WHITE PAPER: FACILITIES AND INFRASTRUCTURE AT THE UNITED STATES NAVAL ACADEMY

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The United States Naval Academy holds as one aspect of its mission "to develop midshipmen . . . mentally,"[1] and developing midshipmen mentally requires physical, financial, and human resources. The availability of these resources is always limited, and effective use of limited space, budget, and human resources requires care and balance in development and support of both instructional and research capabilities. The United States Naval Academy supports its mission through appropriated funds,[2] and must prove itself a good steward of the same. Specifically, the investment of the Naval Academy in our facilities[3] is well-justified by the impact that these capabilities offer across the full range of users, from midshipmen and faculty to the United States writ large. Well-designed, well-maintained, and modern facilities have positive, well-established impacts on students, on faculty, and on the academic charge of the Naval Academy as a whole.

Facilities requirements beyond basic instructional and office space differ greatly across the various disciplines. Each academic division has its own unique needs. Engineering and the sciences require laboratory facilities and supporting infrastructure comprising hands-on equipment, computing capabilities, and design spaces. Mathematic and economics use computing resources with bespoke requirements and heavy computational burdens. The humanities and social sciences facilitate discussion and interaction, but also use specialized IT resources for language acquisition, statistical analysis, and a variety of needs that support the digital humanities. The discussion that follows will use exemplars from various disciplines, but the overarching themes apply across the educational enterprise, with universal impact across the Naval Academy.

IMPACT ON STUDENTS

Facilities play an important role in attracting and retaining a diverse and accomplished group of midshipmen to the Naval Academy. Many colleges and universities use their facilities as selling points for prospective students, through activities ranging from campus tours to longer engagements like STEM Summer camps. These students often view the quality of academic and research facilities as being closely linked to the quality of undergraduate education offered by the institution.[4] Indeed, much advice given to students in regard to the selection of their college includes a discussion of funding, hands-on educational opportunities, and the majors that are supported. Each of these factors is fundamentally linked to the quality and quantity of the academic facilities.

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[1] United States Naval Academy, "Mission statement of USNA." Accessed on 1 Dec 2016: https://www.usna.edu/About/mission.php

[2] Self Study Steering Committee, "Middle States: Self Study – United States Naval Academy." Accessed on 1 Dec 2016: https://www.usna.edu/Academics/_files/documents/accreditation/USNA%20Self-Study%20JAN%202016.pdf

[3] Herein, the term *facilities* will be used to refer to instructional spaces, research laboratories, and the variety of special-purpose spaces that enable the full endeavor of the mission.

[4] Jenkins, Alan. "Reshaping teaching in higher education: Linking teaching with research." Psychology Press, 2003.

Once students have been recruited and admitted, their retention depends on many factors, especially for underrepresented groups in STEM disciplines. Involvement in active, problem-based, hands-on learning[5] has been shown to be a key factor in retention and success in these fields.[6] Active problem-based learning can involve many facets, but in most disciplines the key to such activities is hands-on experience and experiential learning[7] supported by modern, accessible facilities.

Excellent facilities provide additional benefits for students beyond recruitment and retention. Educational spaces and support structures enable proven high-quality pedagogical techniques such as problem-based and project-based learning (PBL),[8] open-ended inquiry, and hands-on experiential learning. Each of these pedagogical approaches has been shown to enhance the quality of education. Cognitive psychology has shown that the use of the project-based approaches via authentic learning tasks results in greater engagement that in turn maintains thought and motivation.[9] While more research is necessary in the assessment of project-based approaches, in engineering disciplines it has been shown that project-based learning provides greater motivation for students, develops better communication and teamwork skills, and engenders a better understanding of the practice of engineering.[10] Further, these methods have been shown to improve the quality of learning, develop foundational cognitive skills, and improve professionalism and collaboration.[11] The use of laboratory exercises must be motivated by deep and meaningful analysis of the underlying pedagogy.[12] ABET, the professional organization that accredits engineering and computing fields worldwide, including those at USNA, itself sponsored a colloquium addressing this issue, the results of which propose that experimentation, real-world validation of models, design, creativity, and teamwork be emphasized in laboratory exercises.[13] To complete degree requirements in the natural sciences, students spend hundreds of hours in laboratories, and these spaces must be adequately sized and outfitted for experiments to be conducted in a safe manner. To achieve these ends, high quality facilities are a necessity.

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[5] *Active learning* here refers to any activity in which students take an active part in their own learning; e.g., reflection on the learning process itself and critical analysis of the knowledge/skills developed during the exercise.

[6] Palmer, Robert T., Dina C. Maramba, and T. Elon Dancy II. "A Qualitative Investigation of Factors Promoting the Retention and Persistence of Students of Color in STEM," *The Journal of Negro Education*, Vol. 80, No. 4 (Fall 2011), pp. 491-504, Accessed on 7 Dec 2016: http://www.jstor.org/stable/41341155 .

[7] Active Learning Continuum, University of Michigan Center for Research on Teaching and Learning, Accessed on 7 Dec 2016: http://www.crlt.umich.edu/sites/default/files/resource_files/Active%20Learning%20Continuum.pdf

[8] Active Learning Continuum, University of Michigan Center for Research on Teaching and Learning, Accessed on 7 Dec 2016: http://www.crlt.umich.edu/sites/default/files/resource_files/Active%20Learning%20Continuum.pdf

[9] Blumenfeld, Phyllis C., et al. "Motivating project-based learning: Sustaining the doing, supporting the learning." *Educational psychologist* 26.3-4 (1991): 369-398.

[10] Mills, Julie E., David F. Treagust. "ENGINEERING EDUCATION – IS PROBLEM BASED OR PROJECT-BASED LEARNING THE ANSWER?" AUSTRALASIAN JOURNAL OF ENGINEERING EDUCATION, 2003. Accessed on 7 Dec 2016: https://www.researchgate.net/profile/Nathan_Scott2/publication/238670687_AUSTRALASIAN_JOURNAL_OF_ENGINEERING_EDUCATION_Co-Editors/links/0deec53a08c7553c37000000.pdf

[11] Thomas, John W. "A REVIEW OF RESEARCH ON PROJECT-BASED LEARNING," 2000. Accessed on 7 Dec 2016: http://www.bie.org/images/uploads/general/9d06758fd346969cb63653d00dca55c0.pdf

[12] Feisel, Lyle D., and Albert J. Rosa. "The role of the laboratory in undergraduate engineering education." *Journal of Engineering Education* 94.1 (2005): 121-130.

[13] Feisel, L., and G. D. Peterson. "A Colloquy on Learning Objectives for Engineering Educational Laboratories," 2002 ASEE Annual Conference and Exposition, Montreal, Ontario, Canada, June 16–19, 2002

Some argue that laboratory simulations can replace authentic learning thereby reducing the investment required in physical resources. While analysis and synthesis of the literature on simulated vs. physical laboratory exercises is challenging due to the various methods used both for the exercises and for their evaluation,[14] fundamental to this question is the accuracy or veracity of the simulations used, and the complexity of the overall systems. Students often find that simulations are more easily managed and digested than hands-on activities[15] because such simulations avoid the challenges of real-world work, including difficulties with hardware and setup, multi-component requirements on testing and data generation, and real-world effects that are challenging to model or even poorly understood. The persistence of tow-tank testing in fluid dynamics and naval architecture, despite decades of computational fluid mechanics work to create accurate simulations, is predicated on exactly this challenge. In short, simulations do not adequately prepare students for the *real* challenges of a project or research effort.

Students often also benefit from the use of high quality institutional facilities through involvement in conducting research with faculty mentors. Because faculty typically are involved with leading-edge research, opportunities exist in which students can gain a much greater understanding of their discipline through direct involvement in knowledge generation, not merely in knowledge acquisition. Students find such activities rewarding and worthwhile,[16] and further find significantly enhanced learning outcomes due to their more in-depth experiences.[17]

IMPACT ON THE FACULTY

Faculty and staff execute the academic mission of the Naval Academy. Attracting and retaining the highest-quality academic instructors is essential to the highest level of success in education of midshipmen. The quality of facilities significantly impacts the overall quality of life of the faculty through the types of courses that can be taught and the quality of research that can be pursued. From office space that supports one-on-one and small group meetings with students to laboratories and workspaces that support cutting-edge research, facilities are the most tangible evidence of the investment and support that the institution provides to various disciplines, and thereby remains a major factor impacting job satisfaction.

In order to provide a world-class education to midshipmen, the faculty must be recruited from a diverse pool of the best and brightest candidates for positions in higher education. Attracting top quality talent requires an appealing environment, characterized by modern, high-quality instructional spaces and well-equipped support for the pursuit of research and pedagogy. Support in this case can refer to physical

[14] Ma, Jing, Jeffrey V. Nickerson. "Hands-On, Simulated, and Remote Laboratories: A Comparative Literature Review,"2006. Accessed on 7 Dec 2016: cheo.pbworks.com/w/file/fetch/66352254/Ma_Nickerson_remote_labs_review_2006.pdf

[15] Taher, Mohammed Taqiuddin, Ahmed S. Khan. "Effectiveness of Simulation versus Hands-on Labs: A Case Study for Teaching an Electronics Course," in Proceedings of the 122nd annual ASEE Conference and Exposition, 2015. Accessed on 7 Dec 2016: asee.org/public/conferences/56/papers/13152/download

[16] Mabrouk, P. A., K. Peters. "Student perspectives on undergraduate research (UR) experiences in chemistry and biology," CUR Quarterly 21, 25–33, 2000.

[17] Lopatto, David. "Undergraduate Research Experiences Support Science Career Decisions and Active Learning," CBE—Life Sciences Education Vol. 6, 297–306, Winter 2007.

infrastructure, proctored access to resources, or facilities specifically designed for active engagement in appropriate activities.

Many faculty members pursuing a career in higher education come directly from their graduate program or from a temporary post-doctoral or research position. The state of facilities at a potential home for the remainder of their career will have a significant impact on candidates' decisions, as they may perceive a lack of quality resources at a potential employing institution as a step down in their career. While it is not necessary that the Naval Academy compete with "Research I" institutions in the arena of research laboratories and facilities, it is essential that the existing infrastructure, and support for the same, be up-to-date and well-appointed, sufficient to attract and retain the nation's top faculty talent.

While a direct comparison of the Naval Academy's resources and facilities to those with which newly recruited faculty members are accustomed in their graduate programs is a natural outcome of the population from which candidates tend to be selected, the research endeavor is a mandatory component of the academic profession for tenure-track professors at this institution.[18] Facilities, in some form, are required for research in every discipline. Attracting faculty members to the institution requires tangible support for research in their discipline.

Because obtaining the PhD (or equivalent degree) is predicated on the development of new knowledge, candidates in the early stages of their careers will have freshly-developed skills that are best utilized at an institution that sees research as part of the educational mission and can leverage those skills. These faculty members will frequently seek to use the research skills that they developed in the pursuit of their degree as part of their pedagogical development as well, outside of the pursuit of scholarship that is an expected part of their employment. As such, facilities that enable use of the skills developed in a research career will be attractive to energetic faculty members,[19] who will then be emboldened to use their skills in support of both instruction and research. There are aspects of both scholarly publication and teaching efficacy that can be leveraged to improve each. Hence, maintaining currency in a field of research will assist the faculty in developing and evolving pedagogy that reflects the most recent advances in their fields, and will assist in the refinement of foundational courses that provide toolsets to support activities in the same field.

Once a high-quality faculty member has been recruited, the institution must be committed to their development and to their career in order to retain those who are suited to the position. In addition to providing support for research and teaching, well-appointed facilities that allow the use of hard-earned skills have an impact on job satisfaction. Research has shown that job satisfaction in higher education is positively influenced by perceived support and leadership, which is in turn positively correlated to available academic resources.[20] Further, the intellectual atmosphere of a university has been shown to

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[18] Phillips, Andrew T. "Annual Performance Review Expectations." Accessed on 1 Dec 2016: usna.edu/Academics/_files/documents/faculty/review_expectations_2013.pdf

[19] Jenkins, Alan. "Reshaping teaching in higher education: Linking teaching with research." Psychology Press, 2003

[20] Ramirez, Trina Jo. "Factors that contribute to overall job satisfaction among faculty at a large public land-grant university in the Midwest." (2011). Accessed 7 Dec 2016: http://lib.dr.iastate.edu/cgi/viewcontent.cgi?article=3109&context=etd.

be a major contributor to faculty job satisfaction.[21] Higher job satisfaction leads to greater retention,[22] performance,[23] and an overall increase in the morale of the faculty.

IMPACT ON INSTITUTIONAL REPUTATION

An institution's facilities impact its reputation through the quality of faculty and students it attracts, the pedagogical enrichments it supports, and also the college's ability to meet commonly accepted standards within the disciplines and majors that it provides.

Within the sciences, the National Science Teachers Association provides the following declaration supporting laboratory experiences in education at all educational levels:

> NSTA strongly believes that developmentally appropriate laboratory investigations are essential for students of all ages and ability levels. They should not be a rote exercise in which students are merely following directions, as though they were reading a cookbook, nor should they be a superfluous afterthought that is only tangentially related to the instructional sequence of content. Properly designed laboratory investigations should:
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> - have a definite purpose that is communicated clearly to students;
> - focus on the processes of science as a way to convey content;
> - incorporate ongoing student reflection and discussion; and
> - enable students to develop safe and conscientious lab habits and procedures.[24]

The American Chemical Society similarly states:

> Hands-on laboratory science experiences are critical to the learning process across all areas of study, beginning with kindergarten and continuing through post-secondary education. Research has shown that students who engage in well-designed laboratory experiences develop problem-solving and critical-thinking skills, as well as gain exposure to reactions, materials, and equipment in a lab setting. [25]

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[21] Lacy, Fiona J., Barry A. Sheehan "Job Satisfaction among Academic Staff: An International Perspective,"Higher Education, Vol. 34, No. 3, Academic Profession (Oct., 1997), pp. 305-322, Accessed on 12 May 2016: http://www.jstor.org/stable/3448259.pdf.

[22] Johnsrud, Linda K., Vicki J. Rosser "Faculty Members' Morale and Their Intention to Leave: A Multilevel Explanation", *The Journal of Higher Education* Vol. 73, No. 4 (Jul. - Aug., 2002), pp. 518-542.

[23] Iaffaldano, Michelle T., Paul M. Muchinsky "Job Satisfaction and Job Performance: A Meta-Analysis," Psychological Bulletin, Vol 97 No 2, pp. 251 – 273, 1985.

[24] National Science Teachers Association. "NSTA Position Statement." Accessed on 7 Dec 2016: **http://www.nsta.org/about/positions/laboratory.aspx**

[25] American Chemical Society, "ACS position statement on hands-on laboratories." Accessed on 7 Dec 2016: **acs.org/content/dam/acsorg/policy/publicpolicies/invest/computersimulations/hands-on-science.pdf**

Specifically at the college-level, ABET, the professional accreditor for engineering, technology, and computing programs, holds the following as a general criterion for accreditation of engineering[26] and computing programs[27]:

> Classrooms, offices, laboratories, and associated equipment must be adequate to support attainment of the student outcomes and to provide an atmosphere conducive to learning. Modern tools, equipment, computing resources, and laboratories appropriate to the program must be available, accessible, and systematically maintained and upgraded to enable students to attain the student outcomes and to support program needs.

Laboratories are an integral component in the achievement of the ABET learning outcomes, including the *ability to design and construct experiments* and to *operate within realistic constraints*. The ABET general curricular criteria also require, explicitly, "basic sciences (some with experimental experience),"[26] again reinforcing the need for laboratories in order to achieve accreditation.

Additionally, facilities impact faculty ability to attract research funds and projects as well. High-quality facilities with unique capabilities that can be leveraged to provide both instructional support and faculty/student research make the institution more attractive to potential funding sources as well as donors for future expansions. The latter is predicated on the proper maintenance and utilization of existing spaces, and it is common for visiting potential donors to be shown Naval Academy resources as a means for the institution to demonstrate both its dedication to the mutual reinforcement of teaching midshipmen with research as well as its stewardship of funds that previously have been provided.

Finally, the reputation of the Naval Academy exists within a network of research universities and research facilities. Proper facilities with unique capabilities in the geographic environs of Annapolis encourage collaboration among faculty at the Naval Academy as well as between Academy faculty and those of nearby institutions. Research collaborations of this sort encourage growth, promote further the attraction and retention of high quality faculty, and build vital community ties that are fundamental to the growth of the research community and of the Naval Academy's perception among peer institutions. According to the Office of Naval Research, multidisciplinary research, driven by unique capabilities and facilities that encourage these efforts, "serves to stimulate innovations, accelerate research progress and expedite transition of results into naval applications."[28]

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[26] ABET, "CRITERIA FOR ACCREDITING ENGINEERING PROGRAMS, 2016 – 2017." Accessed on 7 Dec 2016: abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2016-2017/

[27] ABET, "CRITERIA FOR ACCREDITING COMPUTING PROGRAMS, 2016 – 2017." Accessed on 7 Dec 2016: abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-computing-programs-2016-2017/

[28] Office of Naval Research, "Multidisciplinary University Research Initiatives (MURI) Program." Accessed on 8 Dec 2016: http://www.onr.navy.mil/Science-Technology/Directorates/office-research-discovery-invention/Sponsored-Research/University-Research-Initiatives/MURI.aspx

CONCLUSION

The Naval Academy mission is supported and enabled by the development and maintenance of world-class facilities, from teaching laboratories to research spaces. Facilities impact every aspect of the academic endeavor, influencing recruitment, retention, and the achievements of high quality personnel – staff, faculty, and midshipmen alike.

The investment a college or university makes in its facilities not only is an indicator of the value it places on the disciplines that use these instructional and research spaces, but also of what the institution holds as its core educational values. A dedication to hands-on, modern, experiential learning shows that the Academy is devoted to the development of midshipmen who have skills applicable in the real world, who have the ability to manage the challenges of unexpected complications, and who are confident in their ability to use their skills in the environment in which they will be working.

The education of midshipmen would be worsened by the absence of any aspect of the facilities infrastructure. Further, the external world view of the Naval Academy is inarguably influenced by the facilities, and there is no clearer way to demonstrate dedication to education than to provide modern, well-funded, and well-equipped facilities that encourage the best pedagogy, best research, and best student experience possible.