

Army Officer Corps Science, Technology, Engineering and Mathematics (STEM) Foundation Gaps Place Countering Weapons of Mass Destruction (CWMD) Operations at Risk – Part 1*

LTC Andrew R. Kick¹, MAJ Stephen Hummel^{1,2}, LTC Matthew Gettings¹,
CPT Patrick Bowers¹, and COL F. John Burpo¹

1. Department of Chemistry & Life Science, United States Military Academy, West Point, NY 10996, USA
2. Biology Department, Boston College, Chestnut Hill, MA 02467, USA

**Note – This is the first of three articles from the authors describing the risk to Joint Operations incurred by an Army that is vulnerable to the STEM challenges faced in a great power competition involving CWMD operations. In this article, we describe the problem. In articles two and three of the series, we will elaborate on the problem utilizing the Joint Publication 3-0 as our guide and recommend solutions to address this gap.*

Situation:

Step inside nearly any university research lab and you will find few students destined to become Army officers. In January 2021, the Pentagon published the annual report on U.S. Defense Industrial Base Industrial Capabilities.^{1,2} The findings are alarming: the lack of STEM educated Americans may lead to a “permanent national security deficit”.³ Both Russia and China are producing several times more STEM graduates than the U.S.⁴ As a result of lacking enrollment by American students, the technical programs of U.S. universities are seeking foreign students to fill the gap.⁵ More than half of foreign students in the U.S. universities are enrolled in STEM degree programs.

Lieutenant Colonel Andrew R. Kick is an Academy Professor in Life Science in the Department of Chemistry and Life Science at the United States Military Academy at West Point and serves as the Director of the Center for Molecular Science. LTC Kick earned a B.S. in Biology from the University of Dayton and commissioned as a military intelligence officer. He received both his M.S. and Ph.D. from North Carolina State University with an Immunology concentration. His email address is andrew.kick@westpoint.edu.

MAJ Stephen Hummel is a PhD candidate at Boston College, in Chestnut Hill, MA. He has a BA in political science from Boston College and two M.S. in Free Radical and Radiation Biology from the University of Iowa and Chemical and Physical Biology from Vanderbilt University. He was previously assigned as a Deputy, Commander's Initiatives Group at the 20th CBRNE Command. His email address is Stephen.g.hummel2.mil@mail.mil.

LTC Matthew Gettings is an Assistant Professor at the U.S. Military Academy, in West Point, NY. He has a B.S. in Electrical Engineering from the U.S. Air Force Academy, a M.S. in Nuclear Engineering from the Air Force Institute of Technology, and a Ph.D. in Materials Engineering from Purdue University. He was previously assigned as a Test Operations Officer and Experiment Director at the Defense Threat Reduction Agency (DTRA) Kirtland AFB, NM. His email address is matthew.gettings@westpoint.edu.

CPT Patrick Bowers is an instructor in the Department of Chemistry and Life Science at the United States Military Academy, at West Point, NY. He has a B.S. in Chemical Engineering from the United States Military Academy and an M.S. in Chemical Engineering from Purdue University. He was previously assigned as a as the battalion intelligence officer for the 2D Chemical Battalion, the commander of Headquarters and Headquarters Company, 48th Chemical Brigade, and the brigade threat assessment officer for the 48th Chemical Brigade. His email address is patrick.bowers@westpoint.edu.

COL John Burpo is the Department Head of Chemistry and Life Science at the United States Military Academy at West Point. He has a B.S. in Mechanical-Aerospace Engineering from West Point, a M.S. in Chemical Engineering from Stanford University, and a Sc.D. in Bioengineering from the Massachusetts Institute of Technology. He was previously assigned as the Deputy Commander-Transformation at the 20th CBRNE Command. His email address is john.burpo@westpoint.edu.

During 2010-2019, approximately 42% of graduating STEM program Ph.D. students in the U.S. were from foreign nations.^{6,7} In 2020, the majority of these students arrived from India (18%) and China (35%).^{8,9} Consequently, the U.S. DoD and defense contractors suffer from a shrinking population of U.S. citizens with technical degrees capable of passing background investigations to obtain the necessary security clearances to support our Nation's technical defense requirements.¹⁰

Although the report focuses on education deficit in artificial intelligence (AI) and machine learning, similar trends remain true across the spectrum on STEM fields such as bioengineering, materials science, and chemical engineering, all critical to developing and transitioning key technologies for the Warfighter, as well as providing necessary expertise for the defense industry and higher echelon military staffs. Less than 20% of electrical engineering and computer science students are Americans.¹¹ This has a direct impact on national security given our increased reliance on artificial intelligence and cyber systems.¹² Perhaps in response to this STEM education deficit as articulated in the Pentagon Report, President Biden signed an Executive Order adding the Office of Science and Technology Policy (OSTP) as a cabinet-level agency.¹³

Not only are Chinese students dominating STEM fields in U.S. universities, China's national power is further demonstrated by superior performance among graduate doctoral programs. In August 2021, the Center of Security and Emerging Technology (CSET) presented data which demonstrated that China is fast outpacing U.S. STEM PhD Growth.¹⁴ Since 2003, more Chinese graduate students earned PhDs in STEM fields than U.S. domestic graduate students.¹⁵ Many of the Chinese PhDs are attained at top-tier U.S. institutions. By 2025, China is forecasted to produce more than three times as many STEM PhD graduates as the U.S.¹⁶ The result is not by chance. China has spent significant resources developing its universities to strengthen Chinese human capital as part of "comprehensive national power".¹⁷ China's success is not simply due to increased funding rather its focus and national resolve on increasing its STEM capacity.^{18,19}

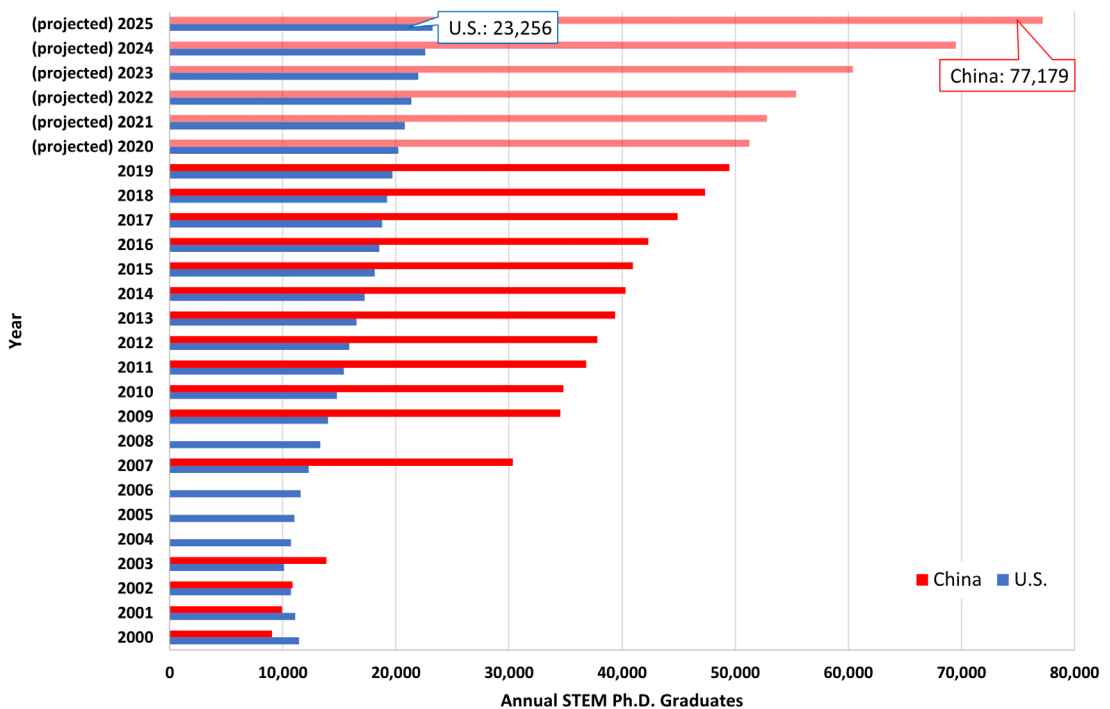


Figure 1. Data obtained from Georgetown University Center for Security and Emerging Technology.²⁰

For perspective, though, a lack of STEM dominance among American students is not a new problem. After the U.S.S.R. successfully launched Sputnik into orbit in 1957, the U.S. government took aggressive action to improve science and math education.²¹ In 1958, the National Defense Education Act authorized \$1 billion to “overhaul the American education system from schools to universities at the federal level”.²² Soon, talented students benefitted from advanced placement in science and math courses where calculus became part of their high school curriculum. These specialized tracks enabled a large increase in STEM degrees beginning in the 1960s.²³

The U.S. federal government by policy and funding levels continues to put a high premium on Science and Technology (S&T) research and education (~\$120 billion annually between FY 2010-2017), which is the largest federal government investment of any world nation.²⁴ This problem and national vulnerability is well-known and is concerning to our national leadership. Key United States of America National Strategy documents identify that STEM competence, competition, and dominance is a national security priority: National Security Strategy (2017),²⁵ National Defense Strategy (2018),²⁶ a 21st Century Science, Technology, and Innovation Strategy for America’s National Security (2016),²⁷ National Strategy for Countering Weapons of Mass Destruction Terrorism (2018),²⁸ and the National Biodefense Strategy (2018).²⁹ Though described differently across these documents, S&T advancement and primacy is linked to our Nation’s strength and defense. Despite this emphasis and unifying theme, the Army Officer Personnel Management System (OPMS) and Officer Education System, to include Professional Military Education (PME), do not prioritize or effectively support our National Strategy because STEM competency is not prioritized through commissioning sources, educational opportunities, or PME.

Thesis:

The Army Officer Corps is developing a widening gap in STEM-discipline undergraduate and graduate degree expertise placing the United States at risk for Countering Weapons of Mass Destruction operations. Accordingly, STEM proficiency at the undergraduate-level and graduate-level is a critical component for all Army branches (not only Functional Areas / Medical Service Corps) and requires resourcing, opportunity, and advancement commensurate to its priority in the National strategy.

Need:

Army Officer regulations, practices, and priorities rightly emphasize leadership and command. Officers lead the Army. Commanders at all levels from the company to the component / combatant command apply mission command to command and control units to achieve the assigned mission.³⁰ Command is referred to as more “art than science because it depends upon actions only human beings can perform” and “incorporates intangible elements of authority, responsibility, decision making, and leadership”.³¹ ADP 6-0 elevates the art of war above the science of war; however, in CWMD multi-domain operations incorporating the six warfighting functions into effective decision making within mission command requires not only tactical competence but STEM competence. In CWMD multi-domain operations, the science of command surpasses the art of command. As illustrated in ADP 6-0, Figure 1-2, Combat Power Model,³² the Commander and her / his staff must possess the S&T competence to unify these disparate functions: as each function becomes more technically complex, STEM competence and the critical thinking / technological competence provided through advanced STEM degrees are necessary on the tactical and operational levels to facilitate right decision making.



Figure 2. The combat power model illustrates the relationship between the six warfighting functions with command and control being the unifying function.³³

A simple word search of key Army doctrine demonstrates the lack of emphasis on STEM / S&T competence in decision making and Army operations:

- ADP 3-0, Operations³⁴ (science always in relation to warfare, operations, or understanding)
- ADP 5-0, The Operations Process³⁵ (science always in relation to operations or understanding)
- ADP 6-0, Mission Command³⁶ (science always in relation to command, warfare, or information)
- ADP 6-22, Army leadership and the Profession³⁷ (science, no link to STEM / S&T)
- 2019 Army Modernization Strategy³⁸ (S&T emphasized but not in relation to officer competence)
- Army Chief of Staff Papers #1 and #2, March 2021^{39,40} (S&T emphasized but not for officer competence)
- The Army People Strategy, October 2019⁴¹ (only in relation to talent management improvement, not actual STEM competence)
- ATP 3-90.40, Combined Arms Countering Weapons of Mass Destruction⁴² (one mention of forensic science)

As far as the Officer Education System, the FY20 and FY21 U.S. Army Accessions Mission Letter⁴³ for Officer Commissioning sources establishes a goal of 25% of contracted cadets assess in an undergraduate STEM program with overproduction encouraged (this excludes AMEDD with specific STEM accessions requirements). Indeed, the Army exceeds this goal for commissioning: the number of Army ROTC graduates with STEM degrees averaged ~30% in FY19-21 and the number of United States Military Academy graduates with STEM degrees is historically stable at approximately 50%.⁴⁴ Within PME, for senior company grade and junior field grade officers, STEM advanced degrees opportunities become available through three routes: a United States Military Academy (USMA) Advanced Civilian Schooling (ACS) fellowship, the broadening opportunity program or through Functional Area designation and qualification. Outside of those categories (and exceptions), PME and graduate-level education is devoted to non-STEM fields. And in fact, officers who pursue advanced civilian education opportunities in STEM will likely experience a delay in

promotion due to an insufficient number of field-grade (O-5) evaluations, or pausing their promotion year group, as a result of their time in graduate school compared to officers who remain in operational assignments. At the Senior Service College / Fellowship level, PME is again focused on competence in strategy, federal government / international relations, and leadership instead of STEM competency.

This dichotomy between declaring a need for leaders competent in STEM and prioritizing the fulfillment of that need can be seen through the Army's FY2021 Broadening Opportunity Program catalog.⁴⁵ The catalog, which lists the assignments the Army will fund for broadening opportunities, has 15 opportunities for broadening assignments with graduate degree outcomes. Of those 15 opportunities, only two have the directive to focus on STEM related topics, the Purdue Military Research Initiative (PMRI) and the Army Futures Command Artificial Intelligence Scholar Program, and while the PMRI attempts to focus on STEM related degrees, it is not a requirement of the program. The cost of these respective programs available to STEM focused leaders versus their non-STEM counterparts is additionally concerning. PMRI falls into the "low cost" category for the Army's Advanced Civil Schooling program, meaning the Army pays under \$26,000 per year per graduate student. Compared to the remaining 13 non-STEM focused programs, three are high-cost category which can be as much as \$55,000 per year per student with an additional three programs that are either medium-cost or high-cost category depending on student selection. In essence, the Army places between a \$17,000 and \$29,000 premium on non-STEM related graduate degrees.

Accordingly, Field-grade and General Officers serving in critical Command billets from Battalion through Component / Combatant Commands largely lack the STEM expertise to integrate the technological advances of the warfighting functions most effectively. Among active-duty Army general officers, 10% earned a graduate degree in a STEM field and 30% completed undergraduate STEM programs.⁴⁶ Though possibly surrounded by staffs for functional area competence, their own limited understanding of STEM creates vulnerability and risk either through over reliance on S&T experts or personal bias with respect to S&T issues. These commanders have commanded at the most challenging operational assignments resulting in positions of command with increasing authority; however, the Army has not prioritized continued STEM education in their career progression and leader development.

Despite STEM-education and excellence being a National-priority as described in Executive Strategic policy documents, the Army does not prioritize STEM education either in accessions (30-50% accessed) or in the PME system. The Army is currently not aligned with the National Strategy for STEM dominance in the face of future CWMD operations in a great power competition. The Army's failure to emphasize STEM competence in the Army Officer Corps outside of Functional Areas creates risk to mission accomplishment in CWMD multi-domain operations. The Army must prioritize STEM education in accessions and throughout PME to prepare commanders for effective S&T informed decision making within mission command in CWMD multi-domain operations.

Approach:

In the next two CWMD Journal issues, the authors will argue our thesis utilizing JP 3-0 as a frame of reference for CWMD Operations. JP 3-0, Joint Operations, describes a Joint Operational Model with notional phasing for predominant military activities.⁴⁷ Applying the Joint Operational Model to a regional or great power competition involving CWMD operations provides a construct to evaluate how Army Officer STEM competence support Joint Operational success in each phase. Our next article (Part 2) will address the risk of our current efforts as we operate in Phases 0 and 1 (Shape and Deter) CWMD operations in multiple theaters of operation. Our final article (Part 3) will examine the transition to decisive action / unified action with Phases 2 - 5 (Seize the Initiative through Enable Civil Authority). Through this project, we will explore and identify specific risks to Joint Operations incurred by an Army that is ill-prepared to meet the STEM challenges faced in a great power competition involving CWMD operations. The goal of this project is to support our thesis through demonstrated facts and scenarios in order to convince Senior Leaders that a new prioritization of

officer education to achieve STEM competence from undergraduate commissioning through senior service college or equivalent is required for the Army to support Joint CWMD operations in multi-domain operations.

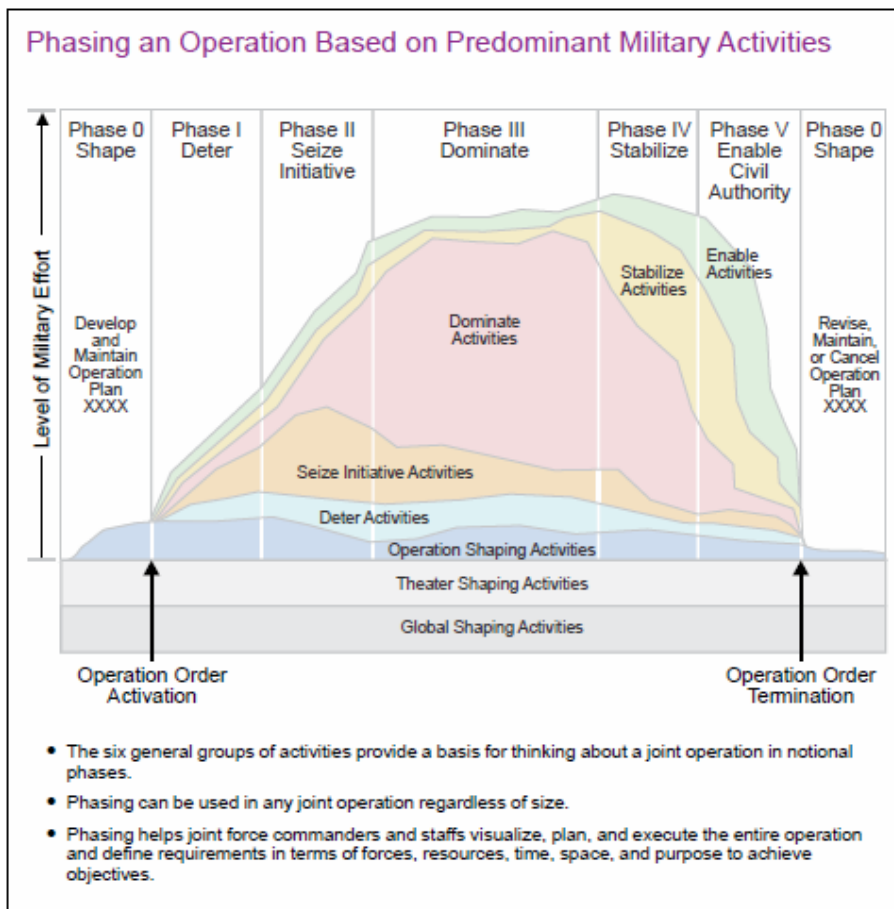


Figure 3. Applying the Joint Operational Model to a regional or great power competition involving CWMD operations provides a construct to evaluate how Army Officer STEM competence support Joint Operational success in each phase. Part 2 of our series will address Phase 0 and 1. Part 3 of our series will address Phases 2 – 5.⁴⁸

Notes

1. Turner, J. (2021, February 7). Report: Pentagon Says STEM Education Deficit is Weakening America. (Center for the National Interest) Retrieved from <https://nationalinterest.org/blog/buzz/report-pentagon-says-stem-education-deficit-weakening-america-177680>
2. Office of Secretary of Defense A&S Industrial Policy. (2021). U.S. Defense Industrial Base Industrial Capabilities. OSD A&S Industrial Policy.
3. OSD A&S, page 8.
4. OSD A&S, page 15.
5. OSD A&S, page 112.
6. Zwetsloot, R., Corrigan, J., Weinstein, E., Peterson, D., Gehluas, D., & Fedasiuk, R. (2021). China is Fast Outpacing U.S. STEM PhD Growth. Georgetown University. Center for Security and Emerging Technology. doi: <https://doi.org/10.51593/20210018>, page 8.
7. OSD A&S, page 102.
8. OSD A&S, page 102.
9. Institute of International Education. (2021). Open Doors 2020 Report on International Educational Exchange. Retrieved from <https://opendoorsdata.org/annual-release/>
10. OSD A&S, pages 102, 112.
11. OSD A&S, page 104.
12. OSD A&S, page 19.
13. Turner, J, page 1.
14. Zwetsloot, R, page 1.
15. Zwetsloot, R page 13.
16. Zwetsloot, R page 12.
17. Zwetsloot, R page 2.
18. Xinhua. (2021, October 1). Xi Focus: Leading China

- on its new journey. Retrieved from China Daily: <https://www.chinadaily.com.cn/a/202110/01/WS6156d-6f7a310cdd39bc6cccb.html>
19. Xinhua News Agency. (2021, September 29). Xi calls for accelerating building of world center for talent, innovation. Retrieved from People's Republic of China State Council: http://english.www.gov.cn/news/topnews/202109/29/content_WS6153c-339c6d0df57f98e108d.html
 20. Zwetsloot, R page 12.
 21. Herman, A. (2019). America's STEM crisis threatens our national security. *American Affairs*, III(1), 127-148.
 22. Herman, A page 15.
 23. Herman, A page 18.
 24. <https://nces.nsf.gov/pubs/nsf21328> (accessed October 5, 2021).
 25. The White House, National Security Strategy of the United States of America, (Washington, DC: White House, 2017), page 20.
 26. Department of Defense, Summary of the 2018 National Defense Strategy of the United States of America, (Washington, DC: Department of Defense, 2018) page 10.
 27. 21st Century Science, Technology, and Innovation Strategy for America's National Security, page 1.
 28. The White House, National Strategy for Countering Weapons of Mass Destruction Terrorism, (Washington, DC: White House, 2018), page 12.
 29. The White House, National Biodefense Strategy, (Washington, DC: White House, 2018), page 16.
 30. US Army, Mission Command, Army Doctrine Publication (ADP) 6-0 (Washington, DC: US Army, 2019), 1-21.
 31. ADP 6-0, 2-1.
 32. ADP 6-0, 1-20.
 33. ADP 6-0, 1-20, Figure 1-2.
 34. US Army, Operations, Army Doctrine Publication (ADP) 3-0 (Washington, DC: US Army, 2019).
 35. US Army, The Operations Process, Army Doctrine Publication (ADP) 5-0 (Washington, DC: US Army, 2019).
 36. ADP 6-0
 37. US Army, Army Leadership and the Profession, Army Doctrine Publication (ADP) 6-22 (Washington, DC: US Army, 2019).
 38. US Army, 2019 Army Modernization Strategy, (Washington, DC: US Army, 2019).
 39. US Army, Army Chief of Staff Papers #1, (Washington, DC: US Army, 2021).
 40. US Army, Army Chief of Staff Papers #2, (Washington, DC: US Army, 2021).
 41. US Army, The Army People Strategy, (Washington, DC: US Army, 2019).
 42. US Army, Combined Arms Countering Weapons of Mass Destruction, Army Techniques Publication (ATP) 3-90.40, (Washington, DC: US Army, 2017). 2-9.
 43. Brigadier General Douglas F. Stitt, FY20 and FY21 U.S. Army Accessions Mission Letter (official memorandum Washington, DC: Office of the Deputy Chief of Staff, G-1, 2019), page 3.
 44. Personal communication with Operations Research/Systems Analyst in Officer Strength and Forecasting, October 13, 2021.
 45. US Army BOP Catalog, FY2021 <https://www.benning.army.mil/Armor/OCOA/content/References%20and%20Guides/2021%20Broadening%20Opportunity%20Program%20Catalog.pdf> (army.mil) (assessed November 23, 2021).
 46. Tingle, Anthony. 2021. Army Generals Are Not Prepared for the Future. *Defense One*. May 22. <https://www.defenseone.com/ideas/2021/05/army-generals-are-not-prepared-future/174130/>.
 47. Joint Chiefs of Staff, Joint Operations, JP 3-0, (Washington, DC: Joint Chiefs of Staff, 2018), V-13.
 48. JP 3-0, Figure V-7.



LTC Matt Gettings, during his Ph.D. research at Purdue University, holds a test container of silver salts, a new lead-free explosive that he synthesized in an Army funded research laboratory at Purdue.