

The ARL Davies Fellowship – A Model for Undergraduate Research

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Abstract

The Davies Teaching Fellowship is a National Research Council (NRC) teaching and research award sponsored jointly by the U.S. Army Research Laboratory (ARL) and the United States Military Academy (USMA) in West Point, NY. For the last 20 years ~40 different civilian scholars from mathematical and engineering backgrounds have been selected from this three-year award. The joint award can be characterized as assistance from an ARL research project while the remainder of the award is granted by a department at USMA. This fellowship not only assists USMA at an operational level, but it also is a unique opportunity for civilian faculty because it provides an environment to conduct research at an undergraduate institution without the interruption of classroom instruction that can minimize original research, grant submission, and publishing. Here, we discuss the history of the Davies Fellowship and offer it as a model to conduct efficient research at undergraduate institutions by enabling a research model in a robust fashion. This analysis will illustrate how undergraduate institutions can efficiently integrate research to bolster classroom activities. Additionally, we draw conclusions and predictions on how the Davies Teaching Fellowship can improve in the next 20 years.

Introduction

The Davies Teaching Fellowship Program

The Davies Teaching Fellowship is a postdoctoral teaching and research award sponsored jointly by the U.S. Army Research Laboratory (ARL) and the United States Military Academy (USMA) in West Point, NY. The fellowship is named after Charles Davies who started his military career at USMA in 1813 at the age of 15 and graduated after studying for 2 years after very little formal education (Arney, 2002). Charles Davies was appointed to USMA as an assistant professor teaching mathematics in 1816 when he resigned from the Army's Corps of Engineers. His tenure at USMA allowed him to develop and change the curriculum, publish several articles and books on mathematical theory that were used for educating the cadets at West Point as well as other colleges and universities in the developing United States (Arney, 2002; Cocke & Moore, 2012; Shell-Gellasch & Rickey, 2010; Shell, 2002). His work ethic and developmental attitude would change how American students learned, particularly mathematics which in the 1800s was important to develop the country's engineers and future scientists.

The Davies Fellowship is granted to civilians with doctoral degrees, contracted through the National Research Council's (NRC) Research Associates Program (RAP) (The National Academies of Sciences, Engineering, 2017). Since 1776, the Army has employed experienced civilians that provide mission-essential capabilities who are committed to selfless service to work alongside men and women in uniform filling critical roles allowing Soldiers to focus on their mission. Particularly at installations such as USMA, the need to employ technically experienced civilians with advanced degrees improves the quality of teaching and academic rigor at the Service Academy (Army, 2018).

The United States Military Academy in West Point, NY is an undergraduate institution with an academic curriculum designed to teach cadets how to critically think and expand their knowledge

in several different disciplines while being exposed to various teaching styles. USMA is designed to educate, train, and inspire cadets so that each graduate is a commissioned leader of character for a career of professional excellence as an officer in the United States Army (Callina Schmid et al., 2017; Superintendent USMA, 2017). This is accomplished through its organizational structure of officers and civilians who are dedicated for the mutual development between faculty and staff that benefits students and faculty. In 1992, the Defense Authorization Act directed the Army to adopt a policy of hiring and maintaining a greater number of civilians on the faculty at USMA which was historically 96% to 4% military-to-civilian mix (Rhynedance, 1993). Under this act, changes were made to diversify USMA and increase the number of civilian faculty to maintain and increase the high level of academic integrity compared to civilian institutions (USA.gov, n.d.). Currently, the ratio of academy faculty and staff is approximately 25% with civilian faculty maintaining a similar structure compared to their military counterparts with rotating military and civilian faculty, and full military and civilian professors within each department (Jebb, 2018). The integration of multifaceted faculty's efforts with undergraduate research improves the mission of the academy and the Army.

One way USMA connects to the Army is through its academic research division by conducting research that is well aligned in ARL directives and Army goals. In order to solidify research ties and establish continuity between USMA and ARL, the Davies Fellowship serves a crucial role of integrating research at USMA and ARL by supporting the professional growth of civilian and military faculty in research and scholarly work directly. In 1996, the first Davies Teaching Fellowship was awarded in the Department of Mathematical Sciences (Science, 2018). For the past 20 years, 41 civilians with doctoral degrees have been granted the Davies Fellowship which is jointly sponsored from ARL and an academic department at USMA. Of the 41 civilians, 37 of them held doctoral degrees in mathematics, two held doctoral degrees in mechanical engineering, one doctoral degree in geology, and one doctoral degree in biomedical engineering. Most fellows came

directly from graduate school, and it is their first appointment after years of schooling. On average, there are less than two new fellows per year, but since the fellowship lasts three years, at any one time there are always multiple fellows at USMA and ARL. Considered young faculty, these Davies Fellows come with novel ideas, excitement, and drive that is consistent with USMA's mission to "educate, train, and inspire" but have a lower teaching load. After their three year fellowship, some take positions at ARL or other DoD laboratories but most (~70%) return to universities to become assistant professors and work their way to associate or full professors in their respective departments. They will progress well within their fields as many STEM careers require fellowships prior to becoming tenure-track faculty.

Teaching requirements from the Davies Fellowship occur in the academic department at USMA that funds the fellow, and the fellow is granted the title of Assistant Professor (Science, 2018). During their teaching semester, fellows hold the same workload as rotating military faculty taking a majority of their time to educate cadets. However, unlike the remaining faculty who teach both semesters and through the summer, Davies Fellows have their second semester and the summer to focus on and conduct research. Nevertheless, throughout both semesters the faculty learn leadership skills, serve as a mentor for undergraduate character development, and take part in the Faculty Council while acting as mentors and sponsors to enhance the cadets' character and leadership development. As future commissioned officers in the Army solving complex problems up to strategic level, cadets will interact with civilians and this opportunity as a Davies Fellow is one way to help provide exposure in those circumstances.

The research requirements for the Davies Fellow is partnered with ARL whose mission is "to provide innovative science, technology, and analyses to enable full-spectrum operations with its diverse assortment of facilities and government scientists and engineers that conduct basic and applied research" (Labs, n.d.). ARL consists of directorates which focus on technology areas

critical to strategic dominance across different operations. ARL's mission is to discover, innovate, and transition science and technology to ensure dominant strategic land power through its fundamental campaigns in material research, sciences of maneuver, human sciences, and sciences for lethality & protection. These campaigns are incorporated with their vision in computer sciences, analysis & assessment, information sciences, and extramural basic research. This mission is combined with the Army's modernization priorities within cross functional teams to advance long range precision fires, next generation combat vehicles (NGCV), future vertical lift (FVL), network/C3I, air & missile defense, soldier lethality, assured position, navigation & timing, and synthetic training environments (Labs, n.d.). Additionally, ARL has extended through Army Future Command's co-location of Army civilian personnel to establish the Open Campus Extended Sites at specific locations in the Central, Northeast, South, and West United States of America. This new platform allows ARL to establish fundamental collaborations by developing collaborative research centers that address problem critical to the U.S. Army and National Security. The 15 new research centers are 1) Atmospheric Science Center (ASC), 2) Center for Adaptive Instructional Sciences (CAIS), 3) Center for Adaptive Soldier Technologies (CAST), 4) Center for Agile Materials Manufacturing Science (CAMMS), 5) Center for Cyber Analysis & Assessment (CCAA), 6) Center for Human Injury and Performance (CHIP), 7) Center for Impact Physics (CIP), 8) Center for Research in Extreme Batteries (CREB), 9) Center for Semiconductor Modeling of Materials and Devices (CSDM), 10) Center for UAS Propulsion (CUP), 11) Cyber Research Center (CRC), 12) Intelligent Systems Center (ISC), 13) Network Science Research Center (NSRC), 14) Novel Energetics Research Center (NERC), and 15) Semiconductor Research Nanofab Center (SRNC) (ARL, n.d.). The goals of the Open Campus and research centers are to bring together government laboratories, academic institutions, and the private sector to form a global network to form new technology directions, perspectives, and discoveries (ARL, n.d.; Labs, n.d.).

With the full spectrum of engineering requirements for the Army, the importance of the Davies Fellowship provides a strong opportunity to strengthen research with the training required for new officers. ARL does offer their own post-doctoral research fellowships through the NRC with a focus on the individual directorates, however, Davies Fellows work closely with ARL advisors but also bridge the gap with officer scholars and future officers as cadets at USMA. Strengthening and increasing the number of Davies fellows in other USMA departments can establish stronger research connections with USMA, civilian institutions, ARL, and with other directorates and departments. Additionally, it represents a shift in undergraduate pedagogical approaches where cadet researchers are expected to publish to improve their chances for advanced schooling. Furthermore, it also creates a new developmental model that helps benefit civilians to become leaders in their respective fields outside of research as the requirements to become a Principal Investigator may involve management and organization.

Benefits of Fellowships

Fellowships are highly competitive awards that grant honor and prestige to the winners to launch them into successful careers (Frame, Johnson, & Rosie, 2006). Fellowships come in many forms and are funded through several granting agencies, each with their own unique attributes providing professional enhancing experiences and responsibilities for the fellows. There are many positive outcomes from fellowships for the awardee and the awarding institution. The awardee is normally granted prestige due to the fellowship, and the awarding agency gains recognition to showcase the talent that matches their award to benefit the institution.

Fellowships are based on future potential as demonstrated by past achievements, and unlike scholarships, fellowships are types of grants that allow individuals to receive funding while pursuing specific interests without having to payback services. Both awards offer unique experiences to the fellows which can help them define their career. Fellowships are normally awarded through

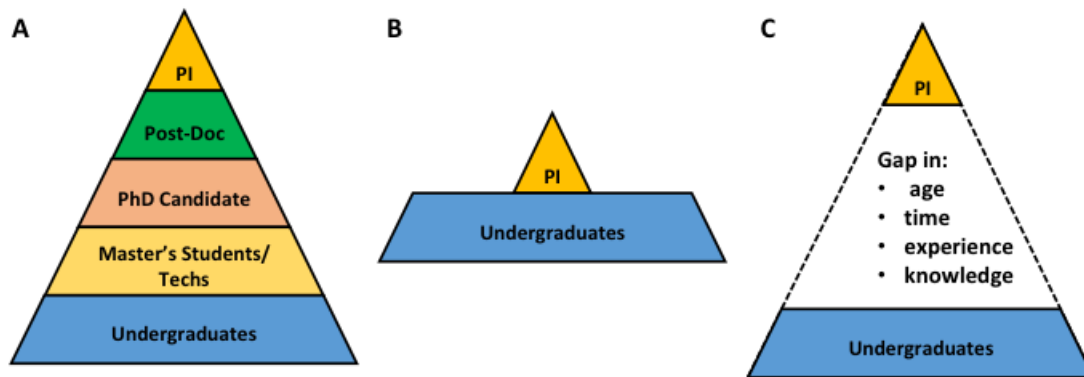
government-funded agencies such as the National Science Foundation (NSF), the Department of Defense (DoD), the National Institute of Health (NIH), or from privately funded institutions. Awards from different agencies can define the career trajectory for the fellow and provide unique experiences that shape their research or teaching expertise as the title associated with each fellowship follows them throughout their career and ultimately forms a network for those individuals to connect at different levels.

At most institutions, particularly in scientific fields, the primary mission of the fellow is to conduct research and publish their work as publications allow scientists to compete for future funding opportunities. Indeed, current Davies Fellows have found success by publishing in peer reviewed journals, acting as principal investigators on research grants through the Office of Naval Research (ONR) and Defense Threat Reduction Agency (DTRA), and won multiple awards in young investigator forums. At civilian institutions, individuals with research fellowships ask for teaching “experience” which may or may not be granted by their advisor. In most cases teaching experience in Science, Technology, Engineering, and Mathematics (STEM) courses are given to Fellows where there are gaps in schedule and needs for instructors. Major research universities represent 3% of higher education institutions but confer 32% of baccalaureate degrees (Katkin, 2003). On examination of teaching and research fellowships, there are few that provide a blend for both research and teaching experiences. However, in the developing academic culture today, most fellows who become professors will teach and conduct research as both have been shown as major developmental components. The Davies Fellowship represents a model to offer both teaching and research experience that can benefit the undergraduate institution and the awarded fellow.

Research at Undergraduate Institutions

Research at undergraduate institutions is challenging since graduate degrees are not awarded resulting in lack of experience at many levels from students with completed bachelor degrees

(Master's students), students with Master's degrees (Ph.D. candidates), and researchers with doctoral degrees (Post-docs). Most research universities develop a pyramid structure similar to hierarchical structures found in any organization, particularly the military (**Figure 1**).



*Figure 1. **Structure of research laboratory.** (A) A standard research university hierarchical structure consists of a Principle Investigator (PI), postdoctoral researchers (Post-Doc), PhD candidates, Master's students or technicians, and undergraduate students. (B) Research at undergraduate institutions consists of PIs and undergraduate students. (C) The gap in age, time, experience, and knowledge that limits high quality undergraduate research.*

Principal Investigators (PIs) are the leaders in any research team at academic institutions or industry. Most academic laboratories, research facilities, government research groups, or private research sectors contain PIs, who have doctoral degrees with several years of research and technical experience. The PI heads a team of individuals who take on the responsibility of carrying out the ideas and ensuring execution of daily tasks are enforced to generate sufficient novel data. Professors are the organizational leaders who define the research goal and vision due to their knowledge and have the final documentation, plan, or execution of the laboratory. Typically, professors are the primary PI's in academia, though post-docs and research faculty can fill that role. The Davies Fellowship offers direct exposure for civilians to become principal investigators where organizational leadership in research can be imperative for career success, and is not the primary focus of many civilian post-doc models.

Following the PI in the hierarchical structure are postdoctoral researchers or “post-docs” who carry out a bulk of the experimental design and execution and advise research following the award of

their doctoral degree. As the name implies the post-doc occurs after acquiring a doctorate and, as in any field such as higher education, medicine, or law, is an advanced training time to solidify and strengthen doctoral training and develop a future research path. A successful lab will attempt to have a small number of post-docs that are the bridge between the professor and graduate students because the post-docs have the necessary experience associated with the degree and are building the skills necessary to become PIs. Post-docs carry out the model scientific skills such as publishing in peer-reviewed journals as well as interacting with students while conducting research and administrative materials. Often it is these individuals who have the most profound effect on students because they handle the day-to-day activity, have a working knowledge of the lab, and deal with students on a first name basis. A talented post-doc can have the skill to work with several teams of students, either on similar projects or different projects, which allow them to develop the depth and breadth to complete long term tasks. Post-docs play a quintessential role because during their transition to a young faculty member or industrial PI, they want to inspire students because they interact with them more closely. A lab can be staffed with qualified post-docs or young faculty who are developing their careers and enrich passion and drive to develop the younger students.

Following in the leadership structure are the graduate students and laboratory technicians who play a critical role in any laboratory as they help carry out experiments and common research techniques that are associated with research projects. Laboratory technicians normally hold Master's degrees and have several years of experience working on technical equipment. They prepare samples and take care of machines and from a military perspective are warrant officers who understand every aspect of the equipment they control. Technicians are a vital part of developing sound and qualified research. At research institutions, lab technicians assist professors and handle administrative tasks associated in the laboratory such as stocking chemicals, tools, and parts when supplies are low. They maintain upkeep of the lab, cleanliness, and are the constant face associated with it. They also run experiments and are part of the team to maintain synergy within the lab. However, more

experienced technicians can assist with grant and manuscript writing as well as be co-PIs on grant contributions.

Finally, the workers in the labs are undergraduate students who are learning experimental material from the theoretical background that they learned in the classroom. However, at undergraduate institutions where graduate students and post-docs are not part of the lab and faculty having a significant teaching burden, time and ability for advisors to appropriately train students in research methods is limited and may require additional time (**Figure 1b, Figure 1c**).

With the high focus on technology in the military and civilian organizations, it seems appropriate for USMA to strengthen research objectives to maintain a competitive advantage. With the strategic changes taking place in the Army and ARL and the close contact to multiple Department of Defense (DoD) agencies such as the Defense Advanced Research Projects Agency (DARPA) and the Defense Threat Reduction Agency (DTRA), Davies Fellows have the opportunity to connect their projects with these agencies to expand their research portfolio which is different than their counterparts at other institutions and fellowship programs. Particularly when students are encouraged to define problems by gathering and synthesize information using a wide range of techniques, research is one of the most well focused methods to collect information. Research allows students to explain ideas using proof that can be corroborated using multiple techniques. Undergraduate research can train cadets to apply creativity and critical thinking in order to logically make meaningful connections and distinctions across different disciplines. At USMA due to the focus on classroom instruction, research can be used as an additional training and teaching experience to develop cadets providing them the opportunity to develop their critical thinking skills. There are opportunities for cadets to work with senior faculty to conduct research, however, with the heavy teaching commitment, time and ability for advisors to appropriately train cadets in research methods is limited. Cadets can experience Academic Individual Advanced Development

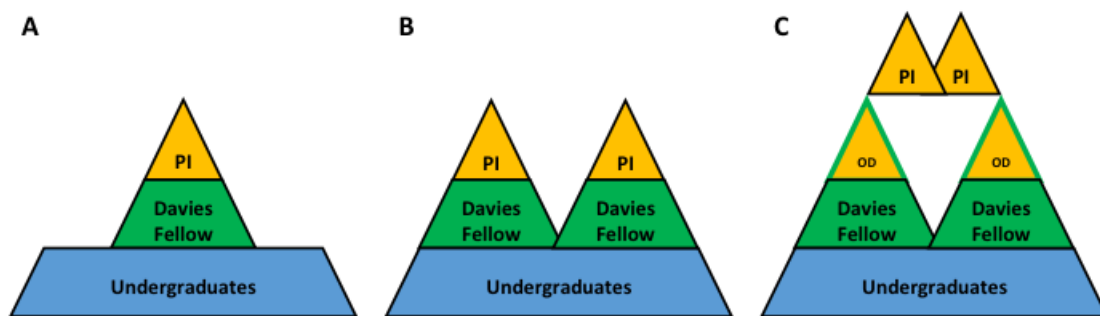
(AIAD) opportunities to strengthen research experiences during their summer months. However, these experiences tend to be several weeks long giving cadets a small exposure of research experience. It is critically, therefore, to find methods to create the necessary leadership structure found in other jobs and research labs. However, without Master's Students or Ph.D. students the pyramidal structure is not available in undergraduate only labs. Therefore, it is only logical that to improve the research opportunities for cadets and other undergraduate students to ensure they maintain a competitive advantage and become leaders in the field of research, USMA and undergraduate universities should establish a similar structure by adding Davies Fellows and additional post-docs as the bridge between PIs and cadets (**Figure 2**).

Expanding the Davies Teaching Fellowship Model

The growth of the information age and the rapid development of technology in the last two decades, scientists and engineers are required to compete in the world market. USMA and civilian institutions have the responsibility to develop leaders that are well versed in science and engineering to ensure they maintain a competitive advantage to attract the most willing and intelligent cadets and attract the most qualified faculty. Training and developing cadets who will work with future leaders to develop and design the next technology need to gain the necessary experience from qualified researchers. In order to develop the highest quality leaders, highly educated and motivated individuals are necessary.

Developing and training is a critical component of leadership training at USMA. Especially in academics, educating in the classroom is the standard procedure, and the use of the Thayer Method has been utilized since its inception. However, education comes in many forms whether it is instruction from a professor or hands on experiences by doing. In the Science, Technology, Engineering, and Mathematic fields, capstone projects strengthen theoretical framework in the classroom. Labs build the technical skills cadets need in science and engineering to allow them to

be well versed in the hard sciences by learning equipment and the processing of data. Research classes and capstone projects provide higher level experiences for cadets to define the problem by making theoretical assumptions and collecting data in real life research situations. Davies Fellows have the ability to act as the bridge to ensure the highest level of research success while training and developing the skills necessary for cadets to be future leaders in science and research institutions. To ensure a high success of several research topics with high quality work, increasing the number of Davies Fellows will increase the ability to ensure constant overlap of ideas and the strength of individual research (**Figure 2b**).



*Figure 2. **Developing the Davies Fellowship Program.** (A) The standard Davies Fellowship program. (B) The addition of a PI and Davies Fellow with similar research objectives. (C) The potential of Davies Fellows as Older Davies (OD) to develop the research structure found at other organizations.*

Allowing Davies Fellows to interact with cadets in the classroom and research situations creates a process for civilian development. Additionally, the 3-year Davies Fellowship allows for leadership development by allowing Older Davies Fellows (ODs) to mentor younger Davies Fellows (**Figure 2c**). This not only strengthens the research group but allows for the advancement of civilian leadership skills which will make them highly sought after in their future employment. Allowing Davies Fellows to share and work together under PIs with similar research topics, more qualified work can be developed to maintain a competitive advantage at USMA. Additionally, allowing Davies Fellows to work together improves the sharing of ideas that can lead to interdisciplinary topics that also improves the competitive advantage of USMA for future cadets and faculty.

ARL directorates are analogous to departments at USMA which could benefit from a Davies Fellow. Additionally, civilian undergraduate institutions can use the Davies Fellowship as a model to partner with local companies that can expand their research objectives. Administratively, the fellow is shared between both locations but benefits both by being a research mentor to students. Specifically, for the Davies Fellowship, funding from other DoD agencies should have the ability to expand the Davies program and expand DoD capabilities which would directly benefit the U.S. Army. At civilian institutions, partnering with the government or with other funding agencies to create a position that provides research and teaching to undergraduates can improve the quality and experience for undergraduates and their researchers. Building and expanding the Davies Fellowship has the capabilities to bridge gaps in several domains across USMA and other DoD and civilian institutions to develop the next leaders in science and engineering.

Conclusions

The textbooks Charles Davies wrote in the 1800s changed public education in mathematics as his textbooks would be used in middle schools, high schools, and colleges across the United States (Arney, 2002). USMA was the first to break new ground on new ideas, whether it is a teaching style, a core curriculum, or a unique course of action of their instructors which translated into being adapted in universities across the country. Davies set the attitude for the future of public education in America that was adopted in many ways. The same way Charles Davies changed how education was taught in mathematics, the Davies Fellowship has the ability to change USMA again by creating a structure that develops military leaders and allows cadets to learn mathematics, science, and engineering through research. It can provide the ability for USMA and civilian institutions to maintain a competitive advantage to attract the most qualified faculty which in turn will attract the most qualified students. The Davies Fellowship can improve the development of junior faculty while improving the academic research quality and interdisciplinary nature at undergraduate institutions. Specifically for USMA it can act as the bridge between DoD research institutions and

departments at USMA. The Davies Fellows can act as ambassadors between researchers that can extend from the academic semester through summer internships to improve synergy between research initiatives. Additionally, there is no barrier to where funding for a fellowship like this comes from, whether it is a DoD funded agency or a partnering lab. The potential of the Davies Fellowship can extend its reach in all areas to improve strategic dominance by training and developing the future generation of students and researchers to maintain competitive advantages that are mission critical in all arenas, military or civilian.

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