

The Future of Graduate-Level Education at APL

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ABSTRACT

Graduate-level education has been the cornerstone for developing the capabilities of staff members of the Johns Hopkins University Applied Physics Laboratory (APL) and those of neighboring governmental and industrial organizations for over five decades. This article briefly discusses the development of graduate-level engineering and applied science education at APL along with its strong historical ties to the Johns Hopkins University Whiting School of Engineering. In particular, this article focuses on the 2020 education upheaval caused by the COVID-19 pandemic and offers thoughts about what the future may hold in store for graduate-level professional education at APL and its Whiting School partner.

INTRODUCTION

The importance of education and the need to keep its staff on the cutting edge of technology have been key elements of APL's culture since its inception. With the end of World War II and the positive decision to keep APL in existence,¹ Laboratory leaders took steps to ensure that APL would not become obsolete. Several of these steps are enumerated in the education article in the *Johns Hopkins APL Technical Digest* issue commemorating APL's 75th anniversary.² This early recognition of the need for and benefit of continuing and in-depth education for APL's scientists and engineers has been a significant factor in APL's development, growth, and success over the last 78 years. As APL has grown and evolved, so have the educational opportunities for its staff—enabling them to gain the knowledge and skills necessary to make critical contributions to significant problems of national and global interest.

This article describes APL's graduate-level educational programs, how they were affected by the global COVID-19 pandemic (in the year 2020 and beyond), and what they might look like when the Lab celebrates its 100th anniversary in 2042.

MASTER'S DEGREE PROGRAM

Historical Aspects

As early as 1958, APL began offering graduate-level courses for its staff,² with APL senior scientists and engineers teaching courses on the APL campus. By 1963, the APL education operation affiliated with the Johns Hopkins University (JHU) part-time program and began offering master's degrees. The first degree offering was in electrical engineering, and it was soon followed

by degrees in several other disciplines relevant to APL's mission.³ These APL–JHU programs were opened to the public in recognition that nearby governmental and industrial organizations shared APL's needs for continuing technical education. The growth and evolution of the APL Education Center and its partnership (since 1984) with the JHU Whiting School of Engineering (WSE) has been extremely successful.

In the beginning, all courses were taught face to face in classrooms under APL's R. E. Gibson Library (now Central Spark). The introduction of new master's degree programs drove pressure to develop more and more classroom space, and the number of classrooms was expanded with APL's opening of the Kossiakoff Center⁴ in the mid-1980s. With classes running five days a week and on Saturday morning, the demand for classroom space continued to increase, so the program, called Engineering for Professionals, or EP, opened satellite campuses in locations around the Baltimore–Washington area. At one time, there were six satellite campuses in addition to the APL Education Center and the Hopkins Homewood campus in Baltimore. The need for more and more classroom space continued until the start of the new millennium when the first online courses appeared.

During the early 2000s, online enrollments represented only a few percent of total enrollments. Starting in 2005, EP embarked on a major effort to develop online courses not only to satisfy local demand but also to offer the Hopkins brand outside of the local area. By 2013, enrollment in online courses equaled that of face-to-face courses. At the start of the spring semester in 2020, the online percentage had jumped to 93%. The bulk of these online courses were taught asynchronously, allowing students to take courses at their convenience. Each instructor offers remote office hours, typically by the Zoom video conferencing application. Today, about 55% of students are regional, 38% are national, and 7% international. Numbers of national and international students are growing rapidly. Current EP course enrollments for a given section are limited to 19. This will likely be re-examined in light of growth and business considerations.

As online enrollments grew, the EP program began closing the satellite learning centers and focused operations in two places: WSE at Homewood and the APL Education Center. At the start of the spring 2020 semester, the APL Education Center operated classrooms and

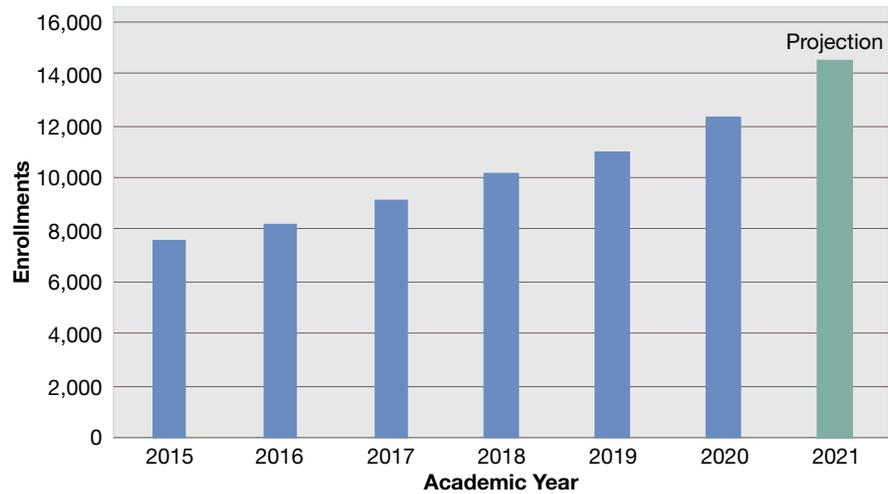


Figure 1. EP total enrollments in its master's degree programs by academic year. The total shown for academic year 2021 (summer term 2020, fall term 2020, and spring term 2021) is a projection based on the enrollments in the first two semesters.

laboratory spaces in the Kossiakoff Center and a building on APL's Montpelier Campus, MP7. In addition, five distance-learning suites or studios are housed in MP4, another building on the Montpelier Campus. The second-floor classrooms in the Kossiakoff Center were also fully equipped for distance learning.

This joint JHU/WSE and APL program continues to grow; with 23 master's degree programs and more than 5,000 students enrolled, it is one of the largest programs of its type in the United States. Figure 1 illustrates the growth in total enrollments for the last six academic years as well as the projection for the current academic year (summer term 2020 through spring term 2021), for which individual course enrollments are expected to exceed 14,000. For additional details about the EP program at APL, see the article in the *Digest* issue celebrating the Lab's 75th anniversary.²

Of the 23 master's degree programs, 12 have APL chairs and vice chairs. These APL-based programs account for about 85% of the total EP enrollments. Table 1 presents the APL-based programs and their current leadership. Also shown in Table 1 is the Applied Biomedical Engineering program, which was started at APL and subsequently migrated to the Homewood campus. As shown in the table, APL-based programs focus on areas of strategic importance to APL and its mission. EP also tailors programs in partnerships with industrial and governmental organizations. EP leadership is exploring many alternative strategies to enhance the educational opportunities for lifelong learning.

The Year 2020

At the beginning of the spring 2020 semester, in addition to the large number of online students, several

Table 1. A list of the current APL-based EP part-time graduate degree programs and their key leadership personnel

EP Program	Chair (C)/Vice-Chair (VC)	Program Manager
Applied and Computational Mathematics	Dr. James C. Spall (C)	
Applied Biomedical Engineering ^a	Dr. Eileen Haase (C)/Dr. Brock Wester (VC)	
Applied Physics	Dr. Harry K. Charles Jr. (C)/Dr. William Torruellas (VC)	
Artificial Intelligence	Dr. John Piorkowski (C)	Dr. Anthony Johnson
Computer Science and Cyber Security	Dr. Lanier Watkins (C)	Dr. Anthony Johnson
Data Science	Dr. John Piorkowski (C)/Dr. James C. Spall (C)	Dr. Anthony Johnson
Electrical and Computer Engineering	Dr. Ashutosh Dutta (C)/Dr. Cleon Davis (VC)	Dr. Ramsey Hourani
Engineering Management	Dr. Timothy Galpin (C)	Mr. Richard Blank
Health Care Systems Engineering	Dr. Alan Ravitz (C)	
Information Systems Engineering	Dr. John Piorkowski (C)	Dr. Anthony Johnson
Space Systems Engineering	Dr. Patrick Binning (C)	Mr. William Devereux
Systems Engineering	Dr. Andrew Merkle (C)/Dr. David Flanigan (VC)	

^aOriginally started at APL, now jointly managed by APL and the JHU Department of Biomedical Engineering. APL staff member Brock Wester is the current Applied Biomedical Engineering vice-chair. It should also be noted that APL staff member Mike Boyle is the program manager for the Homewood-based Mechanical Engineering program.

hundred students were attending face-to-face and virtual live classes (synchronous online with a classroom component) at APL. As the spring 2020 semester progressed, the COVID-19 pandemic did also, and as a result, federal, state, and local governments, as well as JHU's management, enacted many restrictions. These restrictions shut down the JHU Homewood campus. Because of APL's criticality to the national defense effort, the APL campus was allowed to remain open, but as part of APL's processes to minimize human contact, visitors (including students) were not permitted on the campus and most of the staff began working from home. The APL Education Center responded to these restrictions by providing remote instruction so that face-to-face students could finish the spring semester as well as by developing plans for delivering education to students in the following semesters (summer, fall, and beyond).

The EP program was in a strong position during the shutdown and stay-at-home order, because, as mentioned, 93% of the courses were already online. The major concerns centered on how to continue the face-to-face courses and, to some extent, the virtual live courses (which had in-class students as well as remote students) at APL. For virtual live courses, remote students already connected to the classroom instruction via Zoom, so the on-campus students in these courses were instructed to remain at home and connect to these courses via Zoom as well. The virtual live courses featured slides in conjunction with videos and other electronic forms of presentation, all accessible remotely to the students through EP's course management system. Hence, the transition to an all-remote environment went smoothly and quickly.

The face-to-face courses were in a different state. They relied, for the most part, on the traditional on-board instruction methodology—handwritten notes on

a whiteboard. Classrooms were not set up for full video capture of whiteboard work. Instructors of face-to-face courses, working with APL Education Center staff, were able to develop temporary schemes to allow students to finish the spring semester, including creating electronic versions of professors' handwritten notes, installing makeshift whiteboards in distance-learning suites to allow board capture, and installing better cameras in some other classrooms.

During the summer, improvement of the distance-learning suites and classroom equipment continued. Figure 2 is a sketch of the major elements of the new configuration in the distance-learning suites in MP4. Figure 3 is a photograph of the display during operation. All classes were either fully asynchronous online or in a remote synchronous mode. The fall semester followed the summer trends, but with a significant increase in the number of courses. The APL Education Center provided Homewood professors (living close to the Laboratory) access to its distance-learning capabilities so that they could teach several of the full-time program courses during the day. Rigorous cleaning and sanitation protocols were put in place for all APL Education Center spaces (Kossiakoff Center, MP4, and MP7).

Future: Near Term

Hopkins, along with almost every university in the country and the world, worked to respond to the loss of residential students, and the associated revenue, caused by the pandemic by getting as many of its courses online as quickly as possible. As of spring 2021, some students were allowed back on the Homewood campus to attend some classes in person, but online learning was still a major element and is expected to remain so in the post-COVID era. As previously mentioned, the EP portion of the JHU/WSE is in a very strong position in the online

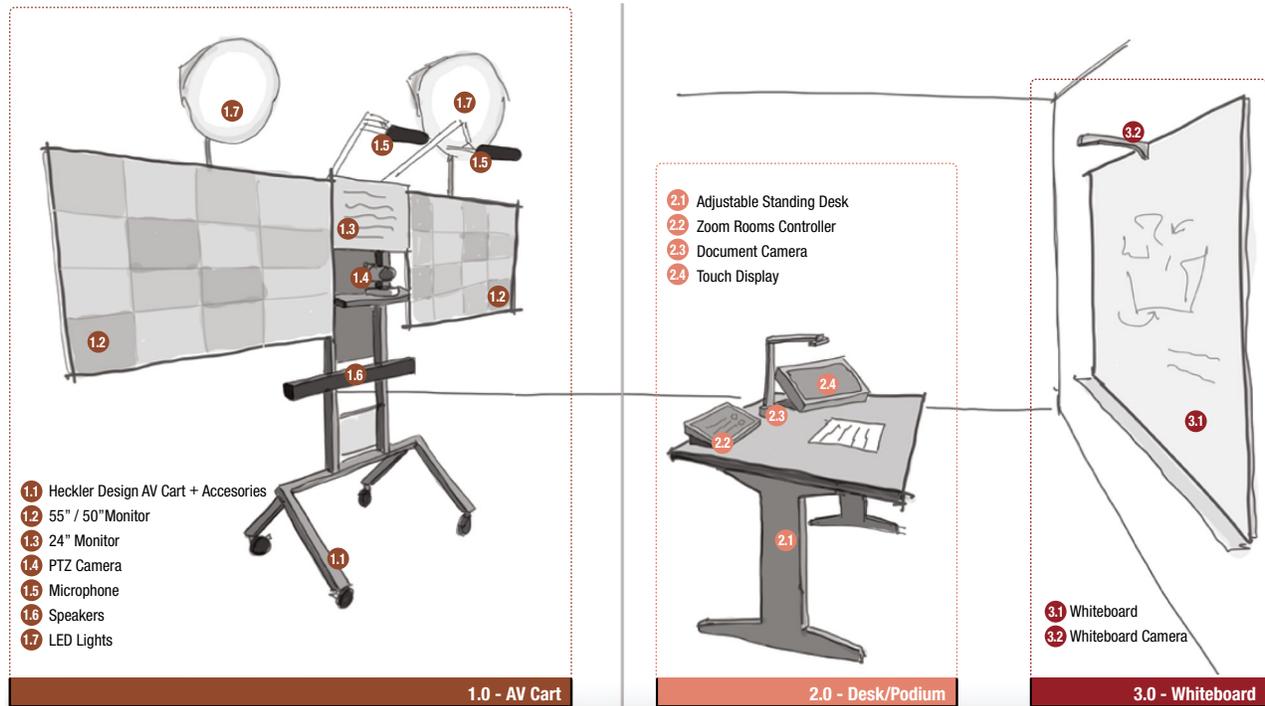


Figure 2. Artist's sketch of the major equipment elements (AV cart, desk/podium, whiteboard) in the newly configured distance-learning suites in MP4.

arena, having 93% of its course offerings asynchronously online and the remainder offered remotely in a synchronous mode. A key goal for EP in the near term has been to obtain the resources necessary to transition its synchronous remote courses into the full asynchronous online mode. The EP online development resources, once exclusively focused on EP, were rapidly deployed university-wide to help prepare the university, especially the Whiting School, for remote learning for the fall semester and beyond. Forty distance-learning suites were constructed on the Homewood campus, and the faculty trained in their use over the summer and fall of 2020.

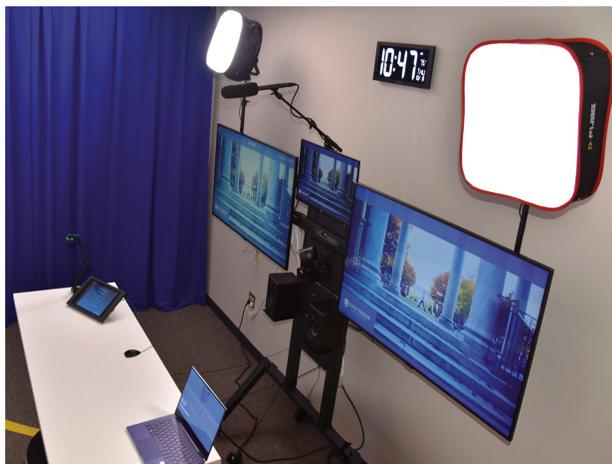


Figure 3. Photograph of the AV cart in an MP4 studio as seen by the instructor during a teaching session.

Thus, in the near term, EP will continue to expand its asynchronous online course offerings (many of its programs still have a sizable face-to-face component) and develop additional degree programs. A major effort will be to automate laboratories to allow students remote access. Once the laboratories fully support remote instruction, enrollments are expected to increase. The introduction of the new artificial intelligence (AI) degree program (summer 2020) has been a resounding success, with over 200 students admitted in only a few months. Several other new programs, such as robotics, industrial and systems engineering, and biotechnology, are under consideration. Within its existing programs, EP is introducing a new post-baccalaureate certificate (PCB). The PCB will allow students to take four courses in a certain area and receive a certificate of completion (as well as university credit). Students who want to continue study can use these four PCB courses to satisfy four of the 10 required courses in a master's degree program. The post-master's certificate (PMC) program course requirements are also being reduced to four courses rather than the current six. These changes, allowing students to stack credentials and to take fewer required courses for the PMC, are expected to increase student enrollments in the near future.

EP is working closely with the Whiting School's associate dean for lifelong learning to develop educational opportunities in addition to the conventional master's degree programs. These opportunities will project EP and the Whiting School into different educational

marketplaces and may include massively open online courses (or MOOCs, which can include thousands of students in a single course), short courses, executive education, and low-cost degree programs. Each of these areas has the potential to increase Hopkins's service to the educational community. Entry into these new (to the Whiting School and EP) educational marketplaces will also face significant competition, and Hopkins will quickly develop a unique identity and a competitive differentiation. As an example, in executive education, Hopkins may stand up key technology-based leadership courses in AI or machine learning in a relatively short period of time, leveraging existing EP and perhaps APL Strategic Education Program course content (this program is described below). In addition, with vaccines for COVID-19 being rolled out as of late 2020, these executive education courses are under consideration for being taught at the new Hopkins facility in Washington, DC (555 Pennsylvania Avenue). The plan is to offer these courses both in person and remotely as they are developed. Several EP programs are also developing MOOCs to test the waters in that arena.

STRATEGIC EDUCATION

Historical Aspects

In addition to formal degree opportunities, APL staff need continuing access to the specialized knowledge and skills they need to remain current and to work at the leading edges of their fields. To address this need for leading-edge non-credit education for its staff, the Laboratory established the Strategic Education Program (SEP) in 2006. SEP leadership, working with APL's Management Forum and an advisory board of subject-matter experts, identifies courses that will help APL staff to grow and be successful in current and future assignments. In addition, on an annual basis, the SEP leadership solicits course ideas and teacher recommendations from the entire APL Technical Professional Staff. The SEP has been a phenomenal success, growing from fewer than 50 enrollments in the 2006 academic year (fall 2005 to spring 2006) to more than 700 in the last three academic years (2018, 2019, and 2020). For additional details on the SEP at APL, see the article in the *Digest* issue celebrating APL's 75th anniversary.²

The Year 2020

Since its inception, the SEP has employed a face-to-face delivery model with small classes allowing for strong student-instructor interaction. The SEP, just like the EP master's program, operates on a semester basis (both spring and fall). At the start of the spring 2020 semester, the SEP planned to offer 26 courses. Since the SEP's longest course is 12 weeks, the spring semester starts in February for the long courses and March for

the shorter courses (6 weeks). Before the start of classes, spring class enrollments totaled over 360. As of fall 2019, the SEP had started to experiment with remote delivery of courses via Zoom.

All SEP spring 2020 courses were scheduled and started in the face-to-face delivery mode. Since most SEP instructors used slides, with the COVID restrictions, it was straightforward for them to teach via Zoom with a fully remote student body. Most of the SEP instructors were able to conduct their courses remotely, via Zoom. For courses including limited classified information, the instructors were able to remove this information and deliver their courses remotely. Despite these issues and changes, the SEP had about 320 enrollments for the spring 2020 semester. In a post-course survey of the spring faculty, the SEP received mixed feedback on whether the instructors preferred to teach remotely or preferred face-to-face instruction.

For the fall 2020 semester, 26 courses were underway, 25 of which were taught remotely via Zoom. The remaining course contained classified information and was instructed on-site, with students and instructors wearing face coverings and practicing appropriate social distancing. In addition, the classroom was cleaned before and after use, with cleaning crews following enhanced sanitation protocols. Enrollment in fall 2020 SEP courses exceeded 400.

Future: Near Term

Although APL's SEP is internally focused, many of its courses are attracting external interest from the Lab's sponsor community and related government agencies, as well as the Hopkins community (as mentioned above). Some SEP courses have transitioned to become EP courses. SEP leadership carefully monitors opportunities to expand as emerging technologies motivate new courses, while always remaining true to its internally focused goal to provide relevant APL-focused technical courses in a timely manner to help APL staff members gain strength in key areas vital for the Lab's future success. Achieving this goal requires constant input on new course ideas from APL management and staff, as well as identification of subject-matter experts to develop and teach the courses. The program has traditionally relied on three sources for course and instructor identification: (1) APL's Management Forum; (2) the SEP Committee; and (3) grassroots input from the APL staff. Starting in fall 2020, in addition to these three sources, program leadership began conducting an annual solicitation of the entire APL technical staff to further identify courses. The goal of the solicitation is to make sure that the SEP has a broad, inclusive set of offerings that reflect the diversity of APL activities and interests. Through this solicitation process, the SEP has received proposals for 23 potential new courses (for possible delivery in

fall 2021 or spring 2022). The spring 2021 program is set with a combination of remote and on-site delivery (which may change as the pandemic plays out).

The success of remote SEP course delivery during the spring and fall semesters (with record enrollments) in 2020 suggests that the course modality for unclassified courses needs to be addressed as we move beyond COVID-19. During the pandemic, unclassified courses are being taught synchronously on Zoom. Is this the right mode for APL students, or should the program be taught asynchronously? Should courses go into full online development, or is there a compromise embodying the best aspects of both face-to-face and online education? Such questions, in addition to questions about introducing new courses, will need to be answered in the next few years to keep the SEP at the cutting edge.

DOCTOR OF ENGINEERING

Historical Aspects

About 3 years ago, as APL approached its 75th anniversary, Laboratory leadership recognized that the nexus for APL's most recognized historical accomplishments (its "defining innovations") revolved around the contributions of several key individuals, many of whom possessed doctoral degrees. This realization led to an increased emphasis on hiring individuals with doctoral degrees as well as providing APL staff members with a straightforward method to obtain doctoral degrees. To that end, APL supported the JHU/WSE leadership in its establishment of a pioneering professional doctoral degree (doctor of engineering, or DEng) program. The DEng program is cohort based and centers on a portfolio of accomplishments associated with research and development opportunities provided in the student's corporate workplace. The DEng program began operation in June 2018. Initially as a pilot program, it included only APL staff members as students in the first two cohorts. After the second cohort, the DEng program was opened to the public. As of this writing, 25 APL staff members are part of the DEng program, making JHU the number one university where APL staff members are seeking doctorates.

The DEng program was designed from the beginning as a nonresidential program. (Note that APL also supports its staff seeking doctorates in their respective technical and scientific areas across a variety of universities.) Each student admitted to the DEng program has an advisory team of three, with the principal adviser being a tenure-track Hopkins professor. The student also has a co-adviser (with a doctoral degree) from their home institution. The third member of the student's advisory team is another Hopkins tenure-track professor. Students do their research at their home institution under the daily guidance of their corporate co-adviser and

meet regularly with the entire team via electronic means. Twice a year students and advisers meet on campus for a conference week during which exams would be taken, presentations given, etc.

The Year 2020

Since the DEng program is nonresidential, it was straightforward to transfer adviser and on-campus conference meetings to Zoom during the spring, summer, and fall semesters during the pandemic. As we moved forward into the winter (and beyond), the need for close adviser-student interaction and in-person meetings remained. Further, the restriction of on-site activities at the winter and summer conferences (remote during the pandemic) has done little to foster the sense of community among members of each cohort, as was expected. Program participants were coping with remote access methodology but looking forward to renewed face-to-face interaction as the vaccine program gained traction.

Future: Near Term

This WSE professional engineering doctoral program is unique among America's universities and could be a major contributor to the growth of the Whiting School over the next few years as well as a major contributor to advanced engineering education nationwide and an excellent resource and benefit to APL staff. To make this impact, the DEng program is expected to become available to a wider range of corporate and government employees. Initially the growth was limited, allowing time to develop program details, listen to feedback from the initial students, and refine the program based on their input. The program has progressed to the point where many members of the initial cohorts were expected to graduate in spring 2021. Growth will also lead to an expanded admissions and management structure; perhaps such a structure could mirror that of EP.

FUTURE: LONG TERM

The longer-term and more significant challenge for EP is increasing marketplace competition, boosted by the need for universities to move to remote learning because of the pandemic. EP has had little competition, despite a few other universities offering low-cost engineering master's degree programs in select subjects. EP enjoys high national ratings in several subject areas (*U.S. News & World Report*), bears the Hopkins brand, offers a large spectrum (23 different degrees and 27 distinct certificates) of applied engineering and science programs (and courses), and has an extremely well-qualified professorial cadre and a highly motivated and qualified instruction design staff. While these things set Hopkins EP apart, as the full ramifications of the pandemic-forced changes

play out, over the next few years many more schools are expected in the part-time online graduate degree space. Even full-time day schools that never competed in the part-time arena will likely enter this market since they have created all-electronic instructional material—especially if the courses are designed for asynchronous instruction. Asynchronous instruction allows students to access course material at any time during the day or night. While viewed as a convenience for local and regional students, this anytime access is key for the participation of nonregional and international students across disparate time zones.

The long-term future of education in the United States, and the world for that matter, is ambiguous at best, with many unanswered questions and uncertainties. These uncertainties and questions manifest themselves in many ways depending on the level of education considered and are well beyond the scope of this article.

For EP to excel in the decades to come, it will likely grow its current student body (over 5,000 students) by expanding into various educational marketplaces and providing those marketplaces with high-quality offerings—the Hopkins brand. This will involve extensive planning, use of the latest tools, and a commitment by current and future educators to create and instruct quality courses that will intrigue the mid-21st century audience.

At APL, the Education Center will grow and evolve with the educational needs of the Laboratory’s staff as its primary driver. We expect to continue to move with EP along its journey into the future as well as to develop and enhance specific educational opportunities for the APL staff, such as the APL SEP and the WSE DEng program. Embracing advanced technology will help foster the learning experience for APL staff as well as support the evolution of advanced learning and instructional methodologies to be developed at Hopkins.

One new technology in its relative infancy in the education realm is virtual or expanded reality. This exciting new field is discussed in a recent *Digest* issue.⁵ As this technology evolves over the next couple of decades, it could have a major impact on education, especially at the graduate level. For example, consider that you are a mid-21st century APL staff member walking into a virtual reality education booth, closing the door, and sitting down at a desk. You hear a voice say “Welcome to quantum mechanics,” and fellow students suddenly surround you in a simulated classroom. An instructor walks into the classroom and begins a 19th or 20th century style lecture by talking and writing notes on the board. You have the classroom experience; you and your fellow students can ask questions and communicate with each other. All is probably doable with mid-21st century technology. Now suppose you can do it at your APL desk, or at home, by putting on a viewer/earphone headset as the portal to educational content

from both APL’s SEP and university offerings, including EP and the DEng program.

Such are the options that might be available for education at APL and for students around the world by the middle of the 21st century, as we continue to depart from the current thinking about in-person instruction as the only or the preferred method of learning. To change the paradigm, many items will be addressed, such as how to replace the socialization and group learning that takes place in the classroom. How do we form a virtual cohort and keep that cohort intact while students move through the various educational stages at their own pace? Does the concept of a class or cohort diminish in the self-paced asynchronous learning world?

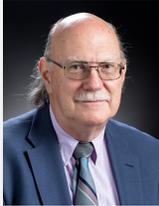
As universities such as Hopkins move into the future in the way courses are delivered and learning occurs, they will likely address the research experience, especially experimental research. Within EP, given its strong commitment to online instruction, several remote laboratory experiences (courses) are underway. These labs typically operate in one of two modes. In the first mode, a laboratory technician sets up electronic experiments and students log in and control measurement equipment attached to various nodes in an electronic circuit. By making measurements on the equipment, the students learn circuit behavior and collect data to complete assignments. The second mode involves sending laboratory kits to the students. The students assemble the kits and, using special software and modules attached to their personal computers, make measurements on their assembled circuits. These remote lab options have been successful for a few EP courses, but the challenge is how to expand such modalities across programs and technologies. These remote labs may be fine for EP classroom instruction, but how do we extend the remote learning concept for experimental graduate school research, which has typically been on an individual basis? Finding answers to such questions will likely be necessary to move forward with all aspects of graduate education and to provide the full research experience for doctoral students.

SUMMARY

This article discusses the three major forms of graduate-level education programs at APL: the WSE Engineering for Professionals (EP) program, the APL Strategic Education Program (SEP), and the WSE Doctor of Engineering (DEng) program. It describes these programs both from a historical perspective leading up to the pandemic and from today’s perspective as we navigate the “new normal” phase of COVID-19. Finally, it presents future near-term plans for these programs, along with a longer-term view of APL staff education, its directions, and its potential impact on our current concepts of educational methods.

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