Engineering.*

of depth and breadth in disciplinesto achieve exceptional performance. Academia has established interdisciplinary curriculums and research centers to facilitate greater advances of knowledge and technology.

Solving complex problems requires different thinking than finding solutions to simple problems. Today's problems are complex and require a balancing of multiple conflicting or competing objectives and constraints. A problem limited to a single disciplinary field is solvable by experts in that field. Complex problems cross disciplinary fields and require the use of multiple disciplines to develop a solution. Integrated product teams (IPTs) are multidisciplinary and include experts from several functional areas. However, an IPT is challenged to fuse knowledge across disciplines (Figures 1 and 2).

An interdisciplinary perspective requires bridging knowledge between disciplines to address complex problems. Successful teams integrate multiple disciplines to frame a problem, agree on a methodological approach, and collaboratively analyze data. Exceptional teams do a better job of integrating knowledge.

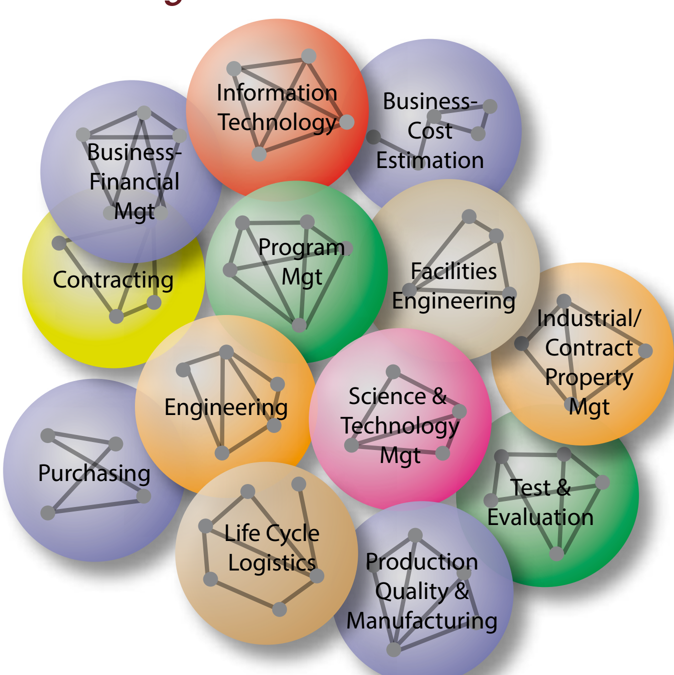
Through cross-disciplinary, interdisciplinary or transdisciplinary concepts, the acquisition workforce develops a systemic view and problem-solving skills using fused knowledge and can develop a multiple disciplinary understanding. Greater integration of disciplinary knowledge enables the development of more effective critical thinking and innovative ideas than are possible in traditional multidisciplinary teams.

An intradisciplinary approach relates to a single discipline. A multidisciplinary approach is an integrated team that gains multiple views from members grounded in different disciplines. Cross-disciplinary views one discipline from the perspective of others, which is sometimes described as akin to looking through a lens. Interdisciplinary approaches use synthesis to integrate knowledge

Figure 1. Separate Areas of Knowledge

Source of figures: Department of Defense

Figure 2. Interdisciplinary Fusing of Knowledge



A discipline is a specific field of learning or body of knowledge with defined elements such as phenomena, assumptions, epistemology, concepts, theories and methods that distinguish it from other fields or bodies of knowledge. The pursuit of further knowledge and exploration typically deals in depth within one field to gain further understanding. The concept of interdisciplinary studies requires not only depth but also breadth across one or more disciplines to understand the integration of knowledge between disciplines. The term "career fields "describes areas of acquisition categories such as budgeting, engineering, logistics, contracting, manufacturing, test and evaluation, etc. In Department of Defense (DoD) acquisition, functional areas are synonymous with career fields that define knowledge areas.

Being a trained expert is a disadvantage in some situations; competence bias hinders thinking beyond that single view. People educated in multiple disciplines are better able to design and apply a process based on certain conditions and constraints. This produces flexible thinking that challenges trained specialists. Using a multidisciplinary approach through a team of disciplinary or functional experts does not achieve integration or synthesis of knowledge because there is no common ground. A common ground provides the linkage between disciplines and creates insight and an ability to gain multiple perspectives and use knowledge in multiple applications.

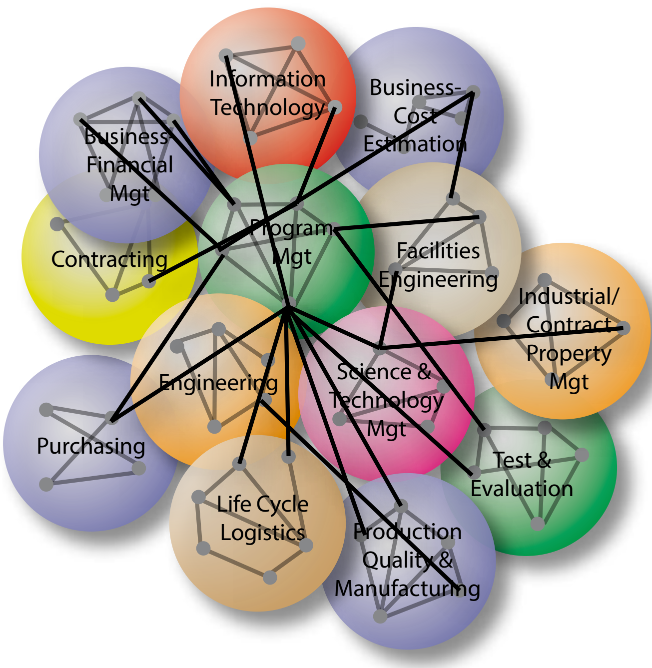
The interdisciplinary knowledge requires that planners know at least two discipline areas in order to be able to establish linkages across those areas. In a knowledge sphere, nodes are the knowledge base and linkages create insight between knowledge bases. The common ground attained through linkages provides the means to gain insight between disciplines.

Teams of experts produce a multidisciplinary approach, viewing a problem from their own discipline and recommending solutions based on their particular areas of expertise. An integrated team lead either selects one solution or needs to merge the multiple solutions into a single fused solution, requiring an interdisciplinary approach and accompanying knowledge of the various functional areas to develop a single, comprehensive solution. A fused solution is different from any single functional solution.

The team lead typically lacks interdisciplinary knowledge, selecting the one solution that appears to offer the most

from different disciplines (Figure 3). A transdisciplinary approach integrates to the extent of producing a new discipline that provides insight into an area not previously understood. Examples include biochemistry, biomedical, political ecology, educational psychology, and neuropsychology.

Figure 3. Interdisciplinary Knowledge Integration



advantages for one functional area with fewer disadvantages for the other areas. This is not an integrated solution. A true IPT lead would have an interdisciplinary background with knowledge and experience across pertinent areas. Therefore, program managers benefit from interdisciplinary competence.

Jay Forrester of the Massachusetts Institute of Technology developed the system dynamic concept as a theoretical approach to understanding complex systems. He initially developed the tool in the engineering domain but later applied it to the business world. The system dynamics paradigm concluded that decisions produce disappointing results because important casual relationships are overlooked or misread—usually by assuming a linear or unidirectional relationship versus a nonlinear and multidirectional relationship. Applying an engineering systems perspective to business operations is an interdisciplinary approach. Specialist- or expert-dominated organizations often simplify problems and reduce them to linear, unidirectional casual relationships, even if the problem is more complex and multidirectional. A simplified problem can lead to solving the wrong problem. Research laboratories recognize the need to solve complex problems with complex solutions.

An example of an interdisciplinary application is the National Synchrotron Light Source (NSLS) at Brookhaven National Laboratory of Upton, New York, on Long Island. The device produces synchrotron radiation, or light produced by charged particles bending in a magnetic field. Although initially established to support physics-related research, NSLS has evolved into an interdisciplinary laboratory:

- It is a single facility that supports multiple projects in different fields.
- Each project, large or small, requires integration of knowledge, techniques and perspectives from several disciplines or specialized fields.
- A few of the projects are creating new disciplines.
- Many projects require more than a single instrument and incorporate knowledge, techniques and perspectives from additional facilities at Brookhaven and other laboratories.

Common ground for integrating disciplines is attainable through mathematics and statistics, which cross many disciplines, including natural and physical sciences, social sciences, humanities, and applied professions. The interdisciplinary field of survey research merged the fields of sociology and political science and created specialists in data collection. Computers transformed areas of multivariate data analysis and mathematical modeling as a foundation for operational research across multiple areas: economics, sociology, political science, engineering, business and military operational planning.

Game theory merged economics and psychology, evaluating strategies based on predicted behavior, and has become foundational for strategic negotiations in business, political science, international relations, and military operational planning. Mathematical modeling, game theory and statistical analysis are tools to create common ground for interdisciplinary learning.

A joint effort by the National Academy of Sciences, National Academy of Engineers, and the Institute of Medicine's Committee on Facilitating Interdisciplinary Research and Committee on Science, Engineering, and Public Policy studied the concept of interdisciplinary research and published the results in the book, *Facilitating Interdisciplinary Research*, to document the benefits that interdisciplinary studies provide for academic understanding.

Although the findings focused on academic application for universities, institutes, and laboratories, they are easily transferable to government organizations and industry efforts to solve problems and improve the management of projects and programs. Complexity theory yields nonlinear results, creating the need for interdisciplinary approaches and crossing disciplines to leverage multiple benefits. Defense acquisition benefits from this objective, leveraging initiatives across multiple functional areas for technology development and achievement of nonlinear results.

A workforce skilled in single disciplines challenges the integration of complex technology development. Defense acquisition benefits from an interdisciplinary approach led through systems engineering and program management. An interdisciplinary workforce facilitates technology development, first by integrating the individual's knowledge within him- or herself and then integrating individual knowledge across the team.

Unconscious bias limits recognizing multiple solutions, resulting in a reversion to the current knowledge base without pursuing further information.

Systems engineering facilitates common ground across development disciplines, and program management facilitates common ground across an entire acquisition team.

When someone is involved in innovation, existing brain connections (neurons) must significantly change and cross wider areas of the brain dealing with different types of knowledge and problems in order to assimilate very different concepts and challenge long-held assumptions. Tara Swart's book, *Neuroscience of Leadership*, states that "working at the interstices of domains of knowledge can also create dissonance, and being engaged and interested in a wider range of activities than just one's own domain is also often a mark of exceptionally creative people." The strengthening of neurons in the brain creates bias and limits problem solving. Unconscious bias limits recognizing multiple solutions, resulting in a reversion to the current knowledge base without pursuing further information.

Interdisciplinary Results—3M Company Study on Innovation

Innovation relies on an individual's expertise to generate new knowledge or create new ideas through recombining ideas to create innovative applications. In the research paper, "Balancing Breadth and Depth of Expertise for Innovation: A 3M Story," the authors state:

> Even though many inventions are created when individuals work in teams, studies allude to the observation that individuals are effective in combining existing knowledge to generate new knowledge and innovations. Innovative ideas and insights first occur to individuals, before such ideas are subsequently shared at the group levels and institutionalized at the organizational level. Fundamentally, this highlights that individuals are the basic unit in which knowledge integration and knowledge creation takes place, regardless of whether individuals work alone or in teams.

If innovative ideas are not created at the unit level, they will not be created at the team level.

A study of how inventors' breadth and depth of expertise influence innovation at 3M exceeded previous research focused on a single indicator—technical success achieved by the inventor. The 3M study examined three indicators:

- The number of inventions generated.
- The extent to which the inventor has a significant impact on the technical domain.
- The inventor's career success, in terms of commercial value brought by converting the inventions into products that generate sales for commercial organizations.

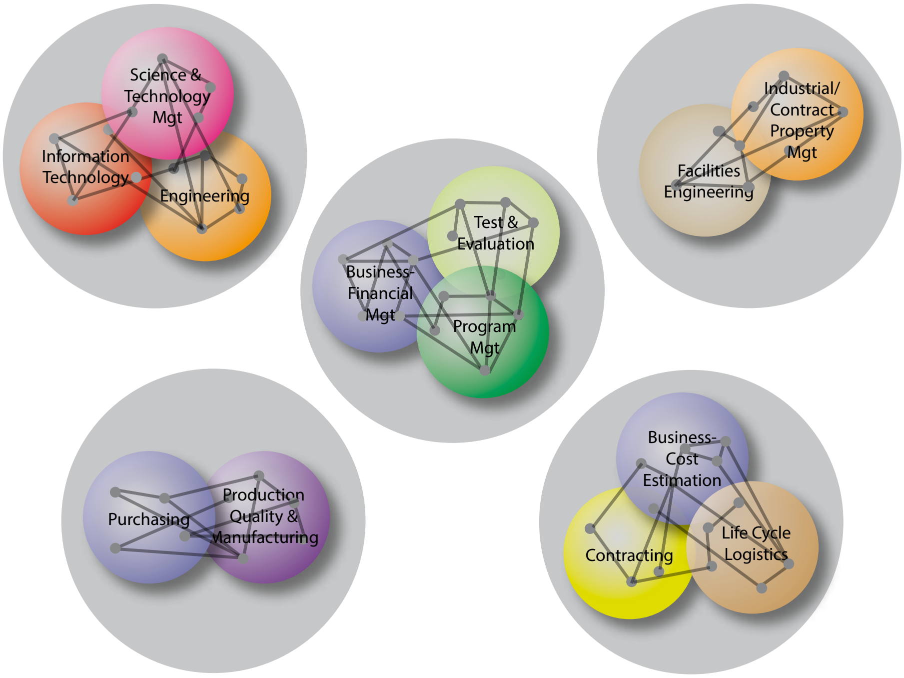
The study concluded that generalists (breadth) create many inventions that are not technically influential; specialists (depth) create fewer inventions but these are technically influential. The combination of breadth and depth (polymath) of expertise creates the most valuable inventors that have established a record for effectively converting inventions into commercially successful products. In other words, the polymath earned the most money for 3M by producing the most marketable inventions.

A "specialist" achieves very deep knowledge through study and experience. Studies found that specialists acquire ability for detailed and accurate analysis that lead to solutions of difficult technical problems in their areas of expertise. Specialists also make difficult trade-offs, and through deep knowledge can better predict what will go wrong. They create groundbreaking innovations by persistently exploring more deeply in a particular area.

Generalists have knowledge in a broad range of areas but lack expertise in any particular area. Generalists tend to enjoy new work and become bored when confined to one area; this inhibits their ability to develop the specialist's depth. Generalists focus on the application of technologies to useful products and integration of multiple technologies into a product, creating innovation through a broader focus.

Polymaths have acquired significant depth and breadth by first becoming experts in one area and then expanding their expertise into other areas. One polymath inventor at 3M had described the benefits of both in the study: "his depth of expertise plays a key role in identifying the technical contributions of an idea, while he draws upon a breadth of expertise to evaluate the potential ways the invention can impact different industries." By balancing the combination of depth and breadth, polymath inventors become astute at applying, integrating and recombining technology of their domains across other technologies and applications. Generalist inventors focus on finding new applications for a developed technology

Figure 4. Lack of Linkage Between Integrated Functions



but lack the depth to develop a new technology. Specialists develop the technology but lack the breadth needed to adapt it to various applications.

How are polymaths developed? The acquisition of depth probably precedes the acquisition of breadth. Once depth is acquired, the polymath can use that learning to accelerate the achievement of depth in other areas—acquiring the ability to go deep and then applying that ability to go broad. When breadth is established without first acquiring depth, depth probably will never be attained.

The study concluded that organizations need specialists, generalists, and polymaths but that "both breadth and depth of expertise are required to effectively convert inventions into commercially successful products that bring sales and value to the organization. The polymaths contributed not only by generating inventions, but applying these inventions widely to multiple parts of the organization, integrating with multiple technologies, thus becoming the most valued scientists of 3M."

This combination is created through starting careers that go into significant depth in single areas. Over time, significant knowledge and experience outside that one domain is acquired. By leveraging an understanding about how one becomes an expert, expertise is developed more quickly in other areas.

A polymath develops an interdisciplinary perspective by attaining depth and breadth across multiple disciplines, leveraging the knowledge interface between functional areas to develop the interdisciplinary perspective faster.

Rockefeller University

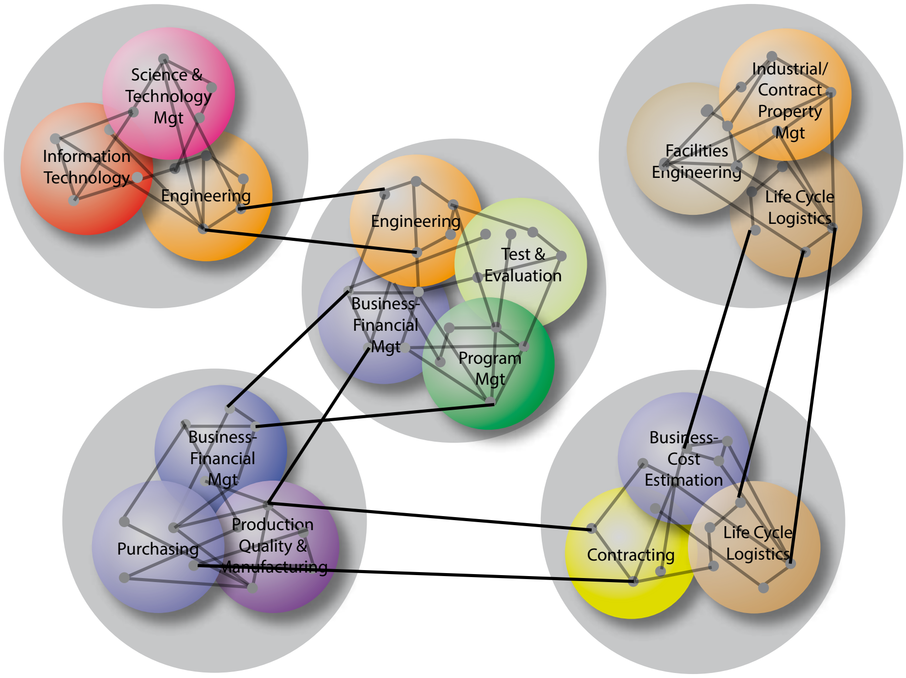
Rockefeller University (formerly the Rockefeller Institute) in Manhattan has implemented a unique approach to biomedicine research. The university holds more major discoveries in biomedicine than any other such research institute. Its faculty, fellows and alumni have included 27 Nobel laureates in physiology or medicine and chemistry, 22 Lasker Award recipients, five faculty members named as MacArthur fellows, 20 recipients of the National Medal of Science, and 18 National Academy of Medicine members. The joint National Academy of Sciences study said of the university that "major discoveries occurred relatedly because there was a high degree of interdisciplinary and integrated activity across diverse fields of science, and because of leadership that gave particular attention to the creation and maintenance of a nurturing environment, though with rigorous standards of scientific excellence ... there are three important characteristics: a high level of scientific diversity, low levels of internal differentiation, and visionary leadership." The university has 13 interdisciplinary centers dedicated to investigating the interstices between general areas of study, such as physics and biology or biochemistry and structural biology. Other centers focus on multidisciplinary methods of addressing specific biomedical problems.

This performance was achieved by recruiting researchers with diverse scientific and cultural backgrounds, most of them working in fields that crossed disciplines. The university did not organize around academic disciplines but instead around a laboratory environment deemed "without walls" to promote cross-knowledge utilization of scientists on research projects.

The Army's *Campaign Planning Handbook* recognizes a multidisciplinary perspective for solving complex problems in the counterinsurgency mission. A system-of-systems concept overlaps the six areas of political, military, economic, social, information and infrastructure and aligns with those disciplines. An interdisciplinary approach integrates the knowledge across these functional areas.

For teams to be effective, team members need common ground in order to develop fused ideas. Greater depth is developed in each discipline through linkages of the knowledge nodes. A team's work likely will evaluate solutions based on a particular functional approach when there is little common ground (few linkages) between the functions (Figure 4).

Figure 5. Knowledge Merger Among Team Members



Promoting development of a primary field for the workforce establishes expertise—and then secondary field certifications develop breadth. Integrated interdisciplinary teams leverage the connections of knowledge and provide a means for "seeing the space between nodes of knowledge." Common ground connects two different areas sharing modeling or statistical tools; analytical tools should complement training curriculums and position assignments. Interdisciplinary individuals resolve complex problems across multiple disciplines through the internal fusion of knowledge and understanding. Common ground is developed through linkages established between functional areas.

An interdisciplinary team merges knowledge across multiple disciplines; each team member's knowledge crosses at least two disciplines (Figure 5). For complex problems, greater insight is gained through crossing disciplines. The need to acquire breadth, even when pursuing advanced degrees, is recognized in recommendations for a new vision on the part of the academic institutional structure. As cited by the National Academy of Sciences:

> A matrix structure in a university might include many joint faculty appointments and Ph.D.s granted in more than one department which would enable participants to address cross-cutting questions more easily. It might create numerous interdisciplinary courses for undergraduates, provide mentors who bridge the pertinent disciplines, and equally important, offer faculty numerous opportunities for continuing education whereby they could add both depth and breadth of knowledge throughout their careers.

Implementation of interdisciplinary competence requires changes in current management recruitment, retention and promotion policies within the human resource management area. Position selections require criteria that balance specific skills for the current position with the ability to grow beyond that position through a breadth of knowledge and experience. Acquisition development requires special recruitment policies to target polymath individuals for certain senior positions. Incentives are needed in recruitment and selection to attract the best individuals for key positions. This means that, for vertical and horizontal development and advancement, a paradigm shift is needed away from traditional thinking. Expertise in acquisition policy should merely complement one's primary functional expertise.

DoD's complex technological advancement requires a paradigm shift from previous knowledge-based training and learning. An interdisciplinary program manager can facilitate the integration of a team's knowledge. In the case of both societal problem solving and technological advancement problem solving, it has been proved that the interdisciplinary approach enables exceptional performance unattainable through a single disciplinary or multidisciplinary approach.

The author can be contacted at **carol.mcilwain@navy.mil**.

MDAP/MAIS Program Manager Changes

With the assistance of the Office of the Secretary of Defense, *Defense AT&L* magazine publishes the names of incoming and outgoing program managers for major defense acquisition programs (MDAPs) and major automated information system (MAIS) programs. This announcement lists recent such changes of leadership for both civilian and military program managers.

Navy/Marine Corps

CAPT Christopher DeSena relieved **CAPT Joseph Kan** as program manager for the Mobile User Objective System (PMW 146) on Sept. 1, 2017.

CAPT Andrew Gibbons relieved **CAPT Mark Glover** as program manager for the Navy Multi Band Terminal (PMW 170) on Nov. 16, 2017.