Engineering and Design Opportunities
at William & Mary

A report to the Provost, as requested via memorandum of 5 August 2015.

Respectfully prepared and submitted in May 2016, by the committee, assisted by numerous members of the faculty and staff of the University, as listed below.
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Executive Summary

The charge as outlined by Provost Halleran for the Ad Hoc Committee for Engineering and Design Opportunities at William & Mary (W&M) was to explore and “find ways to give our students opportunities to become conversant with the tools, programs, and methods” deployed within the fields of engineering and design, to become familiar with “design thinking,” and to “feel comfortable when working in design studios or entrepreneurial incubators.” The committee concurs that the time has come to reinstate the applied arts and sciences in our W&M mission, and it promotes the idea that a return to our earlier embrace of engineering and design is completely consistent with a strong education in the liberal arts. Moreover, as charged, the committee’s recommendations for relevant engineering opportunities are described in the full report.

The committee finds that academic endeavors often separate science from engineering, theory from application, and theory from experimentation. We believe these separations of theoretical activities from activities that result in the rendering of a workable solution are artificial and detrimental. Moreover, we also find that a separation of scientific and engineering endeavors from the liberal arts is detrimental to graduates’ welfare. We believe that graduates must be as comfortable with theory as they are competent at rendering solutions that surmount real-world factors not considered in theoretical models. We also believe that W&M, as a premier liberal arts university with a strong research culture, is well positioned to build a distinctive engineering enterprise that leverages the strengths of a liberal arts education.

William & Mary has embraced engineering in a formal sense, but only episodically. William & Mary’s designation as the “Virginia Polytechnic Institute” in the 1930s was ceded to Virginia Tech and its engineering enterprise was separated from W&M in 1962 to ultimately become Old Dominion University. Virginia Commonwealth University, another of William & Mary’s spin-outs, has an engineering school, and Christopher Newport University, which also spun off from William & Mary, supports an engineering program. These centrifugal effects have left W&M with no identified engineering program of its own.
Nevertheless, engineering activities still are being done across W&M. The committee’s report recognizes these activities and the concomitant competencies that have been developed. The report describes a plan to integrate them and to add needed activities to complete coherent and comprehensive engineering and design experiences for students. The program provides the identified engineering elements that address important societal shifts caused by the ubiquity of data and it describes emergent approaches to design and engineering that require science and engineering to be integrated with humanities, arts, and business. Reintegrating engineering “maker” activities with computational models and other design tools allows our graduates to take on topics of societal import as competent practitioners.

Dr. Henry Rosovsky, former Dean of Arts and Sciences at Harvard and an W&M alumnus, said that the best reasons to go to college are: 1) to enhance one’s value in the workplace in order to assure one’s ability to sustain independence and self-sufficient support for life; 2) to learn to appreciate the subtler forms of beauty in the world; and 3) to participate fully as informed citizens in a democracy [Rosovsky, 1990]. We represent this viewpoint by the triad: <Employment, Enjoyment, Engagement>. While we argue that the integration of engineering with the strong liberal arts background at William and Mary will improve the student experience in all three elements of this triad, the report focuses on promoting the “Employment” element by providing means by which students will attain STEM skills and perspectives valued by employers and, simultaneously, by providing formal curricular content that balances W&M current strengths in theory with opportunities for rendering solutions using engineering and design techniques.

The planned program provides opportunities for all William & Mary students, allowing students who are not seeking technical positions to become familiar with engineering and design processes and to learn both technical and critical thinking skills that permit them to participate in these important processes. For technically-oriented students, the program further provides paths to acquire deeper technical skills. Apart from industry’s need for such skills, documented in the proposal, we recognize that inclusion of engineering in a liberal arts education is integral to reshaping the world, and therefore is required to allow our graduates to be fully informed citizens.
The structure of the committee was designed to take advantage of the many internal connections at W&M, broadly sampling the entire range of activity at the University and propelled by the high enthusiasm of the many faculty who participated in creating the report. Before designing specific solutions to meet the Provost’s charge the committee spent considerable time deliberating the characteristics of acceptable solutions. They agreed to a set of six characteristics that were essential for the construction of each pillar of the program:

1. That they be welcoming to traditionally under-represented groups in engineering;
2. That they encourage methods and modes most appropriate to the design domain of interest to promote creativity;
3. That they involve iterative approaches;
4. That they enhance both verbal and non-verbal inputs and outputs;
5. That they involve safe and secure spaces where teams can examine failures and use them as learning experiences;
6. That they promote a willingness (or eagerness) to routinely seek out and go after “hard problems”; that they teach students not to quit or freeze when faced with “wicked problems”.

The range of ideas that emerged from conversations and brainstorming sessions was very broad. The report aggregates them into five “pillars.” The first three pillars Science, Humanities, and Arts, echo the new COLL curriculum which is now the basis of the W&M liberal arts. The fourth pillar, Business and Entrepreneurship, provides very important support for all of the other pillars, and serves as a highly desirable outlet for students in engineering studies across the entire University. The fifth pillar, Infrastructure, builds our tools, spaces, and resource centers, such as various maker spaces, computational and communication resources, centers for learning design, media, and the liberal arts, and a center for large-scale Data Visualization. A brief summary of each pillar and their respective components is as follows:

**Science Pillar**

- Applied Engineering Physics and Design Science
  - This component provides a pathway for students to earn a B. S. degree in Engineering Physics and Applied Design. It incorporates faculty members from
the Physics Department, the Applied Science Department and the Raymond A. Mason School of Business. This proposal leverages the firm foundation that William & Mary offers in pure and applied science, with laboratory experiences for bridging that science with applications of modern technology.

- **VIMS AUU/Robotics**
  - VIMS offers resources and expertise in Autonomous Underwater Vehicles (AUVs), underwater Remotely Guided Vehicles (ROVs), and unmanned aerial drone technologies to be leveraged across the other sub-proposals.

- **Data Science**
  - The group working on this initiative identified 16 educational units, programs, and centers whose work revolves around “big” data and computation, with multiple pathways for undergraduate, masters, and doctoral students to acquire data science credentials. Academic programs will include undergraduate degrees with a focus on the potential for COLL inclusion, a certificate program, and a Ph.D.

- **Bioengineering/Synthetic Biology**
  - This sub-proposal suggests a pathway for undergraduates to pursue an integrated coursework in bioengineering/synthetic biology and M.S. and Ph.D. program tracks to be offered through the Applied Science Department. The proposed undergraduate curriculum contains many suggestions for COLL courses for independent studies and for Computational Biology.

**Humanities Pillar**

- **Equality Lab: A Space for Digital Scholarship**
  - This sub-proposal includes a center, The Equality Lab, for a multitude of creative and “maker” activities. Many new COLL courses are also suggested.

- **Arts: Engineering Foci**
  - This sub-proposal suggests a formalized pathway for undergraduate students who have heretofore relied on the Interdisciplinary Studies program or double majors to construct programs to satisfy their interests. A detailed curriculum
has been developed for Digital Gaming, integrating new COLL courses into its curriculum. Additional programs are suggested.

Arts Pillar

This pillar suggests COLL courses to provide for the interplay of multidisciplinary creative-engineering programs.

- Art Conservation
  - The report suggests that William & Mary can build a high-quality program around significant laboratory experience taking advantage of W&M’s proximity to Colonial Williamsburg. The report describes a conservation program to restore art, artifacts, and to assist in uncovering and preserving the important history of the Historic Triangle.

- Sustainable Design
  - The report describes a program to blend enlightened approaches to habitat, materials, and a cradle-to-cradle philosophy of community, energy, and environment.

Business and Entrepreneurship Pillar

- Design and Deliver
  - This sub-proposal outlines means by which undergraduate students can gain design experience as elective content that either carries no formal certification or can be pursued as a concentration through 12 credit hours of course work. The former option makes this option accessible to many William & Mary students’ schedules who can find value from learning the design process but whose curricular focus is elsewhere. This sub-proposal also provides for a project qualifying for COLL 400 status. This sub-proposal provides for a number of online programming, prototyping, and electronics modules that can be redeployed across many internal William & Mary programs as well as in outreach programs.
- App School – describes spaces and programs to develop various applications for smartphones, tablets, or other devices.
  - This sub-proposal suggests curricular content that, upon completion, would result in students having created a minimally viable software product. Some of the courses in this sub-proposal would qualify for either COLL 200 or COLL 400 status.

**Infrastructure Pillars**

- Maker Spaces
  - This section outlines maker spaces that are available through campus to support the curricular proposals herein.

- The Center for Innovation in Learning Design
  - This center provides for innovation in K-12 education using, among other techniques, design thinking. Teacher candidate training is involved as is collaboration of many William & Mary educational units to design problem-based learning content. This center can support other sub-proposals in this document.

- Center for the Liberal Arts
  - This Center, long in the planning provides support and coordination for many of the new features of the Arts and Science COLL curriculum in a physical space centrally located in Swem. Here College Fellows and other faculty and staff will be available for consultation. This Center, along with the Center for Teaching and Learning (CEeL), and the Reeder Media Center, is equally important to e-Learning and other elements of the strategic direction for academic programs campus-wide. Swem Library has led a systematic campaign to provide modernized spaces of these needs; this Center (along with Reeder and the CEeL) will be a valuable asset to the engineering programs

- Swem Library Central Data Visualization Lab
  - The sub-proposals above, along with other work across campus, require intense computational efforts with geographic information systems (GIS), modeling and simulation, and big data. This facility will enhance student and faculty research
and learning in these and other realms by making available a unique, large-scale visualization platform comprised of hardware and software for visualizing high-dimensional data sets and the analysis thereof.
References for Executive Summary

Introduction

The committee believes that the separation between theory and application, between thinking and making, between science/engineering and the rest of the liberal arts, is artificial. We believe that W&M has positioned itself as a premier liberal arts university with a strong research culture, and therefore, it is well positioned to build a distinctive engineering enterprise that could become a national model.

The distinctions between theory and experiment in science and engineering have become more subtle, largely as a result of ubiquitous data collection using low-cost sensors, fast high-resolution imaging tools coupled with advanced mathematical methods and powerful algorithms for computational modeling, simulation, pattern recognition, data compression, and visualization, done in ever-larger and faster machines. Academic planners, in considering how to achieve balance among various programs, have long been fond of metaphors like the “three-legged stool” where a triad of inputs or conflicting demands must be balanced. So, for example, academic planners speak of Computational Science as the third leg of “three-legged stool” of scientific inquiry as part of the triad: <Theory, Experiment, Computational Modeling>.

We accept that it is almost never possible to deal with conflicting operational demands “three-at-a-time,” but the three-legged-stool metaphor is very convenient for many purposes. Another notable triad, at the heart of why students seek higher education, was articulated by a W&M alumnus, Dr. Henry Rosovsky, former Dean of Arts and Sciences at Harvard. Professor Rosovsky says [Rosovsky, 1990] that the best reasons to go to college are: 1) to enhance one’s value in the workplace in order to assure one’s ability to sustain independence and self-sufficient support for life; 2) to learn to appreciate the subtler forms of beauty in the world; and 3) to participate fully as informed citizens in a democracy. We abstract this as the triad: <Employment, Enjoyment, Engagement>. All three reasons are critically important to W&M graduates. Our success at balancing this triad at W&M puts us in a better position to institute

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1 We note in passing that W&M began to build its “high-performance computing” infrastructure in the early 1990’s, and like most Universities, after more than 20 years, a large portion of our research success relies on that computing capability.
powerful new approaches to engineering and design in keeping with a recent National Academy of Engineering document [Olsen, 2016] that strongly echoes Rosovsky.

A traditional way to differentiate science and engineering departments is to say that engineering departments almost always provide formal instruction in “designing” and “rendering,” whereas most traditional science departments might not. By ”rendering” we mean the transition from an idea -- the ”design” -- into a physical thing or working algorithm that acts on real-world data. This distinction relies on another important triad: <Tools, Techniques, Processes>. Distinguishing science from engineering requires assessing what fraction of the tools, techniques or processes are given over to teaching how to design or how to render in a given problem setting. Since the end of WWII, in science departments at William & Mary, this fraction of attention to instruction in design and rendering has been traditionally quite small. In what follows, we propose to rectify this imbalance, by tapping into activities that are already ongoing but which have been ”flying below the radar” until now, often making W&M appear to be disengaged from the applied problems of the communities we serve. We propose ways to promote these activities and to raise their visibility on campus. We address this by encouraging greater blending of those problem-solving activities with the rest of our research and teaching mission, especially maximizing opportunities provided by the new COLL curriculum. Our new approach to general education encourages both faculty and students to think about the connection between teaching and research in more creative ways.

Why hasn’t this happened already?

A brief historical digression is needed here to note that once, back in 1930, W&M did offer full-scale engineering education. W&M even had an aeronautical engineering department, complete with a flight school that operated out of a university-owned airport in Williamsburg. Indeed, the W&M engineering enterprise was sufficiently extensive that in 1931, the legislature appended the title “Virginia Polytechnic Institute” to William & Mary. This “VPI” title later moved to Virginia Tech, the land-grant institution in Blacksburg, which became known as VPISU (Virginia Polytechnic Institute and State University). In a separate later action, the remnants of W&M’s engineering enterprise separated from W&M in 1962 and became Old Dominion University in Norfolk [ODU]. We note that similar W&M remote campuses in
Richmond and Newport News eventually separated from us to become Virginia Commonwealth University, which has an engineering school, and Christopher Newport University, which offers limited programs in engineering education. The interested reader will find a more thorough discussion of these decisions in [Godson 1993]. Study of these failed attempts to manage remote campuses suggests that the ability and willingness of faculty and students to undertake the necessary round trip travel daily, or even a few days a week, in our rural/suburban environment appears to be limited to less than roughly 60 minutes of door-to-door drive time. Sustaining partnerships with remote campuses, centers, institutes, and other academic outposts beyond that time boundary, though occasionally successful in metropolitan areas with good public transportation, must either be done primarily by local residents or by reassigned or seconded personnel. In the absence of these conditions, such remote enterprises have a history of rebellion (or abandonment), and often create as much friction or competition as they do collaboration. Of the remote enterprises spawned by William & Mary in an attempt to become a “system of higher education institutions,” the only one that is still (weakly) associated with W&M, is Richard Bland College, a two-year institution in Richmond.

In summary, these centrifugal forces undermined William & Mary’s efforts in engineering because, back then, learning and research in applied fields were not viewed as central to the liberal arts mission; hence engineering and design was seconded to remote venues. These fields then died on main campus when the eventual falling out occurred between us and our rebellious children.

After these major troubles, other attempts were made to re-install more applications-oriented or business-oriented work at W&M, with the onset of Ph.D. graduate work in Physics and Marine Science in the 1960’s, the establishment of the MBA in 1966, and the approval of the BBA in 1971, proceeding through an abortive attempt to create a program in “Applied Science” in the 1970’s. In the early 1980s there followed a failed attempt to resurrect a consortium from the ashes of W&M’s failed extension graduate campus that was known as the College of William & Mary Virginia Associated Research Campus (VARC), again remotely located at the NASA Space Radiation Effects Laboratory (currently the site of Jefferson Lab). The consortium activity that followed, which was chartered as the Virginia Associated Research Center (again VARC), was intended as a partnership between W&M and other state universities in science and engineering, associated with the then-new Continuous Electron Beam Accelerator Facility
(CEBAF, now known as the Thomas Jefferson National Accelerator Facility, TJNAF) in Newport News. The records of these discussions and decisions have been collected and studied, and a detailed account of the failure of the VARC venture was presented in a W&M Ph.D. thesis [Ward, 1993].

Reading the available accounts of these later failures makes it clear that the residual trauma of the very serious remote-campus problems that led to the split of ODU, VCU, and CNU left a legacy of risk aversion at W&M, a remnant fear that the very existence of graduate work dilutes undergraduate excellence in some zero-sum-game theoretical way, and a general distaste for “hands-on work” that could not be overcome until the present new COLL curriculum was debated and installed.

The hard work of the latest curriculum reform itself followed a series of “shocks to the system” in university life, including two decades of political arguments over higher education as a public versus a private good, the contraction of state support for US higher education, the emergence of asynchronous online alternatives, Baumol’s (cost) disease [Archibald and Feldman, 2010], attempts at tuition control, and the effects of recent financial crises (the dotcom bust of 2000, the mortgage bubble of 2007). The famous quote of Max Planck comes to mind: “A new scientific truth does not triumph by convincing its opponents and making them see the light, but rather because its opponents eventually die, and a new generation grows up that is familiar with it.” [Planck, 1949] This quote is usually paraphrased as: “Science advances one funeral at a time.”

It is the main thesis of this document that the time has come to reinstate the applied arts and sciences in support of the W&M mission, promoting the idea that embracing engineering and design is completely consistent with a strong education in the liberal arts. It is the committee’s position that engineering and design students at W&M will be distinctive and highly sought-after in the job market. They will rise to positions of leadership and have outsized influence, precisely because they will pursue their E&D studies in a liberal arts context, rich in contact with the humanities, arts and related fields. This will broaden and deepen their understanding of the social, political, and cultural contexts in which they will apply their skills.

As an additional historical note, it was only 15 years ago that faculty in Arts & Sciences debated whether or not incoming students should be required to own their own laptop computers,
unsure how they would even integrate the devices into their classrooms. Today, first-year students are expected to be fluent in digital technology as they build websites, record podcasts, and research vast databases in their COLL 100 and 150 classes. To them this isn’t new technology. This is what they have always known: a smaller world in many ways, much more international in its scope, and a world that requires nimbleness and flexibility. And yet, through it all, the core mission of W&M, “to provide a challenging undergraduate program with a liberal arts and sciences curriculum that encourages creativity, independent thought, and intellectual depth, breadth, and curiosity,” hasn’t changed or diminished.

**Our students will benefit from Engineering at W&M**

The academic (departmental) distinctions between science and engineering that we discussed in the beginning of this introduction do not apply in the workplace. When teams are assembled to solve perplexing and urgent technical problems, lines between disciplines almost always dissolve. At one moment, the pressing issues resemble those familiar to the traditional physicist, at another moment, the project needs the skills of a mathematician or computer scientist, at another time the most urgent issues might require knowledge of chemistry or metallurgy. In other stages of the work, the skills of a linguist, social scientist, or experts in government affairs or policy may be the dominant concern for successful completion of a project. Such inter-disciplinary boundary-crossing became very common during WWII and thereafter, when the current system of fundamental scientific research blended with engineering and application-oriented research. Interdisciplinary teamwork remained important to the post-war (and Cold War) economy, became more intense during the post-Sputnik space-race of the 1960’s, and intensified even further as global competition accelerated in the late 1970’s and early 1980’s. Nowhere has this acceleration been more rapid than in semiconductor development fueling applications of high-speed computer and communication technology. The secondary effects of these developments have driven a related acceleration of business productivity following the widespread adoption of automation in manufacturing, automation of business processes, financial products involving risky international debt swaps, outsourcing, offshoring, assimilation of competitors through mergers and acquisitions which reduced employment and
applied downward pressure on wages, while pushing the benefits of increased productivity unequally toward those in the upper income brackets.

The rapid pace of product development in many industries can be a source of immense financial pressure on a company, even when it comes to performing the experiments needed to develop new products. In moving from the laboratory to the supply chain, something as simple as altering a single step in an established multi-step process can represent serious financial risk to a company. The incorporation of a superior high-performance aircraft material into the design of a plane, the creation of a new drug for human use by “tweaking” a molecular side-chain, or the substitution of different metal conductor or insulator with a smaller linewidth in a new version of a computer chip may cost many millions of dollars to test, and can require tens or hundreds of millions of dollars to build a full prototype. When more major changes are considered, it is not possible to try every conceivable arrangement of tooling, or to try every combination of experimental conditions, when each test is so expensive. Consequently, in many applications there is an increasing emphasis on extracting as much guidance as possible from data accumulated in a limited number of careful experiments, and then using this data to reliably predict the outcome of tests which one cannot afford to run. These predictions often involve complicated mathematical models to simulate the behavior of the system of interest, to search in advance for the best arrangement of components and materials, changing temperatures, process times, pressures, and so on, to find the candidate design to build (i.e. to render) for actual trials. Thus, major economic growth in this century will be driven by R&D that is increasingly conducted using modelling and simulation. Developing better methods of simulation itself has become a multi-billion dollar industry with fast growth potential [Forbes online].

In the various pillars described below we will presume the continuing growth of our computational science infrastructure at W&M, which has grown from delivering a few thousand core-hours\(^2\) of computational power each month when we aggregated HPC assets at the end of FY 2000 to 1.25 million core hours per month in FY2015.
Figure 1: Delivery of Core hours per month, shown for the HPC cluster-of-clusters, each month from March 2001 to December 2015. Blue: SciClone cluster, Green: Storm cluster, Red: Chesapeake cluster.

We also presume that the vigorous pursuit of effective numerical modeling required for continuing progress in the disciplinary departments of computer science, mathematics, physics, applied science, and marine science will continue. Further, at W&M we are seeing the adoption of computational modeling in other disciplines such as government, linguistics, history, and international relations. Computational science is a rapidly evolving field, driven by the three-pronged advances in computing power, advanced algorithms, and cyberinfrastructure; this is the realm of computational science. We will not spend much time justifying this necessity, except for a brief set of comments by way of background here.

2 A ‘core hour’ refers to the time of dedicated processor usage for computations. With multiple processors running in parallel, this number is calculated using the length of time on each processor, multiplied by the number of processors. So, a calculation that takes one hour on a hundred processors requires ‘100 core hours’.
Computational science as an identifiable discipline has only had a short history, following the birth of modern computers during World War II. Since then computing power has roughly doubled every two years (Moore’s law), and data storage has grown even faster. Although the trend has shown the sign of slow-down recently, the imminent availability of exascale computing ($10^{18}$ operations per second) enabled by next-generation many-core chips is going to fundamentally change the face of computing in the coming decades.

Anticipation of this change has created cloud and fog computing$^3$ designed to meet the needs of a world population expected to reach 8 billion in the next decade. With the Internet of Things (IoT) connecting 80 billion devices [Akers 2016], large corporations and government agencies have invested heavily in High-Performance Computing (HPC) equipment. W&M has invested also. In addition, other types of computing paradigms, for example, hybrid GPU-CPU, such as the clusters we have developed at W&M for quantum chromodynamics calculations, have shown great promise. In addition, through Internet 2 to which W&M has been a primary subscriber, and through its coming successor schemes, a new cyber infrastructure is being built to move the vast amounts of data generated by the IoT quickly.

Novel numerical algorithms and computing paradigms are being developed to effectively take advantage of such new equipment. We see these forces as compelling reasons to incorporate computational science into the W&M liberal arts education. We also know that our students must master engineering process design tools and methods they will encounter in workplace. We will not provide a close analysis of the workplace needs here, nor will we be able to discuss the detailed decisions that are required to decide which computational programs our students will need to use. We will provide very brief discussions of these matters in the science pillar sections below, and remind the reader that decisions about E&D curriculum design and content will be made and re-made repeatedly as our STEM programs evolve and begin to intersect broader areas of activity to create new ways of thinking about problems.

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$^3$ ‘Cloud’ computing refers to the use of large data centers for computation or data storage (e.g. the Google model), while ‘fog’ computing refers to the networked use of distributed small processors or devices, much closer to the end users.
Why W&M can lead the way

A compelling case for building an engineering and design activity at W&M has been eloquently made by various studies of the National Academies, especially by the Academy of Engineering, which over the last decade or so has published dozens of analyses of national needs in STEM higher education. A 2016 NAE report [Olson 2016] reviewed the central features of engineering practice and education. This forum listed 14 Grand Challenges for US Engineers as follows:

- Make solar energy economical
- Provide energy from fusion
- Develop carbon sequestration
- Manage the nitrogen cycle
- Provide access to clean water
- Improve urban infrastructure
- Advance health informatics
- Engineer better medicines
- Reverse-engineer the brain
- Prevent nuclear terror
- Secure cyberspace
- Enhance virtual reality
- Advance personalized learning
- Engineer the tools of scientific discovery

W&M has much to offer in these areas. Through the W&M Environmental Science and Policy (ENSP) Program, the Sustainability Initiative, the Center for Energy and the Environment, the Keck Center, the Virginia Coastal Policy Center, ITPIR, and other W&M centrally-organized efforts, our students and faculty are currently working on at least five of these Challenges. Work on the Challenges has prompted collaboration across W&M disciplines including economists, computers scientists, geographers, political scientists, and others promoting undergraduate and graduate research and learning opportunities.
One of the most interesting sections of the NAE report summarizes the comments of Robert Socolow of Princeton University, who echoes Rosovsky’s second triad element: “enjoyment.” The following excerpt from the report bears repeating:

“Robert Socolow observed that the 14 Grand Challenges fall into four categories. The first is sustainability—maintaining air and water quality, protecting freshwater quantity, preventing sea level rise, keeping forests and other ecosystems in good condition, and minimizing artificially triggered climate change. Next is personal and community health, because, he pointed out, ‘as individuals we can live fulfilling lives only if we are healthy.’ But, he added, ‘people have a record of being dangerous to each other,’ hence the third category, vulnerability and security. The fourth category, joy of living (emphasis added), does not sound like a traditional engineering concern, Socolow admitted, but ‘electronics deliver us music with marvelous fidelity. Air travel brings us access to the extraordinary variety of human cultures and natural settings. Electronics nurtures our curiosity by providing incredible access to information. Engineering in many forms enables many discoveries about our universe and the history of life, which we then share.’ Joy of living is not commonly found in an engineering course syllabus, Socolow said, but engineers should view it as part of their calling.”

Socolow’s thoughtful classification of these challenges could serve as “big ideas” for the COLL curriculum. Enhancing the joy of living is a worthy goal that has long been an item in the strategic plan of liberal arts university. Among the most urgent of the National Academy Reports was the NAS 2007 “Rising Above the Gathering Storm,” which has been revisited and reaffirmed, and the analysis of the need for a new and different approach to engineering in the NAE 2005 “The Engineer of 2020: Visions of Engineering in the New Century,” which also has been revisited and expanded numerous times since 2005. In reading this material, one comes away believing that the very thing that is needed most is to try to recapture some of the liberal arts core that is often lacking in engineering schools. The “2020” document articulates this very clearly:
“We aspire to [train] engineers in 2020 who will remain well grounded in the basics of mathematics and science, and who will expand their vision of design through a solid grounding in the humanities, social science, and economics. Emphasis on the creative process will allow more effective leadership in the development and application of next-generation technologies to problems of the future.”

The Ad Hoc core committee, appointed by Provost Halleran to study this issue at W&M, and their associates writing this report, gave considerable thought to the triad at the heart of the W&M undergraduate liberal arts core: <Arts, Humanities, Sciences>. Proposed aspects of engineering and design described below will build on that structure and will enhance activity in all of these areas. We believe that embedding engineering and design skills into the liberal arts core of W&M will be easier and more fruitful than trying to recover the apparently lost liberal arts core at many existing engineering schools. W&M is singularly positioned to take on this approach to the study of design and engineering. Understanding how technology has reshaped our notions of power and accountability, our sense of time and space, and our relationships with each other and our communities is something that can only occur within a liberal arts institution as equally committed to both the sciences and the humanities as at William & Mary. We describe this aspect of the work of the committee in the next section, emphasizing our care in preserving the liberal arts core that has become the hallmark of a W&M education.

Our Committee’s Approach

The charge as outlined by Provost Halleran for the Ad Hoc Committee for Engineering and Design Opportunities at William & Mary (W&M) was to explore and “find ways to give our students opportunities to become conversant with the tools, programs, and methods” deployed within the fields of engineering and design, to become familiar with “design thinking,” and to “feel comfortable when working in design studios or entrepreneurial incubators.”

As the committee began its work surveying the various “ways of making” and prototyping capabilities throughout W&M, it became immediately clear how far-reaching this initiative could become. Since the creation of the Department of Fine Arts in 1937, “making” as it is now known, has taken place throughout the entire William & Mary ecosystem. The desire
then, as it still is today, was to provide the liberal arts student with a practical, hands-on experience, to understand the material world to its full extent and to engage in design iteration, critical thinking and problem-solving. This has expanded over the years to include areas such as Physics, Biology, Data Analytics, and more. Leaders in Business have recognized the utility of design thinking and product development through prototyping. Educators are integrating new technologies into the classroom and many in the Humanities are taking advantage of the power of new digital research tools.

Current fields of study require multidisciplinary approaches with teams of distinctly capable individuals who are able to pool their respective expertise and skills for a common purpose. This triad: <Autonomy, Competency Development, and Purpose>, is known to be the best way to motivate students, even more so than offering money or grades [Chacra, 2008]. To excite students and to help them discover their passions, we need to build upon the foundation laid down by the new curriculum, to define pathways and weave threads across and through all of the university’s domains, schools, and programs, to create an inclusive environment that not only respects the diversity, differences, and unique talents of many individuals, but also shares common purpose and the spirit of exploration and risk taking, where, in Samuel Beckett’s words, students will “Try again. Fail again. Fail better.”

Recent years have seen a renewed appreciation for more holistic approaches to design and engineering in which individuals are engaged in the full process of “making” from concept to final object [Franklin, 1989]. The dangers to an organization of a too-narrow focus was highlighted, for example, in the influential article ‘The Decay of NASA’s Technical Culture’ [McCurdy, Space Policy, 1989] which posited that during NASA’s early ‘heroic’ phase, what we would now call a ‘maker philosophy’ was the guiding spirit, with the early rocket scientists engaged in everything from design, to building and testing. Increasingly, the dichotomies of “science/technology,” “pure/applied,” internal/external, and “technical/social” are giving way (or perhaps, returning) to more integrated, networked, and system-oriented methods [Pinch, et al., 2012]. We are even seeing sustained interest in handwork and craft, and a re-evaluation of pre-digital, non-electronic, technologies.

All of this activity at W&M resides in a location that provides our students and faculty with a very rich set of potential partners within an approximately half-hour drive, such as NASA
Langley Research Center, Thomas Jefferson National Accelerator Laboratory, and a number of high-tech command Headquarters (TRADOC and Logistics Command at Ft. Eustis, Air Combat Command at Langley AFB, and others). Figure 2 shows federal facilities near W&M, and indicates the potential for federal jobs; the light-red zone shows one half hour drive times which include Camp Peary (CIA), Ft. Eustis, and Jefferson Lab. NASA Langley is slightly outside the half an hour drive time from main campus.

![Government engineering jobs near William and Mary](image)

*Figure 2 Government Engineering Centers (green circles) close to W&M*

These facilities all have intensely interesting and challenging engineering problems to be solved, so these US government neighbors are very well-positioned to provide a rich set of opportunities for hands-on learning and research needed for the liberal arts education we seek for our new COLL curriculum. Furthermore, as can be seen in Figure 3, current job postings for engineering graduates among local companies within a one-hour drive time may provide an attractive way to keep some of our best and brightest W&M students in the Williamsburg area.
after they graduate. The proximity of these neighbors is important, but as we mentioned above it is necessary to not overestimate the importance of external influences to the success of internal programs.

![Engineering job openings near William and Mary](image)

Figure 3 Job openings at companies close to W&M presently hiring engineers. [Indeed.com Apr 2016]

We need to install or reinforce academic structures or mechanisms that allow for the necessary pathways between disciplines to be created. No existing system at W&M currently fosters collaboration across the entire constellation of schools, department, programs, and institutes. The proposals presented here aim to build on the strengths of W&M to create an inclusive environment which respects the unique capabilities of all students regardless of race, gender, or sexual orientation. These new structures and mechanisms will weave existing resources from the sciences, the arts, and humanities together with new innovations that we
might not now envision, by creating a scaffolding within which students and faculty can develop their competencies. We will encourage our students to explore critically the history and implications of design and technological development in all of its forms and manifestations. Students will engage not only in the design process itself, but the will also understand its context, for whom we design, and what human values are hidden inside the design itself, encoded in what we mean by a "good" solution, and how this has affected the human condition over time.

Outcomes of Committee Discussions

The structure of the committee was designed to take advantage of the many internal connections at W&M associated with each member of the “core writing team” comprising 17 members and chartered by the Provost. This group was ably assisted by a second-layer of close associates comprising about 20 faculty members, who attended meetings, contributed ideas, and/or assisted in the writing of one or more of the sections that follow, working in consultation with fellow faculty and others in their orbits. The guidance to the committee was to take no pride of ownership or authorship, but rather to try to produce sustainable structures to benefit our students and faculty. The members were asked to devise possible interdisciplinary degree programs for each of three kinds of students: traditional residential students fresh out of high school, transfer students with two years of community college or other higher education, and students returning to degree or certificate programs, possibly retraining after military or other career experience. Emphasis was placed on various approaches to develop or incorporate the most recent thinking in “Design,” without getting mired in debating the exact meaning of jargon or buzzwords. Key elements strongly required for any program suggested were:

1. That they be welcoming to traditionally under-represented groups in engineering.
2. That they encourage methods and modes most appropriate to the design domain of interest to promote creativity.
3. That they involve iterative approaches.
4. That they enhance both verbal and non-verbal inputs and outputs.
5. That they involve safe and secure spaces where teams can examine failures and use them as learning experiences. [Stefan, 2010]
6. That they promote a willingness (or eagerness) to routinely seek out and go after “hard problems;” that they teach students not to quit or freeze when faced with “wicked problems” [Ritter, 1973; Camillus, 2008; Kolko, 2012].

The range of ideas that emerged from conversations and brainstorming sessions was very broad and the apparent enthusiasm among faculty is very high. For the purposes of presentation we organize the resulting contributions into five pillars that include Science, Humanities, Arts, which form the basis of the new COLL curriculum, Business and Entrepreneurship that provides very important skills for the other three and an outlet for students engaged in engineering studies across W&M, and finally the pillar of infrastructure and resource centers, such Computational Science, GIS, a Visualization Center, Learning Design, and various distributed Rendering Centers.

The Undergraduate Curriculum

The guidelines for the new COLL curriculum, while innovative and exciting, are silent on the place for technology in our general education. The descriptions of the three COLL ‘Knowledge Domains’ (ALV = Arts, Letters, and Values; CSI = Cultures, Societies, and the Individual; and NQR = The Natural World and Quantitative Reasoning) don’t even use the word “technology.” George Steiner said that music was silence interrupted, so we argue that this lacuna around the role of technology in our domain descriptions in fact provides an opening for innovation that will make our engineering and design enterprise distinctive in American higher education. If we read the domain descriptions in this light, as an invitation to create new forms and types of courses, we find that technology could be understood to live throughout the COLL curriculum. For example:

In the ALV Knowledge Domain, students study the various “expressions of values.” We can interpret technology and tools as physical embodiments of human desires, and manifestations of values. We can examine the historical impact of new technologies on the way humans live in a changing world, how those new technologies influence movements in the arts and literature, the impact on the human imagination of the coming of the steamship and the spaceship, while celebrating the present-day hacker and maker cultures with humanistic insight. Students in the humanities might build robots or 3D print specialized drone attachments to
capture novel video imagery for film projects, or learn how to dance with a robot or drone. Making new art with new tech, William & Mary students will be at the forefront of the humanization of technology, empowered to explore their passion for tech while aware of the cultural matrix they work in, self-confident and steeped in technical lore, but also fluent in the multiple languages of poetry, dance, film, and storytelling.

In the CSI Knowledge Domain, students study cultures and their artifacts, examining how societies change and adapt. Public policy, psychology, sociology, and anthropology, for example, all deal routinely with the impact of technology on their subjects of study, use new apps for new kinds of survey methods, or apply analysis to large datasets.

In the NQR Knowledge Domain, the connection with more traditional forms of ‘engineering and design’ is more direct. In these fields the use of new technologies for measurements and observations is part of the workaday bread and butter of the NQR student scientist. The goal of our engineering and design conversation has been to look for new ways to bring more students into that cycle of tech problem solving and invention, by exploiting our recent investments in computation and maker spaces, as resources available for general use.

In each of these Knowledge Domains, the goal of this committee’s work has been to seek ways to open up new tracks for engineering and design students to study the connections across the knowledge domains, and to develop their entrepreneurial chops. So, instead of the absence of an explicit mention of technology in the COLL domain descriptions being a weakness, we argue that it is a strength. It doesn’t isolate technology in one particular locus, as might have happened if we had a traditional engineering school. Instead, it makes all of A&S, and the university generally, an open field for engineering and design activities, and allows this to done in a manner that is completely consistent with the guiding principles of the new COLL vision. We aim to bring our students as quickly as possible into the kitchen where new things are being cooked, and then hand them the spoon so they can make their own soup.

We emphasize that the way we frame the question of how to incorporate more engineering and design into our liberal arts education is merely a fast start along a path that will require much iteration and change over the next five to ten years or more. The list of topics and proposed structures is not exhaustive, nor are the ideas outlined below complete. There will be numerous additions, deletions, and alterations as we proceed to implementation. Clearly we will
have to stage the execution of these ideas. Some items, like the visualization center in SWEM, must await large gifts before it can even begin. We include as much as possible in this document, with an idea of implementing as many items that are reasonable to do as soon as possible, and with the intent of establishing a strong strategic plan to accomplish the remainder.

The advent of the new COLL curriculum has injected a new wave of creative energy into the university, and we seek to surf that wave. Maker spaces for all of the various activities are already well under way (see Infrastructure Pillar below), and these spaces have been under development for more than two years in anticipation of this committee’s work; investments in these spaces will continue. The maker space philosophy is to promote prudent risk-taking, by building a safe space for students and faculty to invent and create new things, outside the usual classroom setting. Ungraded “play” with a serious purpose, it gives our students a sense of the freedom afforded by a creative life, and does it in a supportive environment with fellow hackers, inventors, entrepreneurs, playwrights, and artists.

The degree of cross-talk between the five pillars of our proposed enterprise is very high, and each will benefit from investments in the other. What follows are the writings of various teams for each pillar, presenting possibilities.

*Science Pillar*

- Applied Engineering Physics and Design Science
  - Engineering Laboratory Teams
- VIMS AUV Robotics
- Data Science
- Bioengineering/Synthetic Biology

*Humanities Pillar*

- Equality Lab
- Digital Gaming

*Arts Pillar*

- Sustainable Architecture
- Art Conservation

*Business and Entrepreneurship Pillar*
- Design and Deliver
- App School

**Infrastructure Pillar**

- Rendering Centers
  - Maker Spaces
  - Main Shops – Andrews, Small, ISC, Clay, Foundry/Casting, Architecture
- Learning/Curriculum Development Centers
  - School of Education – learning design
- Swem Centers
  - Computational Science – GIS – Visualization
References for Introduction


Planck, M., as cited in Max Planck Scientific Autobiography and Other Papers, Gaynor (New York, 1949).

ODU:http://www.lib.odu.edu/special/manuscripts/norfolk-division.htm)


Science Pillar

Applied Engineering Physics and Design Science

Introduction and Historical Perspective

William & Mary prides itself on delivering an excellent undergraduate liberal arts education with strong programs for science majors. However, most of our undergraduate science programs have emphasized pure science, deemphasizing the technical and engineering parts of a STEM education. There are exceptions to this rule, of course, because the science programs use current technology in the faculty members’ research programs, so many activities around that research are in engineering-related fields, or require an acquaintance, or even a mastery, of engineering and design principles. For example, undergraduate Physics majors require two lab courses (three for honors), with overall four lab-courses available. This breadth of laboratory offerings is not very common for liberal arts universities like W&M. In addition all Physics students are involved in research for at least a year, and many for longer periods. In Applied Science, most undergraduate students undertake two semesters of mentored research for credit, and additionally they do ten or more weeks of intensive research training during the summer session. Therefore, while engineering and design are not emphasized programmatically, interested undergraduate students have multiple opportunities to receive top-notch training in engineering and design, and their competitiveness for post-graduate training in top Ph.D. programs, or direct employment in STEM fields, are the best testimonials for what we do to prepare them. Yet, the emphasis on pure science often means a greater emphasis on theory in our approach to STEM education. This creates a firm foundation, but does not necessarily emphasize for our students the many bridges that connect pure science to modern technology.

As an example, consider a physics major who takes courses in Classical Mechanics, Electromagnetism, and Thermodynamics, but never sees how these all interrelate in an electronic device that suffers thermal stress when it draws too much current. These problems are difficult or impossible to do analytically, which is the approach emphasized in the theory classroom, but
present commercial software programs can incorporate such disparate issues to make more realistic modeling relatively quick and very informative. Moreover, our theoretical emphasis also ignores the impact of financial and/or social, political, and cultural constraints on the technical innovation chain that carries us from idea to product.

As another example, consider students who take cross-disciplinary courses on photonics applications, but who do not get the opportunity to examine the advanced image-formation capabilities of contemporary lasers in biological laboratories. It would be advantageous if students had the classroom (theoretical) training in addition to practical hands-on training. This shows that deep understanding of basic physics can potentially lead to new diagnostic tools to improve human health, but only if the physics student knows where the technological problems lie in those more applied areas.

Not wanting to rest on prior achievements, we recognize that William & Mary can always improve the STEM opportunities we offer for some of the Commonwealth’s best students. In last year’s graduating class of 24 physics majors, equal numbers are attending graduate school in engineering and physics, while most of the rest opted for employment in technical positions in private companies. Recent graduates with experience in Applied Science have entered graduate programs in materials science, applied mathematics, and computational neuroscience, as well as attending medical school. The Departments of Physics and Applied Science have witnessed increasing numbers of students who want to work on energy, environmental, or biophysical projects for their senior projects. Presumably, a curriculum that is less theoretical and more applied would draw even more students into STEM majors. The proposed program will allow students who love fundamental physics a chance to see how their understanding of basic physics can transform their understanding of other fields in ways they may find compelling. Finally, the proposed program will also provide a background in business basics sufficient to enable these graduates to join small companies or start-ups upon graduation, in accordance with future needs of the Commonwealth.

The crucial idea of this program is to move beyond the standard example problems covered in a typical physics curriculum, \textit{i.e.} those problems that \textit{can be} solved either analytically ‘by hand’ in closed-form with pencil and paper, or by using simple perturbative approaches around those special solutions. Instead, this proposed new program will challenge students with
more complex problems that require piecing together the fundamentals from many subfields to model a real-world situation.

There are two key features to the new courses for this program: Analyses of topics will introduce topics using complex problems (rather than over-simplified, idealized, theoretical constructs), similar to the case study method used in business, law, and in related disciplines. In that way, the idealizations that are inevitably studied through modeling are motivated by starting with real-world problems and simplifying, rather than starting with an abstract problem that has no other motivation than to teach an isolated theoretical skill. In addition, most student work will be done in small groups. Most of the new courses for this program will be advanced laboratory courses. These would require students to either make objects or to simulate an object’s response or behavior. These courses will be closer to a research experience than typical laboratory courses because research work, especially in small groups, has been identified as a very high impact teaching practice [Kuh 2008]. These laboratory courses will also be preparation for the senior capstone (COLL 400) project.

The ad hoc committee has identified four primary activities for these efforts: Problem (statement and) Solving; Abstraction; Designing; and Rendering. The Engineering Physics and Applied Design program incorporates all four of these features because the case study approach begins with a complex problem, moves to abstracting the important concepts, and then follows with design and rendering activities.

Consider an example from fluid mechanics. Imagine proposing an irrigation system that mixes fertilizer into a water flow and then delivers it to crops with a minimum loss through evaporation. In this case, the abstraction step requires defining the crucial parameters involved. This requires fluid dynamics concepts, such as how to ensure enough turbulence to mix the nutrients into the water without reducing flow or overburdening the pumps, how to calculate the necessary pump power to move all that water, and how to actually deliver the water to the fields (via a drip, spray or permeable membrane). But, brainstorming (assisted by a review of existing systems) might introduce other concerns, such as minimizing the evaporation loss and identifying the source of the water. Is it river fed, or pumped from an underground aquifer? Is this a sustainable use of that water source? How does the local hydrology affect this water use?
This abstraction of characteristics would lead naturally to the design step, which itself is likely to uncover yet more considerations and force a re-evaluation as issues like the structural integrity and the material composition of the delivery system would become new considerations. At some point, a model irrigation system would actually be rendered. Again, we anticipate iteration as additional issues in need of solving arise naturally in the fabrication process, such as the need to use commercial-off-the-shelf (COTS) components wherever possible, or to minimize maintenance.

Thus, the procedure involving abstraction followed by design and rendering continues to iterate, as is always the case with complex real-world problems. This experience will be valuable for our students, because they will learn that there is not a single ‘right’ answer for these types of problems, there are only solutions that are more or less useful, and that learning by doing is actually the fastest way to achieve useful results, even if a few false starts happen at the beginning. If they are creative failures, and opportunities to learn, they are extraordinarily useful to the problem solving team.

As an educational and training exercise, the faculty would set limits to ensure that the process concludes on a satisfactory solution. The iterative process (as opposed to the theorem/proof process in mathematics, or the mathematical derivation process in advanced physics courses) encourages students to change their evaluative perspective from “right versus wrong” to “less satisfactory versus highly satisfactory.” It also can help to create an environment that fosters brainstorming, creativity, and innovative solutions to design problems. We expect that many ideas will not end up not working, but nonetheless lead to clever new ideas, some of which do work. “Not working” should be seen as part of the iterative process rather than failure. The iterative process also forces students to deal with ambiguity as the definition of the problem continues to evolve as more is learned, and that expanding the circle of design characteristics that need to be taken into account as the problem-solving activity matures encourages the student teams to reach across disciplinary boundaries for expertise and resources, and prepares them for the collaborative opportunities that will be part of their capstone project.

The second key feature of the proposed program is regular work in small groups. As described in detail below, this will follow a process of developing team participation and team leadership so as to encourage trust and self-confidence, while developing communication skills.
Studies have found that trust, self-confidence, and a sense of belonging to a team, a class, or a school, are crucial for improving the retention of traditionally underrepresented groups in STEM disciplines [Strayhorn, Terrell L. “Factors Influencing the Academic Achievement of First-Generation College Students” NASPA Journal Vol. 43, Iss. 4, 2006 DOI:10.2202/1949-6605.1724]. More generally, recent studies have also shown that the sense of belong is also a good predictor of future career happiness for all students [Gallup, 2015].

Detailed Description of the Proposed Program

This new program would result in a B.S. degree in Engineering Physics and Applied Design. The degree would have its home in the Physics department, the Applied Science Department, or (preferably) operate as a joint venture between the two departments. William & Mary already has key resources for this Engineering Physics and Applied Design major. Specifically, many faculty in the Physics and Applied Science departments can provide the science plus engineering skills envisioned in this program. The popular campus Makerspaces (in Physics, at the Mason Business School, in the Department of Biology, and at the School of Education) have already encouraged many students to design and to render (a notable example is the 2015 award-winning iGEM, the International Genetically Engineered Machine competition, team of synthetic biologists). Some student clubs (such as the Rocketry Club and the Robotics Club) already have project-oriented efforts, and have contemplated participation in NASA’s Small Spacecraft Technology Program (Smallsat). The Careers in Physics course has already brought many industrial scientists to campus, stoking the interest of students and demonstrating that physics has many applications beyond academic research.

The degree requirements for this new program would parallel the core lower-division requirements of a B.S. in Physics, but at the junior and senior years the new program would replace several of the advanced physics courses with new or existing courses drawn from both physics and applied science. These courses would emphasize laboratory or simulation work with specific applications in engineering and design. The new program would also encourage internships (especially during the summer) although this feature would not become a requirement until after a robust internship program was established. The new degree would require a capstone COLL 400 experience: a major project involving a team of 3-5 seniors with two faculty
mentors, one from either Physics or Applied Science, with a second faculty drawn most likely from the Business School. Each of these proposed new components is detailed in the following sections.

The laboratory courses would serve two independent purposes. These courses would teach problem solving skills, with the primary emphasis being a technical area (such as Modern Optics, Structural Mechanics, or Fluid Mechanics) and they would develop effective team participation. The problem of how to teach and to promote effective teamwork is one of the most persistent and difficult tasks in every area of education. We will discuss this in detail below, and show one attempt to incorporate a new approach starting in Fall 2016 with a revised version of a Scientific Instrumentation lab appearing in Appendix 1 to this section.

The technical area exploration would be problem-based, as described above, to emphasize the iterative nature of problem solving and the need for an ever-broadening network of differing expertise. Each technical problem would be expected to incorporate some focus on the aesthetics of the product and on the human interface.

The team participation training is the most novel part of these advanced laboratory courses. Students often work in small groups in our laboratory courses, but the group dynamics are almost never addressed by the instructor. In traditional laboratory instruction, the team aspect of the work is secondary to the primary goal of gathering the data needed to write an individual lab report. True teamwork, with the social psychology of team building addressed by the instructor in the setting of a teaching laboratory would be a great innovation. In her classic paper, J. Billson [Billson 1986] outlined a number of principles for group learning. One of the most important of these principles (Principle 2) is: “Group interaction is based on feedback,” especially feedback from the members of the group. Consequently, facilitating trust, communication, and participation among the group members is extremely important for a productive group learning experience. Of course feedback and evaluation from the instructor is also important, and this often generates discontent if students do not feel their contribution has been recognized or rewarded. But, individual recognition can conflict with Billson’s first principle: “Every participant in a group is responsible for the outcome of the group interaction.” Both types of feedback can benefit by training proper group participation behavior through repeated exercises.
For example: In each of the advanced laboratories, students will be divided into groups by the instructor (not self-selected) to work together through a sufficient number of exercises so that each member serves as the group leader. The group leader will have three major responsibilities: (1) to define tasks so that each group member agrees to accomplish a task; (2) to provide a brief report on the progress of each member after a preset time; and (3) to present an oral report to the class at the conclusion of the assignment. The instructor will devise these assignments and set their due date so that the complexity increases slowly throughout the semester. Initially, the assignments may be accomplished during a single class period, but by the end of the semester they will extend over at least a two-week period. The instructor also has the responsibility to encourage discussion and brainstorming when one of the tasks results in more problems than solutions. In these laboratories, group members should not specialize, for example, having one student do only programming while another does only model construction. There are no standard procedures for optimizing short-term team dynamics, and we expect that instructors will develop a variety of methods specialized to such laboratory courses. We propose that a May seminar on the topic of Engineering Physics and Applied Design laboratories would be appropriate and useful once the program gets underway. In addition, some of the advanced laboratories will also introduce concepts such as business plans and management plans in preparation for the capstone course.

In addition to the advanced topic-based laboratories, we would also develop a junior engineering and design course which will serve as a precursor to the senior research capstone course. This would be a 3 or 4 credit Spring semester course that would build on the first two physics electronics labs (PHYS 252 and PHYS 351) but incorporate aspects of electronics and mechanical engineering. The novel aspect of this course is that it will be based on a competition among 2-3 person teams to design and produce novel devices that will be useful in a research lab setting, although this would be a friendly competition following the “Olympics principle” that earnest and friendly participation is more important than winning. Each team will write a successful proposal explaining their design in order to be awarded budgeted funds to purchase required parts. Following this, they will build, debug, document, and present their device. The course would meet twice per week for three or more hours, directed by a faculty instructor and a Teaching Assistant. The first few weeks of the course would feature lectures on how to manage a team and to carry the project from design to working device. The first few weeks would also
include tutorials on mechanical construction, including – but not limited to – 3D printing, laser cutting methods, as well as other basic machine shop training. (taught by machine shop personnel). This course will teach complex device design to meet technical specifications, project budgeting, proposal writing, component selection device construction, trouble shooting, and presentation skills. But, most importantly, it will teach how to work as part of a team and how to understand failure modes.

Internships, like research experiences, can be especially important for developing self-confidence and the maturity to leave the academic community. Consequently, commercial internships will be especially important for the Engineering Physics and Applied Design degree. Many of our current physics majors join a research group at other universities or at national laboratories for a summer research experience, but this research experience is not the same as working for a commercial enterprise. In many engineering schools the internship serves a dual purpose: it exposes the student to industry, but it also provides the industrial partners with a direct route to recruit and to train future employees. However, developing a partnership with a sufficient number of industrial partners will take considerable time and effort on the part of W&M faculty. We expect that industrial internships might eventually become required for the degree, but that they will only be one possible option for summer research until the program has matured.

One of the most successful components of the B.S. in physics as well as the senior capstone experience of students who up to this time have only done a minor in Applied Science has been the Senior Research experience, in which a student works on an individual project mentored by a faculty member. Such research experiences are routinely held as examples of high impact practices [Kuh 2008] and are correlated with a high degree of success in a student’s later career [Gallup-Purdue Index 2015]. The Engineering Physics and Applied Design degree would revise this so that each student would spend a full academic year as part of a team doing a design/rendering project, satisfying the requirements for a COLL 400 course. Each team would consist of 3-5 students working with two mentors. These team efforts would require at least three components:
1. The team would develop a science plan that would lead to a functioning product. Although this plan could extend beyond the one year, it must be more detailed for the year over which the project will be completed.

2. The team would develop a Business Plan, incorporating finance and marketing ideas for a final product. This plan will not be limited to the single academic year of the project. The business plan could be a for-profit or non-profit model, but it must think through issues like initial funding sources and long-term financial sustainability of the operation.

3. The team would develop a management plan for overseeing both the science advancement and the business development. This plan would include timelines, milestones and identify the crucial steps and alternative approaches if milestones are not met. Although this plan would also cover the time beyond the one year, it must be more detailed for the year over which the project will be completed.

Part of the evaluation of the project will be based on adherence to the schedule provided in the management plan. The two mentors on the team would likely include a science faculty member and possibly a second mentor with more business experience (likely from the Mason School). These projects are expected to be more complex than anything that could be completed in a single year. The sources for these projects would likely include a mix of internal ideas and external calls for proposals, such as Small Business Innovation Research, Broad Area Announcement, and Non-Governmental Organization calls. Another possibility for sources of ideas are requests from local businesses (especially those involved in the Internship program). These projects will seldom complete the work requested in such calls, but instead would provide near-complete business plans, management plans and science plans, while the rendering part would be much more limited to fit the one-year time line.

Recommended Background Courses (14 or 15 credits):

- MATH 111 Calculus [Fall and Spring (4)]
- MATH 112 Calculus [Fall and Spring (4)]
- MATH 211 Linear Algebra [Fall and Spring (3)]
- MATH 212 Multivariable Calculus [Fall and Spring (3)], or
- MATH 213 Multivariable Calculus for Science and Mathematics [F and S (4)]
Foundational Courses (24 credits):

- PHYS 101 General Physics I [Fall (3)]
- PHYS 101 General Physics I Lab [Fall (1)]
- PHYS 102 General Physics I [Spring (3)]
- PHYS 102 General Physics I Lab [Spring (1)]
- PHYS 256 Practical Computing for Scientists [Fall (3)]
- PHYS 201 Modern Physics I [Spring (3)]
- APSC 201 Introduction to Materials [Spring (3)]
- PHYS 208 Classical Mechanics of Particles and Waves I [Spring (4)]
- APSC 301 Mechanics of Materials [Fall (3)]
- PHYS 401 Electricity and Magnetism I [Fall (3)]
- PHYS 403 Thermodynamics/Statistical Mechanics [Fall (3)]
- APSC 422 Introduction to Materials Characterization [Fall or Spring (3)]

General Laboratory Courses (4 credits):

- PHYS 252 Electronics [Spring (2)]
- PHYS 351 Scientific Instrumentation Laboratory [Fall (2)]

Elective Laboratory Courses (choose two) (6 credits) [NB these would be new courses]

- Fluid Dynamics Laboratory (3)
- Structural Mechanics Laboratory (3)
- Instrumentation Laboratory (3)
- Computer Interfacing Laboratory (3)
- Optics Laboratory (3)
- Materials Characterization Laboratory (3)

Business Courses (5 credits):

- BUAD 352 Decision-making through Visualization and Simulation (2)
- BUAD 466 Developing Business Intelligence (3)

Capstone Course (6 credits):

- Design Capstone [Fall and Spring (3)]
In summary, we believe that this new Engineering Physics and Design program, building upon the existing foundation in Physics and Applied Science, could attract more students into the physical sciences at W&M, and provide them with a strong preparation for work in engineering and more applied areas, including making them more competitive for work in tech industries. This preparation, combined with their liberal arts education will make them distinctive, poised to succeed in a wide variety of work settings, and prepared to live satisfying and productive lives.
Appendix 1 to AEPDS

Electronics II (Digital Electronics and Equipment Interfacing)

In this appendix we include a plan for a revised approach to the teaching of an upper division laboratory presently for physics majors, that had been reconfigured to emphasize better methods for creating and evaluating individual performance in team environments. This will be the basis for an evolving approach to team building in the engineering domain.

This laboratory will meet for an overview lecture each week (Mondays 2:00-2:50 pm) followed by a three hour laboratory session (either Tuesday 2:00-5:00 pm or Wednesday 2:00-5:00 pm, not both). During the laboratory sessions, the students will work in five member teams, and part of the laboratory will be devoted to training effective teamwork. The five members will be:

1. Circuit architect and project leader
2. Materials manager
3. Resource manager
4. Construction manager
5. Quality Assurance manager

The general responsibilities of each team member will be:

1. Circuit architect and project leader: organize the team; maintain the general plan for the circuit.
2. Materials manager: find and test components to be used; program microprocessors when used.
3. Resource manager: propose alternate components; find data sheets for components to be used; and extract the most important parts.
4. Construction manager: assemble the parts into a test circuit.
5. Quality Assurance manager: plan tests for the final circuit to demonstrate that it is working and to test the limits of the circuit.
The instructor will choose the team members and the architect/project leader before each session. The session will begin with each group having a brief meeting at which the project leader will:

1. Present an overview of the project, showing the logic flow and describing the types of circuit elements that will likely be necessary.
2. Guide the other team members to volunteer for one of the other four positions and to designate what they expect to accomplish.
3. Keep records of the meeting, as this will form the first part of the project report.

The group will then proceed to work on the project, concluding on (or before) a specified time. The project leader will then hold a close-out meeting at which each member will report:

1. Progress made in agreed-upon tasks.
2. New ideas that led to changes in plans, and how that plan change was instituted.
   (For example, a major change might require all members to be informed and to agree, whereas a minor change might not even merit a mention.
3. What problems arose, and how they were solved (if they were solved).
4. Which members collaborated on which tasks.
5. Which members assisted other members on which tasks.

The project leader will submit the final report before the next laboratory session. Grading will be based on the performance of the team and of the individual members. Project leaders will earn extra credit for prompt completion of the tasks.

- Individual members will be given credit for accomplishing their agreed-upon tasks, or for developing imaginative responses to unexpected problems.
- Any member who is listed as assisting will earn credit, while the member who receives assistance will not be penalized.
- Collaborating members will both earn extra credit.
- At the conclusion of the last session, each student will be allotted 100 points to distribute among the team members (excluding themselves) with whom they have served.
This grading scheme needs further refinement. The hope is that this level of reporting and the rapid changing of roles and teams (typically once per week) will result in a pretty clear picture of who are the strongest and weakest players.

The tasks will begin as easy assignments, and conclude with a complicated final project that may take 2 weeks. Except for the project leader, who writes the final report, the bulk of the work will be accomplished during the laboratory class time.
VIMS AUV/Robotics

VIMS has a number of unmanned system assets and capabilities that can be leveraged for research and education activities at W&M. In addition there are a number of technologies developed at VIMS such as sensors that can be integrated in the future into unmanned systems.

Underwater Gliders

Underwater gliders are Autonomous Underwater Vehicles (AUV) that depend mainly on controlled changes in buoyancy for propulsion. Hybrid gliders, with thrusters, are currently available that enables dual-mode propulsion. VIMS has three underwater gliders, two Slocum hybrid gliders (Gong lab) and one standard Seaglider (Smith lab). The two types of gliders are optimized for different oceanographic domains based on the research interest of the principal investigators. These two Slocum gliders are ideal for coastal ocean applications where the depth is less than 400 m. The thrusters allow these gliders to operate in environments with strong currents. They have been flown in the coastal waters and submarine canyons off the Mid-Atlantic coast as well as the shallow continental shelves in the Arctic. The Seaglider on the other hand is ideal for deep water application down to 1000 m and it has been mainly used over the deep continental shelves off Antarctica.

Each glider is roughly the same size and weight as an adult human, thus it is easy to deploy and recover with a minimal crew using almost any size ship that is available. The gliders also have extended endurance and range that allows it to be a regional and global platform. Sensors on the glider allow measurements of basic physical properties of ocean water. Bio-optical and acoustic sensors also enable the study of the marine biology and chemistry and would be suitable objects for upper division undergraduate research projects.

Remotely Operated Vehicles (robotic vehicles)

While not autonomous, ROVs are unmanned systems that enable operations in high risk marine environment for a lower cost than manned systems. ROV is ideal for applications where
real time communication and feedback is necessary. VIMS has a professional grade Seabotix ROV (Lipcius lab) and an OpenROV system (Thaler lab). The ROVs have been used extensive inside Chesapeake Bay for studying estuarine ecology as well as in tank environment for studying oil slick thickness and droplet size distribution. The ROV systems are very light and easily deployable by a single person. It has also served as a testbed for new marine sensor development. Again, these are wonderful platforms for undergraduate research projects.

Unmanned Aerial Systems (“drones”)

VIMS has a number of small UAS (under 55 lbs) that are currently being explored for research and education. The drone fleet includes two DJI Inspire 1’s (Kirwan lab, Gong lab), and two DJI Phantom 2’s (CCRM). The systems can carry Electro-optical (visible) and near IR sensors. The drones have demonstrated capability in mapping/monitoring marsh land and coastal erosion, identifying of Harmful Algal Blooms, and documenting recovery and deployment of AUV. The VIMS main campus is also ideally situated by the water in Class G airspace, outside of 5 miles of any airport, and not near National Park land, so testing of UAS assets at VIMS poses minimal risks to people and properties, as well as regulatory restrictions. Such drones have been used routinely on the Williamsburg campus, and are perfectly suited for undergraduate research.

The unmanned assets at VIMS are supported by a number of manned technical assets including vessels, seawater test facility, geospatial data processing software and expertise. Coming online in the 2017/2018 time frame is a new state-of-the-art 90 ft coastal research vessel. The vessel will enable operations in all of Chesapeake Bay as well as access to the outer continental shelf. Though better suited for graduate and post-doctoral research, undergraduates could easily be incorporated into programs for data processing, for sensor development, for display, and even for short summer cruise experiences.

Unmanned Systems Development in Virginia

Having major governmental research agencies and military installations in Virginia naturally leads to significant development and testing of Unmanned Systems. NASA Langley
Research Center as well as NASA Wallops Flight Center are working on all different aspects of unmanned systems with regards to space and aerial applications. The Virginia Space Grant Consortium works with regional partners to provide K-16 students opportunities in learning, developing, and applying unmanned systems technologies. The Mid-Atlantic Aviation Partnership based in Virginia Tech hosts one of the FAA test centers for Unmanned Aircraft Systems. The Virginia Center for Autonomous Systems also at VaTech is developing a number of advanced underwater technologies and systems for the US Navy. Finally, the Navy is working with local industry partners actively developing and testing autonomous surface vessels in the Hampton Roads area. All of these agencies and institutions are potential and willing partners with W&M and VIMS in developing, testing, and application of Unmanned Systems whether in the sky, on the water, or below the surface. They are also great potential resources for our students to learn and may be places for gainful employment locally when our students graduate.
Data Science

This section represents a culmination of multi-year discussions across multiple disciplines of how best to prepare William & Mary students to participate in the data revolution. This is desirable not only to prepare students for the modern workforce, but to ensure that incoming students are prepared with the critical thinking and other skills necessary to engage with cutting-edge faculty research. There already exists a great deal of momentum around these topics at William & Mary. The various domains, ideas and centers being coordinated with, integrated, or otherwise improved include (but are not limited to):

- Computational / Data Science*
- Social Science Research Methods Center (SSRMC)**
- Digital Equality Lab / Digital Humanities***
- Center for Geospatial Analysis (CGA)**
- AidData**
- Computational Foreign Language Analytics**
- Computational Anthropology**
- Business Analytics**
- Computational Applied Math and Statistics (CAMS)**
- Systematic Text Analysis for International Relations (STAIR)**
- Institute for the Theory and Practice of International Relations (ITPIR)**
- Computational Linguistics (CELL)**
- BioMath Initiative**
- Center for African Development (CAD)**
- Charles Center**
- Ph.D. in Applied Science and Computer Science**
- MA in Systems Analytics***

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4 Recognizing the import of this growing field to nearly all departments at William and Mary, a critical objective of this working group was to be as inclusive as possible. As such, participants involved came from the following departments and units: English, Economics, Business, Applied Science, Linguistics, Government, Mathematics, Computer Science, Anthropology, Global Studies, VIMS, ITPIR, Charles Center, and Russia and Post-Soviet Studies.
* Denotes an entity, program, or element that we intend to create as a part of the engineering effort.

** Denotes an existing entity, program or element that would integrate with, be supported by, or be built upon by this program.

*** Denotes a proposed entity, program, or element that this effort would support.
What is Data Science?

Spurred by the increasing availability of computation and data in new disciplines, Data Science represents a new frontier of critical thinking which necessitates individuals not only have a breadth of knowledge about the computational tools with which problems can be solved, but how to formulate and answer interdisciplinary questions that leverage data in ways that will advance understanding. A data scientist has a breadth of knowledge about the computational tools with which problems can be solved, but also has the ability to frame questions in a way that will advance understanding, starting with COLT.

Fig. 4. Infographic overview of Data Science at William and Mary.
https://my.visme.co/projects/g7mxnve6-wm-ds

Spurred by the increasing availability of computation and data in new disciplines, Data Science represents a new frontier of critical thinking which necessitates individuals not only have a breadth of knowledge about the computational tools with which problems might be
solved, but how to formulate interdisciplinary problems that leverage data in ways that will advance understanding. The Infographic of Figure 4 provides a schematic overview of data science as we conceive it being structured at W&M. Data science is a blend of many fields, including many subdomains of mathematics, computer science, computational science, statistics, and information science. Critically, a data scientist goes beyond purely quantitative fields, and also has a depth of substantive knowledge and applied experience within at least one knowledge domain — for example, linguistics, history, or government. This combination allows data scientists to (a) efficiently define and solve computational problems within his/her own knowledge domain, and (b) manage teams of more specialized individuals to answer far-ranging questions. Individuals with this set of knowledge and critical thinking skills are revolutionizing a wide set of domains, and are in very high demand not just by faculty researchers at William & Mary, but also by the public and private sector. While there is a projected shortage of nearly 200,000 individuals with data science skills in 2018, that number jumps to a shortage of 1.5 million when “managers and analysts with the know-how to use analysis of big data to make effective decisions” are included [Manyika, 2011].

Why Data Science at William & Mary?

William & Mary is uniquely positioned to build on existing strengths – not only in our High Performance Computing (HPC) infrastructure, computer science and mathematics departments, but also the unparalleled liberal arts education offered in departments such as government, anthropology, and the experiences of the Applied Science and Charles Center interdisciplinary majors. Further, the high quality of scholarship offered by William & Mary has continued to attract the best scholars across all disciplines, resulting in a critical mass of faculty members pursuing computational and statistical analyses in fields that might not traditionally be associated with such work.

These scholars seek to engage our students in research, but are frequently unable to do so due to the lack of appropriate coursework and coordination that would enable faculty-student research collaborations. This lack of appropriate preparation for our students has implications not only for existing initiatives on campus - including the fulfillment of the capstone COLL 400 – but it also has broader implications if William & Mary will continue to attract the best scholars.
and students in a rapidly changing world. Acknowledging similar challenges, many of the universities in William & Mary’s peer group have begun to take similar steps. Following in the footsteps of the public and private Ivies, William & Mary is well positioned to offer a world-class Data Science program, providing students who already receive a depth of training in the traditional arts and sciences with the ability to find novel solutions - or revolutionize disciplines - by leveraging the wealth of computation and data available across the globe today.

Most of the resources and mechanisms to train students in Data Science already exist, alongside traditional degrees. These include the depth of coursework offered by the Computer Science, Computational Operations Research, Mathematics, and Applied Science departments; quantitative and substantive courses already offered in related disciplines; computational facilities available at our High Performance Computing Center in the new Integrated Science Center; physical space; interdisciplinary infrastructure; and a breadth of interested, tenured or tenure-eligible faculty.

**Student Learning Opportunities**

Across William & Mary classrooms, labs, and research units there is a defined need for students with a broad set of skills related to the collection, computation, visualization, and critical analysis of data. This need is also apparent in the field of applied learning, where government agencies, research labs, and private institutions seek to hire students with not only substantive and topical knowledge, but also the capacity to define and solve data-intensive problems. However, institutional and cultural barriers create a scenario in which many of the students that are most likely to disrupt new industries are those least likely to take Data Science oriented coursework. Here, we (a) identify and (b) propose solutions to overcome these barriers.

**Data Science as a COLL 100**

Students should be exposed to the key concepts of Data Science early in their academic career. This is particularly true in disciplines that have not traditionally employed data intensive computational methods. We believe that most students can benefit from being trained in the use of data to construct compelling arguments, to deconstruct arguments made by others, or to carry
out an informed critical analysis, whether the object of study is an ancient text, the distribution of particles created in a collision, or the current distribution of foreign aid.

The new COLL curriculum provides significant opportunities to advance the University’s position as a place for inquiry-based learning within and among the three Knowledge Domains (ALV, CSI, and NQR, see the Introduction). We propose to introduce students to Data Science early in their academic careers by creating a first-year COLL 100 course focused on the big ideas of Data Science. This course is designed to take a different approach than traditional, quantitative methods courses in that it introduces students the use of data in the 21st century, how it has shaped the human condition, and pushes them to critically consider how data could be used to answer complex questions in new fields of inquiry. Students explore the landscape of the Data Revolution in topics from the mundane basics of information literacy and computer skills, and tools for manipulating data, to the exploration of larger questions such as the methods of data analysis used to identify the Higgs Boson, or how investing in agriculture in the middle of Mexico can reduce hurricane related deaths on the east coast, or how data analytics is used in professional baseball.

At the same time, students are introduced to a variety of concepts and tools that they can use in subsequent courses. The course further teaches students how data can be visualized, and the increasing role of visualization in experimental design. A prototype of one such course, Breaking Intuition, has been taught during the Fall of 2015 and Spring of 2016. We plan to build on this experience by providing pathways for students that seek to continue down Data Science pathways throughout their academic career, mechanisms for which are described below.

Data Science Teaching and Coordination

Undergraduate students in disciplines that have not traditionally used data intensive computational methods -- for example, linguistics, government, literature, and history -- do not currently have well-worn pathways they can follow to acquire that knowledge. We hope to provide all students with accessible, formal pathways to acquire data science skills, with entry possible at multiple points within their academic careers, by offering core coursework that is coordinated with interested departments and programs in ways which are compatible with relevant existing degree programs. In Appendix A, example courses are described that, in
tandem with introductory courses that an engineering offering in Data Science can provide, could be used to build interdisciplinary B.S. degrees.

**Applied Science Ph.D.**

Cross-disciplinary lines of research in Data Science are emerging which are attractive to both undergraduate and graduate students. The graduate degree programs in Applied Science, which are already highly interdisciplinary, can easily be modified to accept a Data Science track of study for the Ph.D. degree, or for a terminal M.S. This type of MS degree may be desirable, for example, in a future regime of retraining via continuing education. The development of a sufficient graduate cadre to assist in the crafting of high-quality undergraduate research options will be one of the many benefits of the program.

A specialization in Computational Science has long been an option for the Applied Science graduate degree. Modification of what is already in place in order to accommodate the needs of a Data Science focus would not be difficult. This will be discussed in the next section. Possibilities include: an expansion of the offerings for the undergraduate Minor in Applied Science; creation of a Data Science certificate program (described below); or the creation of a B.S. in Applied Science with a Concentration in Data Science (and/or Computational Science). Existing courses that may be used to create interdisciplinary options toward a Data Science B.S. are shown in Appendix A of this section.

**Graduate Degrees**

The Data Science Ph.D. will live within the existing Applied Science Ph.D. program - focusing on applied, multidisciplinary, computational analysis. These will be academic, research-oriented Ph.D. degrees that emphasize multidisciplinary training in computational research in various topics (i.e., social and environmental sciences; linguistics; anthropology; history). The program will leverage the complementary research interests of faculty across a wide set of disciplines to facilitate a strong, interdisciplinary research and Ph.D. training paradigm, and build heavily on existing coursework. Following this, the degree will have participant faculty from departments and programs including - but not limited to - Government,
Anthropology, Global Studies, International Relations, Computer Science, Math, Anthropology, Linguistics, Biology, and the Applied Science. Unifying this cadre of students is a core set of objectives, including:

- Training individuals who can understand, create and undertake research using computationally demanding datasets in new disciplines.
- Producing new knowledge using computationally-intensive methods and data analytics in a wide variety of disciplines, and using advanced methods that enable this goal.

This degree would relate closely to a number of existing programs, pulling heavily on existing coursework. While each student will work closely with his or her advisory committee depending on their backgrounds, goals, and training, a core sequence all students will follow will likely include: APSC 603 and 604 (Introduction to Scientific Research I and II), APSC 607 and 608 (Mathematical and Computational Methods I and II), CSCI 678 (Statistical Analysis of Simulation Models), and CSCI 688 (Stochastic Optimization). Each student will have these courses augmented by discipline-specific methods 600-level independent studies, co-supervised by relevant faculty members in the discipline of focus.

**Data Science Certificate**

Undergraduate, MA and Ph.D. students frequently require basic training in purely technical Data Science skills, but do not have adequate room in their academic schedule to take broader, formal coursework. The objective of the certificate sessions would be to provide students (or faculty), who are interested in rapidly acquiring baseline competency in data-science skills, with certificate or otherwise-accredited.

We envision very intensive training sessions which offer extra-curricular workshops to provide students with foundational skills training and professional development needed to participate in data science research. These workshops may be led by a graduate student (see above) who will guide students to gain the skills and confidence necessary to work with different data types using a range of methods, e.g., statistical and computational analysis with R and Python. Such intense training sessions will alleviate course bottlenecks, while providing a rich, hands-on experience for students. Certifications provide students with W&M-official recognition...
of their extra-curricular achievements in the boot camp program. To ensure that prospective students can adequately memorialize this experience, we will offer a formal Data Science Certificate, for inclusion on a student’s dossier or resume. The appropriate office of W&M will be responsible for coordination and curation of a W&M-recognized certification, to be offered upon the successful completion of these sessions, which will include examinations, projects, or other means of assessing the student’s acquired knowledge.

Undergraduate Student Research Opportunities

There are many opportunities for undergraduate students to participate in data-science research, so long as we can formalize opportunities to (a) train and (b) pair students with appropriate faculty. Promoting more opportunities for undergraduate students to engage in research with faculty members pursuing Data Science research themes will help to fulfill the objectives of COLL 400. We intend to provide information to W&M students undergraduate...
students who may be interested in engaging in faculty research under the theme of Data Science. Ideally, working with the Charles Center and other organizations there may be limited funds to support some well-defined, short-term research projects.

Across all disciplines, Data Science relevant labs and courses are oversubscribed, leaving many students unable to receive the training they are interested in. Appendix B to this section provides numbers on these enrollments. Means to meet existing demand, while creating additional demand associated with programs being developed here, will have to be found. In addition, the unique setting of many Data Science courses - computer labs - results in a large demand on instructor time to solve frequently minor, technical issues - preventing instructors from teaching key theory and more advanced skills to undergraduates. A pool of teaching assistants drawn from departments like applied science, physics, or computer science research students who have fallen back on university central support from the graduate dean’s office, might help to ease this technical burden on instructors. Staffing such a data science “help desk” could provide an improved learning experience at a significantly lower cost than identifying individual TAs on a course-by-course basis, and could expand coverage by taking advantage of opportunities such as pooled office hours. TAs will also gain the benefit of developing their skills in teaching and communicating data science in a supportive environment. It is anticipated TAs can also be found from existing upper-level (senior) undergraduates.

**Coordination & Collaboration**

Successful implementation of a Data Science curriculum at William & Mary, cutting across departments and schools, will require coordination of existing resources contained in those units. Installation of “emigration courses,” possible changes to pre-requisites, or various cross-listings may be needed to permit students to take upper division classes in other departments or schools. Shared technical resources are anticipated throughout the engineering enterprise, but directories of technical resources, and instructions on their use will be needed, as will expert advisors who can stay abreast of changes. This is not unique to data science; such problems are already being addressed by IT, Online and E-learning groups, Computation Cluster personnel, and many others who work across schools or disciplines.
Data Science CLA Fellows and Advisory Committee

As required for all aspects of the engineering enterprise, the core liberal arts mission must be retained. This is particularly key for the Data Science initiative, as it seeks to provide teaching and research experiences that enable a broad range of students, including students from humanities and social sciences to engage in data science education – pathways such students may not usually engage in. One means to assure this is to allow for the regular inclusion of Data Science faculty fellows among the Center for Liberal Arts (CLA) Fellows, and to provide the CLA with access to advice from a standing committee comprised of representatives from each domain of Data Science, who would be charged with assisting the CLA in mentoring new scholars across all disciplines seeking to teach Data Science. Broadly, the Data Science faculty fellows and committee would be tasked with working closely with the CLA in order to identify strong pathways to introducing students to new ways of critical thinking that leverage computational tools and large data sets. This committee, working with the CLA, will further serve several functions designed to enable a broader breadth of William & Mary students to participate in Data Science courses through the following approaches:

Alignment of Technical Skills. Where possible and reasonable, encourage alignment of (for example) computer programming languages being taught.

Coordinated Crosslisting. Ensuring that a sufficient number of introductory-level courses are crosslisted so that a larger subset of students to take upper-level Data Science courses.

Interdisciplinary Coordination. Help with coordination across disciplines, for example in recommending or providing guest lecturers, or providing seminar series, workshops, or other short-duration sessions to assist students with filling in (data science) gaps in their background. For example, students taking a class on social science methods would greatly benefit from a lecture on R just so they know the tools are available. They might also use video lecture capture to create online “help” modules, or to describe and discuss useful new tools of interest to this internal community.

We expect that members of this committee will find other ways to assist with the CLA’s task of integrating data science, and other engineering oriented materials into the learning experience of our students.
Data Science Appendix A. Existing Curriculum and Options for Integration

This appendix outlines the existing courses that could be integrated into departmental degrees in order to provide students with discipline-specific specializations in data science.

Early Steps: Broad Exposure to Research Design, Methods, and Tools

The goal in a student's first three semesters is to take the prerequisites necessary for more advanced courses in a variety of disciplines, and to get a sense for the kind of things one can learn from various approaches to data science. Further, COLL 100 experiences can provide introductions to students interested in the topic early in their career.

First-Second Year: Introduction & The Basics

Math, CS and Statistics Baseline

Relevant COLL 100 (see above sections; i.e. Breaking Intuition)

Psychology (PYSC) 201 and 202 Statistics

MATH 106 / MATH 351

Government (GOVT) 301

Economics (ECON) 101 and 102

APSC (COLL) 150 - First-Year Seminar

APSC (COLL) 210 - Predictability

CSCI 141 - Computational Problem Solving

MATH 112 / MATH 132

BUAD - Design Thinking

Computer Science (CSCI) 141

CSCI 241 – Data Structures

MATH 352

INTR 204 – GIS / INTR 490 Remote Sensing

Subsequent Years: Specialization
Experimental Methods

PSYC 301 – Elementary Statistics (while this course material overlaps with a basic statistics course and GOVT 301, it is a prerequisite for advanced PSYC courses)

PSYC 302 – Experimental Methods

PSYC 314 – Social Psychology

ECON 380—Experimental Economics

GOVT special topics courses related to experimental design

Applied Modeling

Advanced MATH courses related to student interests, with a focus on optimization

ECON 307—Econ Statistics (while this course material overlaps with a basic statistics course and GOVT 301, it is a prerequisite for advanced ECON courses)

ECON 308—Econometrics

GOVT 391—Quantitative Methods Advanced econometrics courses

GOVT 307—Polling and Analysis

Business and Design

BUAD 317 Organizational Behavior & Mgmt

BUAD 351 Operations Management

BUAD 352 Decision-making through Visualization & Simulation

BUAD 442 Psychology of Decision Making

Materials Science

APSC 422 - Introduction to Materials Characterization

APSC 201 - Introduction to Materials Science

APSC 301 - Mechanics of Materials

Life Science

APSC 431 - Applied Cellular Neuroscience

APSC 432 - Applied Systems Neuroscience

Engineering Whitepaper Final 5-13-16 (Edited 12-19-16)
APSC 450 - Computational Neuroscience
APSC 327 - Introduction to Laser Biomedicine
APSC 351 - Cellular Biophysics and Modeling
APSC 456 - Random Walks in Biology
## Appendix B. Example Oversubscribed Courses

<table>
<thead>
<tr>
<th>Course</th>
<th>Students Fall 2015</th>
<th>Cap</th>
</tr>
</thead>
<tbody>
<tr>
<td>COLL 100: Breaking Intuition</td>
<td>46 (2 sections)*</td>
<td>50</td>
</tr>
<tr>
<td>MATH 351: Applied Statistics</td>
<td>68 (2 sections)*</td>
<td>70</td>
</tr>
<tr>
<td>MATH 451: Probability</td>
<td>35</td>
<td>35</td>
</tr>
<tr>
<td>INTR 204: Introduction to GIS</td>
<td>52</td>
<td>56 (4 sections of 14)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Course</th>
<th>Students Spring 2016</th>
<th>Cap</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH 351: Applied Statistics</td>
<td>71 (2 sections)</td>
<td>70</td>
</tr>
<tr>
<td>Math 352: Data Analysis</td>
<td>58 (started as 1 section)</td>
<td>35</td>
</tr>
<tr>
<td>INTR 204: Introduction to GIS</td>
<td>53</td>
<td>56 (4 sections of 14)</td>
</tr>
</tbody>
</table>

*Indicates post-withdrawal numbers

**Prior to registration, students need to fill out a pre-registration survey for the course. For Spring 2016 semester, we had 90 applicants for 56 seats. With drops we end up just under capacity for the semester but currently have no ability to meet demand for this course.
Bioengineering and Synthetic Biology at William & Mary

Background:

Bioengineering, a quickly evolving, multidisciplinary field that applies engineering principles to biological systems at all levels of organization from molecules and cells through tissues and organisms, is playing an increasingly central role in virtually every realm of contemporary science and medicine. At the “macro” level, bioengineering is resulting in new prosthetics, transplantable engineered organs and tissues, novel devices patterned after various biological processes, and the use of naturally occurring biological products for novel applications. On the “micro” level, the discipline of synthetic biology is designing unique biological parts with functions unknown in nature as well as redesigning existing biological systems for novel purposes, ranging from DNA computers to toxin- and tumor-seeking microbes.

The central role that bioengineering plays in contemporary science stems not only from the new devices and practical applications that have emerged from the field, but also from the development of novel tools and reagents that have transformed our ability to understand basic processes (e.g. lab on a chip, microfluidics). But perhaps even more importantly, advances in bioengineering and the application of design principles to living systems has provided new insights into basic biological processes such as gene regulation and signal transduction.

Bioengineering encompasses two complementary areas: (1) engineering biological systems and (2) bio-inspired design: using biological systems to inform applied engineering design.

While individual faculty members across science STEM departments at William & Mary are engaged in various research endeavors that fall under the broad umbrella of bioengineering, and while there have been productive yet isolated collaborations, there has not been a central programmatic focus for investigators interested in pursuing various bioengineering initiatives at William & Mary that would promote collaboration. Despite the isolated efforts of some investigators, there is also a corresponding lack of bioengineering approaches in the life science curriculum. The expertise and interest already present on campus and the availability of a truly integrated state-of-the-art facilities in the new ISC3 presents a unique opportunity to leverage the facilities new building and expertise to develop a program that benefits both faculty and students.
Rationale:

Increasing the presence of bioengineering on campus will: (1.) Bring faculty together to pursue new avenues of research and more effectively to develop novel (patentable) tools and reagents; (2.) Increase research, development and funding opportunities not currently being pursued; and (3.) Enhance student opportunities and is essential for providing students with unmet curricular needs. Furthermore, the arena of bioengineering and systems biology is overflowing with extremely hard problems of great importance to society, presenting challenges that are worthy of our best students. As such is an ideal area for pushing design thinking to its creative limits.

Initiatives:

Integrate Bioengineering Into Life Science Curriculum:

- In place of the standard biology lab offer an Honors lab that focuses on Synthetic biology; two-semester-long labs that allow student to build something either with standard iGEM parts or other widely used components
- A synthetic biology/bioengineering readings/journal club course
- An upper division synthetic biology/bioengineering lab
- Infusion of engineering approaches into existing classes, in particular Molecular Cell Biology, a class designed to be taken by almost all Biology, Neuroscience, and pre-medical majors; other classes such as Developmental Biology would be suitable for this approach as well. Functional Ecology and Vertebrate Biology already has a strong engineering component and the latter will introduce an innovative lab aspect that will employ the BioMakerSpace, the rudiments of which have already been established. We will need to develop more courses such as this.
- A May seminar or workshop that would allow faculty to brainstorm and develop courses, labs, and independent challenge problems to initiate individual student projects and topical portfolios.
- Developing a “track” or emphasis in the Computational and Applied Mathematical Studies program (or other engineering heavy minor) for bioengineering
• Develop a program of Ph.D. or M.S. graduate studies opportunities in systems biology applications in neuroscience, operated through Applied Science

Biology today does not only entail examining and understanding processes, but also guides the design and rendering of physical, functioning things. Our goal is to educate undergraduates and graduate students in specific methods, techniques, tools and give them the necessary skill to pursue these designs, and render these objects.

Given the central role that synthetic biology and bioengineering play in contemporary science and technology and the widespread interest in design and design thinking among students and faculty alike, it is highly desirable that we insert the field of bio-engineering into our curriculum. The benefits will be obvious and immediate as this field dovetails with the COLL curriculum and our desire for interdisciplinary hands-on opportunities, fundable research, and additional coursework suitable for the COLL curriculum. Some possible courses for COLL include:

COLL 100: With the focus on Big Ideas, the COLL 100s lend itself to the theme of engineering and design or design thinking. A COLL 100 that focuses on, for example, the ideas in the Neri Oxman TED talk – Design at the Intersection of technology and biology, i.e. “Material Ecology” – lends itself to a course that lies anywhere on the continuum from Area 1 by stressing the art & architecture or Area III by emphasizing the science and engineering. The course would investigate novel bio-inspired fabrication methods inspired by nature and students will “reconsider the way things are designed and made in the 21st century.”

Another intriguing course similar to one taught at MIT would easily fit into our COLL curriculum: “Design Across Scales.” This could be easily adapted from the MIT description: “Inspired by Charles and Ray Eames’ canonical Powers of Ten, the course explores the relationship between science and engineering through the lens of Design. It examines how transformations in science and technology have influenced design thinking, and vice versa. It covers interdisciplinary tools and methods to represent, model, design and fabricate objects, machines, and systems.”

Another very interdisciplinary course would be “Engineering Life.” This would entail a history and philosophy of “creating life” from Aristotle through Craig Venter’s genomes, and
would focus on approaches of making life and alternating life. The course would of course necessarily address the subject of “What is Life?”

“Design Thinking” could also serve as an effective cognitive tool to enhance learning. Analysis of the neuroscience of employing this as a pedagogical tool would involve discussion of the neurobiology of cognition, learning and memory as well as the literature on pedagogy. Students could apply this approach in their ongoing courses. All of the above courses could easily be adapted for a COLL 100, 150 or COLL 200.

COLL 200: Existing COLL 200s could easily have special laboratory sections that are taken in place of the regular standard introductory biology laboratory. The focus would be on synthetic biology in which first semester the students design and engineer something that addresses and environmental problem and the following semester something addresses a biomedical issue.

COLL 300: For COLL 300s, it would seem that there are so many opportunities/ service trips/study abroad that focus on engineering/building/designing in underserved or developing areas; with some tweaking these would fit beautifully into the engineering and design curriculum. We note that St. Andrews has a cogent group of scientists engaged in related areas.

COLL 400: COLL 400s that focus on the exciting multidisciplinary world of specific aspects of bio-engineering/synthetic biology would be extremely well subscribed since students are so eager to address and solve real-world problems. These could be capstone seminar type courses or lab-based research experiences or a combination of both.

Development of a bioengineering “track” could entail students taking a certain number of courses in this field along with some type of research experience. Overall, development of this curriculum addresses: (1) giving students the tools to address key social-economic needs; (2) preparing students for a job market that where the application of design thinking is very much in demand; (3) preparing students for post graduate programs in STEM fields where the demand is equally high for students trained in engineering approaches; (4) increasing retention and engagement of students from diverse or non-traditional backgrounds; literature has consistently shown that these students fare better when alternative classroom pedagogies are employed.
Promote and Sustain iGEM (International Genetically Engineered Machines)

iGEM would serve as the central annual event for undergraduate synthetic biology and bioengineering at the molecular level. Having the ability to raise endowment funds to assure annual participation for iGEM would ensure its longer term success and perhaps garner the interest and infrastructural investment or operational funds from various sponsoring commercial enterprises.

Development of the BioMakerSpace As an Incubator Space For New Ideas and Collaboration

THE VPR has provided initial funding for basic equipment for this space and it already serves as the iGEM home base. Seed funds for two or more annual faculty-student teams to pursue new projects involving making bio-objects or developing a reagent that falls into the category of bioengineering. Projects would be evaluated by an interdisciplinary BioMakerSpace advisory group comprised of those who expressed initial interest in the engineering. Seed funds would be targeted toward externally fundable proposal development and may attract funding from a variety of additional sources.

High-risk, high-reward, research in all areas, but particularly in bioengineering, should be encouraged. This needs to be incorporated into the structure of the program with the known fact that many projects will ‘not deliver translatable technology but will nevertheless provide the basis for future projects for translatable products. This is in keeping with the requirements for our version of engineering, where the design-thinking jargon term is “failing forward.” Projects within these areas will almost always be collaborative and the goal of projects within these realms should be to provide solutions or building blocks to address real-world problems. In order for William & Mary to stay at the forefront of modern biology, the plan will be to work to hire a synthetic and systems biologist.

Close associations with entrepreneurs, philanthropists, and industry are needed to help identify key ‘holes’ in current technology and ensure that solutions emerging from W&M’s “engineering and design enterprise” are brought to the real-world in a timely manner. The BioMakerSpace group could serve to nucleate the organization of interested parties. There needs
to be low-friction cross-talk among the MakerSpaces on campus, where BioEngineering students can be trained in basic electronics, mechanics, and robotics.

**Potential Research Related topics**

A broader recognition of the causes and consequences of global warming combined with the depletion of many non-sustainable resources has resulted in dramatic growth in the sustainable biobased products market Driving this point home, a 2008 study from the Office of the Chief Economist estimated that the “global market for biobased chemicals and plastics is projected to reach $160 to $280 billion by 2010. By 2025, biobased chemicals likely will contribute over $500 billion annually to the chemical and materials industry” [Conway, 2008]. The pattern of high demand for these products is predicted to drive huge growth in this industry was further supported by a 2015 report to congress [Golden, 2015]. For example, this study reported that “renewable chemicals and Biobased products will increase from approximately 40,000 jobs in 2011 for the biobased chemical/product sector, which represents three to four percent of chemical sales, to more than 237,000 jobs by 2025, which would represent approximately 20% of total chemical sales.” Similarly, this study found that the market for bioplastics is increasing at an astonishing rate (20-30% per year). Biologists working on such problems would almost necessarily forge close collaborations with researchers from Applied Science and Chemistry. In addition, they are likely to work closely with entrepreneurially minded faculty and students at the business school to move from ideas to marketable solutions.

**Promoting Bioentrepeneurship**

We would like to develop more emphasis on bioentrepreneurship. The idea would be to develop the resources and connections to help students and faculty take discoveries to the marketplace if they were inclined to do so.

Faculty have expressed interest in bio-engineering projects in various domains. Once established, regular brainstorming and planning sessions with faculty are likely to open a large number of opportunities. We list a few topics below:
1. In terms of engineering biological systems, several faculty would like to see a strong emphasis on plant bioengineering. Solutions to the major issues (energy, environment, sustainability, agriculture, population growth, etc.) of the next couple decades will undoubtedly involve engineered plants. In terms of bio-inspired design, the goal of this area is to use nature’s solutions as the basis of applied engineering designs. Plants have evolved unique and diverse sets of structures and compounds to interact with heat, cold, light, moisture, wind, gravity, to produce toxic compounds, etc. Given the diversity of plants, a large emphasis should be placed on using plants as the basis of bio-inspired design.

2. Environmental Problems: Many faculty are interested in addressing real world environmental problems; a few years ago, roughly 70 faculty indicated that they were either working in such a domain or expressed an interest in participating in environmental work when we did the faculty-interest-survey leading to the creation of the now extant Center for Energy and the Environment. Faculty currently try potential solutions to problems, but often require additional expertise and collaboration. For example, Crim Dell receives massive loadings of nitrogen from runoff, so faculty members have been examining different sorts of natural polymer fibers that serve as carbon sources for denitrifying bacteria that could reduce the load of nitrogen. It is necessary to find the best fibers and construct the best sorts of polymer “filters” to create denitrifying biofilms that can intercept and process the nitrogen-rich runoff.

3. There is interest in designing inexpensive, durable remote sensors that could be placed in the environment and/or on individual animals.

4. Discovery and production of novel proteins and signaling pathways, particularly in yeast model systems. Freshmen in phage lab have discovered phage with dozens of novel genes with unknown function.
References to Science Pillar


Strayhorn, Terrell L. “Factors Influencing the Academic Achievement of First-Generation College Students” NASPA Journal Vol. 43, Iss. 4, 2006 DOI:10.2202/1949-6605.1724
Humanities Pillar

Introduction

Design thinking has attracted considerable attention in the humanities in recent years, as scholars and students consider new audiences and purposes for their work. For example, in explaining how she has become both “brand consultant” and “brand manager” in her faculty leadership position, Julia Lupton writes “my colleagues are prototyping when they try out a new programming format (such as a charrette, a skill share, or a research slam). They are brainstorming when they imagine possible outcomes of their research. And they are being iterative when they retool an academic article for a broader audience and then use that effort to reframe their academic work” [Lupton, 2016]. Lupton is drawing attention to how intense periods of collaborative production outside of conventional classroom time in late-night “charrette” sessions first adopted in architecture and design schools could support creative problem-solving and deadline-driven urgency, as hackathons, rapid prototyping, or wikistorming events do. She is also championing the value of reciprocal peer-to-peer learning with “skill share” opportunities, as those showing how to use different digital humanities platforms do at regional THAT camp unconferences (Online: thatcamp.org) and suggesting other models for disseminating scholarly research, such as high-energy performance-oriented “research slams” that borrow from the successes of urban poetry slams that include community members.

Intersections between design and traditional humanities scholars extend to practice as well as theory. New collectives of self-described digital humanists are arguing for “making things with physical computing and desktop fabrication techniques” to facilitate “hands-on, conjectural approaches to material culture, history, and preservation” (Sayers et al., 2015) in new practices of “experimental humanities” or “forensic humanities.” The concept of “critical making” (Ratto, 2011) or “building” in the humanities (Ramsay, 2011) has drawn many adherents who are applying techniques from archeological reconstruction, information visualization, and digital curation to research projects in the humanities. Yet even those who are sympathetic to reforming humanities research to emphasize dynamic processes and collaboration
may encourage their colleagues to step back from fads that might be wasteful (Miller, 2015), poorly executed and amateurish (Varnelis, 2016), rushed and ill-considered (Irani, 2015) or likely to exclude women and people of color (Wernimont and Losh, forthcoming). At William & Mary the liberal arts focus of the institution and its attention to maintaining inclusive learning environments minimizes the risks of such endeavors, which are already part of the campus culture rather than an add-on.

Proper spaces for informal learner-directed membership are also important for developing what Lave and Wenger have called “communities of practice” in which affinity groups understand their efforts as part of a joint enterprise that must be understood and renegotiated continually and that binds members together into a social entity with a set of relationships in a shared repertoire developed over time. William & Mary already has a number of research labs that bridge disciplines and foster collaboration and hands-on learning, including the SNaPP Lab and the Linguistics Laboratory. We see benefits to bringing this approach to the humanities and arts as well, where students often express strong desires for finding a cohort of fellow researchers, and believe this approach is particularly important for students who may be the first one in their families to attend college. We believe that cultures develop inside boundaries of various types, both real (geographic, architectural, etc.) and symbolic. Properly outfitted spaces and places have always been triggers for specific forms of thought, introspection, ideation, and inspiration of creative activity. It was a strong desire of the Ad Hoc committee, and a stated goal to try to evolve physical spaces in the W&M version of engineering that will reflect our desire to satisfy the need to embrace the humanities and arts as seamlessly as possible in the emerging enterprise. We defer detailed discussion of these to the separate section addressing future needs, and in the sections below, concentrate on conveying the core of the efforts we intend to implement initially. Like so much of the engineering enterprise, some of these efforts were anticipated several years ago, and are already well underway at W&M. Nevertheless, integrating them into the overall engineering enterprise must be done with great thought and care to avoid reinforcing of the difficult “two culture” problem famously described by C.P. Snow more than half a century ago.
The Equality Lab: A Space for Digital Scholarship

The Equality Lab addresses the need to overcome biases in our contemporary computational culture by applying the values of a liberal arts education. Using an integrated approach based on understanding the historical, philosophical, psychological, social, technological, aesthetic, and rhetorical origins of longstanding inequities and patterns of privilege, the Equality Lab will provide open access to course materials, service learning opportunities, curricular support, equipment, mentoring resources, and digital scholarship lab space to students, faculty, staff, and community members.

This initiative is already an official partner of FemTechNet [http://femtechnet.org], an international organization of over a thousand scholars and researchers working in science and technology studies and media arts practice known for their Wikipedia write-ins, rapid prototyping sessions, action kits for countering online misogyny and racism, online town halls and open office hours, and distributed open collaborative courses (DOCCs).

Students affiliated within this forthcoming digital scholarship lab are already experimenting with new forms of scholarly communication for disseminating their research, including blogging, podcasting, creating web-based multimedia books in digital humanities platforms (such as Scalar), Ignite-style speeches with automatically advancing slides, code work with open source authoring platforms (such as Processing), games and simulations, and design prototypes that use the principles of critical making activities.

This work directly addresses the calls for proposals coming from the new COLL curriculum and initiatives on both engineering and design and public humanities, as well as celebrations of milestones relating to ending segregation of the college by gender and race. Specific courses are also cross-listed or will be cross-listed with GSWS and Film and Media Studies.

Digital humanities currently uses multimedia equipment, gaming laptops, prototyping supplies (including a 3D printer and 2D cutter), and physical computing components. Students in the humanities learning about new digital methods will benefit from the space which has been reconfigured in Morton Hall to more intensely pursue these objectives, where it will be easier to
experiment with collaborative construction, iteration, and play that is explicitly dedicated to the mission of digital inclusion and critical cultural studies of technology. Interested students are currently using existing spaces in the Reeder Media Center, Small Hall Makerspace, and the Center for Geospatial Analysis, and a core group in the graduate program in American Studies is provisionally using improvised space in College Apartments for the computation, fabrication, layout, display, play testing, user studies, and storage needs of student projects. Further developments of these humanities laboratory spaces will be an integral part of our operation, alongside continual reinforcement of a welcoming environment for humanities students (and artists) as collaborators and regular occupants of various spaces in ISC, Small, MS Hall, and other locations where concentrations of computational and technical tools reside.

Connection to New Undergraduate Curriculum

COLL 100

Because COLL 100 requires that students explore multimodal communication opportunities, EDI presents a unique opportunity for students to examine the confluences of design and composition in oral, written, and digital practices. Existing texts such as Writer/Designer (Arola, Sheppard, and Ball) and Multimodal Literacies (Bowen and Whithaus) make connections between iterative prototyping practices and procedural expression explicit. As William & Mary students work in “formats other than a traditional written essay,” they are blogging, coding in programming languages, designing websites, presenting data, creating visuals or graphics, and editing videos.

COLL 150

Writing has long been recognized as a “mode of learning” (Emig) that is iterative, collaborative, and user-centered in its design philosophy. With the COLL 150 emphasis on “the rhetorical nature of academic writing” students are encouraged to consider questions of audience. Furthermore, the requirements in COLL 150 for drafting and revision facilitate participating in a culture of iteration that reflects many of the best practices of design thinking.
COLL 200

Because COLL 200 requires that those claiming expertise in one domain “reach out” to another domain and its experts, these courses facilitate interdisciplinary research and collaborative learning that is understood to be essential for fostering a culture of innovation. For example, in Gender and Digital Culture, students edit Wikipedia entries using the site’s markup language, write executable code in the Processing programming language, and design an ethnographic project based on observations of a specific online community.

COLL 300

Good examples of the community and global implications for the Digital Equality enterprise at William & Mary will be modeled after former initiatives of its new Director who emphasized new ways to apply theory at UCSD. Interested readers may find information on the Culture, Art, and Technology Program at http://sixth.ucsd.edu/cat/, which includes a practicum requirement mandating study abroad, service learning, laboratory or clinical experience, or internship.

COLL 400

Signature Activities

Honors Projects

Creative Arts Requirement

Connection to Graduate Education

The public humanities focus of next-generation PhD campus initiatives between American Studies, Anthropology, and History emphasizes the importance of a diversity of audiences, practices, and products and highlights potentials for design thinking in fields such as museum studies, geographical humanities, media archeology, and historical interpretation through reenactment. Collaborations between Education and American Studies around attention to digital methods also foreground connections between the front-end and back-end of data presentation and data gathering processes.
Arts: Engineering Foci

To date, many students interested in an applied path beyond their majors have used the mechanism of creating individual Interdisciplinary Studies major, advised and administered through the Charles Center. Other students have amassed baskets of courses on their own to supplement traditional majors, or even double majors, that come closest to their individual interests. Years ago, in response to student demand, the Environmental Science and Policy (ENSP) program was created to permit closer cooperation of departments and schools in delivering major and minor studies along their two tracks (Science and Policy). The classroom experiences for ENSP have been supplemented by research and independent studies, including laboratory and field work, through the Keck Center, or in association with VIMS, Thomas Jefferson Public Policy, PIPS, independent work in connection with the Committee on Sustainability, and other venues such as those that emerge in the Howard Hughes Medical Institute grant, the ENSP GIGS (Global Inquiry Groups), such as the work to understand the effects of mercury pollution [WM News, 2012]. So a large number of undergraduate students have been engaged in work of this type. At the graduate level, for the last 24 years, Applied Science has encouraged Ph.D. work across departments, and with partners outside W&M at NASA, Jlab, and at other Universities, as have other Ph.D. granting departments. It is our intent that W&M’s nascent engineering enterprise will expand such interdisciplinary and multidisciplinary efforts to provide a wider participation, and greater ease of partnering in degree or certificate production for departments and programs. In particular, we want to foster work that engages the whole range of our students’ talents and concerns. For the past two decades, more and more attention has been directed towards the need for multidisciplinary education. This desire has sprung from the acknowledgement that all academic fields, including physical sciences, social sciences or humanities, are deeply connected, and that opportunities for growth must allow for differing perspectives, shared experiences and resources.

Students clamor to understand practical applications of their studies, especially applications that promote beneficial social changes. Our students entering the workplace, embracing active citizenship, know that they need to be conversant with, even if not experts in, a wide variety of methods and ways of perceiving, understanding, and knowing the world. As we
continuously plan for improvements to liberal arts education at W&M, we are ever cognizant of the changing environment, the evolving aspirations of our students, and the will of their benefactors.

For many reasons, departments and schools tend to become bound by the overwhelming needs to deliver their existing degree programs. This is a ubiquitous problem that constrains growth of new things quite generally: contraction of funding coupled to the mechanics of resource allocation leads inexorably to “zero-sum” thinking that impedes the process of devising creative responses to challenges. The incorporation of engineering into W&M’s traditional liberal arts education can expand the model for collaboration: a shared focus, or interest that requires many individuals with unique points of view, methodologies, and passions to work together for a common purpose. Sharing tools and techniques of design and rendering objects will help these individuals learn to speak the same language and become conversant with each other’s world views and problem-solving strategies. We give an example of one such focus, Digital Gaming, which falls in the arts domain, but contains potential to also engage humanities scholars. We anticipate that over time more foci will emerge. Additional examples will follow in this section devoted to the Arts Pillar, again, with an expectation that over time, and with the construction of the new Arts Center to come, others will follow.

Each focus will be designed and implemented by an advisory committee representing a select number of participating departments, programs, schools, and institutes across the entirety of the William & Mary community. The purpose of these foci will be to pool shared resources to allow for the implementation of applied studies and create opportunities for collaboration between disciplines. The overall curriculum will not change (majors, minors, concentrations, COLL courses, honors theses, etc.), but will be supplemented and enhanced by these foci.

Undergraduate students will complete their major requirements as presently constituted, but will now be given pathways through their electives, COLL courses and possibly, internships to provide additional context and support for their core field. Interdisciplinary courses and cross-cultural programs within the COLL 200 or 300 may also be constructed. Beyond coursework, students will also convene with their Focus cohort for events, brown-bag lunches, field trips, or discussion groups, to give members the opportunity to mingle with other undergraduate and graduate students, faculty and experts in the field to broaden and deepen their understanding and
foster collaboration. Finally, students will be required to collaborate on a long-term project during their senior year, fulfilling the COLL 400 Capstone.

Upon completion, students will earn the academic designation of their selected focus appended as stamps to the major. For example, “Computer Science Major, with a Focus on Digital Gaming.” Note that there is nothing novel about this plan. What we are calling “a focus” here has been called “a track” in other contexts. What a new enterprise like engineering will offer is an opportunity to change structural problems having to do with faculty evaluation in programs, apportionment of “credit” for tuition production, and other aspects of central and distributed administration that have led to serious trouble for interdisciplinary enterprises in the past.

The promise of this approach is quite broad and has the ability to provide benefits throughout the entire W&M community. In particular it offers value to both undergraduates in the new COLL curriculum and value for graduate students, similar to the track system that has been long in use. We enumerate some of these benefits here:

**Undergraduate Students**

- Create a sustained focus throughout their college career.
- Opportunity to work and collaborate with like-minded students from different disciplines.
- Opportunity to work more closely with faculty and graduate students from different areas.
- Interaction with professionals from local, regional, and national institutions.
- Provide clarity of resume (“Art History Major with a focus in Art Conservation.”)
- Increase breadth and depth of their study.
- Assist in developing Honors thesis by providing a collaborative cohort.
- Assist in developing capstone research (COLL 400)

**Graduate Students**
• Provide a broader conversation for their interests
• Provide opportunities for collaborative partners.
• Provide teaching opportunities in seminars and workshops

Faculty
• Provide opportunities for collaboration across disciplines.
• Provide guidance to create COLL 200 & COLL 300 (on campus) classes and seminars
• Provide opportunity to work more closely with students and others.

Departments, Programs and Schools
• Provide the ability to create and test pilot programs.
• Create possibilities to pool resources
• Provide marketing opportunities to attract students and develop internships

The College
• Create an environment that ties together disparate schools, programs, institutes and research centers.
• Provide clarity for targeted fundraising

Employers
• Ability to employ graduates who have demonstrated a sustained focus over an extended period of time.
• Provide opportunities to be involved in collaborative endeavors and internships.
Digital Gaming

Introduction

This proposal is a joint venture of the Departments of Computer Science and Art & Art History with the goal of establishing a working relationship to share resources and build a curriculum for students interested in the field of digital game production.

Game design is an intensely complicated venture, requiring multidisciplinary teams from domains across the liberal arts. Students engaged in this Focus should have a core foundation in computer science, being at least conversant with gaming relevant topics such as Artificial Intelligence, Graphics, Networking, Human Computer Interaction, Software Engineering, and Physics. They should have a common experience in art-making and a grasp of the design process to gain an innate sense of form, space, light, color, and interaction.

By sharing and organizing their existing course offerings, both departments will be able to offer their respective concentrators pathways through these core requirements and remove roadblocks to collaborative practice. This is intended to be a hands-on, experiential curriculum where all students, regardless of their majors or skills, will participate in all aspects of game conception, design, construction and evaluation, extending to the end-user experience. Conversation between members of disparate units will follow guidance from an Advisory Board, and are intended to be modeled after current best practices.

Not only has gaming become an enormous cornerstone of the multi-billion dollar entertainment industry, it has also proven to be beneficial in the areas of education and health care through meaningful play and challenges to undertake “serious games” (Burke, et al, 2009). This presents multiple opportunities to solicit additional partnerships with other disciplines within William & Mary and engage in outreach to the broader community.

Rationale

The purpose of this Focus is to establish clear pathways for undergraduate students interested in pursuing a foundation in digital gaming development with an emphasis on the
application of studio art. At present, those students must create their own interdisciplinary roadmap combining a major in either Computer Science or Studio Art with courses from the other. There exists no mechanism for consistent advisement or coordination of Digital Game production between the departments. For these reasons, students find it difficult to find collaborative partners and to engage in long-term team-centered projects.

This Focus will construct those pathways through and between each department’s existing curricula, and propose creating additional cross-listed COLL 200 classes. Other departments and programs will be invited to add pathways to and from their disciplines where it seems appropriate to provide greater learning opportunities and context and to share resources. The emphasis, however, will remain on the practicalities of game design.

<table>
<thead>
<tr>
<th>Additional Partners for Game Design</th>
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<tbody>
<tr>
<td>1. Music (music and sound effects)</td>
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<tr>
<td>2. Theatre (set design, stage management, lighting)</td>
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<tr>
<td>4. Dance, and Performance</td>
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<tr>
<td>5. English (creative writing, literary history and critical theory)</td>
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<tr>
<td>15. American and Cultural Studies</td>
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</tbody>
</table>

Establishing this Focus will benefit students by providing for them a curated path between disciplines and giving them priority in registration. Students will become conversant with the methodologies of the other disciplines, working on multidisciplinary teams on long term projects. They will graduate with the degree attribute, Digital Gaming Focus and have in hand a well-documented portfolio/signature project to present to post-baccalaureate and graduate programs as well as potential employers.

Beyond expanding their reach to a more diverse group of students, participating programs will also profit by having, ready to hand, clear advising materials and departmental marketing.
opportunities to attract students and open doors with partners beyond the campus walls. There already are journals awaiting academic research output in this area; see for example: http://www.rit.edu/gccis/gameeducationjournal/

**Learning Objectives**

Following the model of the leading programs at USC, MIT, Georgia, and others, the learning objectives will be organized around interdisciplinary projects requiring multidisciplinary teams. Through this Focus, the participating departments will strive to:

- Develop game design and development as an academic discipline.
- Prepare students for careers in the entertainment software industry.
- Facilitate interdisciplinary learning.
- Research the social and technical aspects of games.
- Motivate diverse groups to pursue technical studies.
- Perform and disseminate research on game design in multidisciplinary education.

**Advisory Board**

This Focus will be overseen by a Digital Gaming Advisory Board that will be empaneled by the two departments and may include interested faculty from other departments and programs. The Advisory Board will cooperate in determining which courses will be taught over a given 2-year period, in consultation with the Registrar, and all affected Department Chairs or schedule coordinators.

**Resources**

Digital Gaming will take advantage of resources which are, for example, resident in SWEM, Media Center, A&AH Visual Resources, Center for Digital Equality, and visualization tools in various maker spaces and in SWEM.
Possible Curriculum

A possible path for students to accumulate necessary credit, 21 credits (min) of core courses outside of the Major, is contained in the table below. Hypothetical cross-listed classes are shown. Model programs exist, one of which, at Rochester Institute of Technology (RIT), has described its experience over more than four years of operation. Interested parties may wish to read their account at http://www.rit.edu/gccis/gameeducationjournal/evolving-interdisciplinary-collaborative-groups-game-development-course

<table>
<thead>
<tr>
<th>Major</th>
<th>Game Specific Major Requirements (42-48 credits)</th>
<th>Cross Discipline Requirements (12 Credits)</th>
<th>Joint Focus Requirements (9 Credits)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computer Science</td>
<td>CSCI 420/680 - Introduction to Game Design and Game Dev.</td>
<td>Art 211 - 2D Drawing &amp; Color Art 212 - Form &amp; Space 3 Credits - Art 300/400 3 Credits - Elective</td>
<td>New COLL 200 Course 6 Credits - COLL 400 Senior Capstone Project Additional Activities: Brown Bag Lunches Field Trips Visiting Lecturers</td>
</tr>
<tr>
<td>Additional Partner</td>
<td>CSCI 141 – Comp Prob. Solv. CSCI 241 – Data Structures Art 211 - 2D Drawing &amp; Color Art 212 - Form &amp; Space</td>
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</tr>
</tbody>
</table>
**Existing Gaming Centric Courses**

CSCI 420/680 - Introduction to Game Design and Game Development

AMST 350 - Gender and Digital Culture

AMST 350 - Video Game Studies

**Proposed COLL 200 Course**

ART 340 – Topics in Art: Materiality and Immateriality
References For Humanities Pillar


Snow, C.P. “The Two Cultures” (Rede Lecture, University of Cambridge, 1959), Canto Issue, Cambridge University Press; Reissue edition (March 26, 2012)


Thatcamp: http://thatcamp.org/


Arts Pillar

Introduction

As we’ve seen in the previous example, the arts can and should play a central role in engineering education and practice. During the discussions around Digital Gaming, it was pointed out that Computer Science students struggled to imagine a world beyond their immediate surroundings. When tasked to construct a “space” in which to set their games, they often simply built the room in which they were working at that moment. Though technically adept, they were lacking in experience. Looking, building, performing, dancing, singing, and writing are crucial to the design process. Each provides an avenue towards understanding the world from a subjective, human perspective.

The Committee cited as learning objectives for the prospective engineering students:

- Create a culture of constructive failure
- Encourage students and faculty to reach across all boundaries for knowledge, expertise, resources and collaborative opportunities
- Reduce self-imposed constraints & increase confidence
- Enhance students’ ability to effectively communicate

It is through the arts that we communicate complex ideas, express our individuality, and define problems and visualize solutions. We learn to shape the world around us with our hands through material: the photographer as chemist, the sculptor as metallurgist. A potter rarely makes a single object; she iterates; she prototypes; she experiments and many times she fails. She engages with her fellow students and faculty in critique, learning to present her ideas, defend them, and accept the constructive advice of her peers. The studio is a safe space to try new ideas, to shove fear aside and push an idea to its breaking point. More paper ends up on the floor than on the wall, more clay goes in the reclaim bin than the kiln. That’s been the tradition for thousands of years.

Our biological features dictate our response to the world around us, the way our hands conform to a tea cup or grasp a door handle – what architect Juhani Pallasmaa calls the “handshake of a building.” More than just adding beauty or aesthetic interest, the arts can serve
as the nexus within the liberal arts, joining the humanities with the sciences, engaging with business, and inspiring education. The creative act is inherently interdisciplinary. For example, the new Stryker Building in town is a structure that serves many masters and many functions: The City Council, the Williamsburg Public Library, and of course the citizens of Williamsburg. It exists in the public sphere, within an existing built-environment, its design and construction having to conform to the realities of business and finance, supply chains and ecological responsibility. Yet, these forces serve as more than just hindrances to the vision of the architect, they are inextricably linked in the design process itself, the interplay of form and function providing opportunities and suggesting novel solutions. For example, an architect and sound engineer could share their expertise and provide guidance to each other, to create a gallery space that functions acoustically as well as visually (all while coming in under budget).

These collaborative skills must be learned and honed like any other, making the diverse environment of William & Mary ideal for an all-encompassing, holistic engineering program. If our traditional majors are centered on individual competency and mastery, the new curriculum is essentially one that emphasizes reaching out beyond our disciplines and areas of expertise, connecting with others through the acquisition and development of communication skills, cross-disciplinary and cross-cultural exchange, and expression through the creative arts.

Opportunities to join the arts with engineering within the new curriculum present themselves through the development of innovative new courses:

1. COLL 100: “Creative Destruction:” An investigational and design course where students will learn through breaking and reverse engineering. Study historic examples of failure (Tacoma Narrows Bridge), create projects that are designed to fail, or more specifically, utilize failure within the design process, and perform autopsies on “found” tech to find the science and design hidden therein.

2. COLL 100 or 200: "Iterative Design: Models & Maquettes, Studies & Sketches, Renderings & Rough Drafts, Prototypes & Puppies:” A multidisciplinary course that investigates the various methodologies for developing, prototyping, visualizing, and communicating individual and collaborative designs. Historic and contemporary examples will be studied along with active learning and design practice by the class.
3. COLL 200: “Three-Dimensional Design for Engineers:” A course where students will study 3D design, but with an emphasis on engineering concepts. Where existing 3D design courses are built around formal elements such as line, plane, volume, and mass, projects for this course could be structured on statics, dynamics, deformable bodies and fluid dynamics. Students will study both form and function in this hands-on class, combining aesthetic considerations with the practical concerns of math, physics, and materials.

4. COLL 200: “Electronics and Music:” An opportunity to study electrical circuits while learning the rudiments of musical composition. Who wouldn’t want their very own Theremin?

Many of the proposals within this document take this idea a step further: reaching out beyond even the Arts and Sciences, to Business, Education, and Law, to the wider community, the Commonwealth and the world beyond. The Arts have the ability to be that bridge, to make what is imposing, approachable, to make what seems impossible, conceivable. These various pathways and links will provide multiple vectors for undergraduate and graduate students, faculty, and independent researchers to enter into collaboration. Multiple vectors means that a greater diversity of people can enter the engineering fields through nontraditional avenues, individuals who previously thought that they possessed neither the interest nor the skills to engage in the design process, that engineering wasn’t for them.

The next two proposals presented here, Art Conservation and Sustainable Design, will further illustrate this capability. The arts again will play a central role in connecting various elements of the William & Mary system, across programs, departments, schools and institutes while creating opportunities to link to regional institutions such as Colonial Williamsburg and The Jamestown/Yorktown Foundation.

These plans will showcase the variety of ways these Focuses can be structured. Digital Gaming is essentially a product of two departments with the potential for additional partners. In addition, Digital Gaming has a very natural outlet for arts students interested in pursuing small businesses of their own through the WBMEC and the “App Program,” that are described below in the Business and Entrepreneurship Pillar. Art Conservation is very much built around the
models of existing pre-professional programs such as Pre-Med and Pre-Law, while Sustainable Design is a looser configuration, owing to its greater potential to tie a vast array of resources from across the entire William & Mary enterprise.
Art Conservation

Introduction

Art conservation has a long and illustrious history in the Williamsburg area – the historic village at its core is a testament to the desire to conserve, preserve, and disseminate the material and cultural artifacts of the United States colonial period. The town itself, its plan, its roads, and its buildings have been painstakingly resurrected from degradation wrought by time and neglect. This continuing study, analysis, and restoration extends to the smallest objects and tiniest details and depends on its own “three-legged stool:” <Historical Analysis, Material Analysis, and Material Conservation>. This is yet another example where William & Mary stands in a unique position as it enjoys a proximity with an historic site with a world class conservation laboratory.

This Focus is designed to provide an aspiring student with the capability to pursue a career path in Art Conservation broadly understood. The college’s deep resources in the sciences and humanities, coupled with the real-world experience and application of Colonial Williamsburg is an opportunity very few universities can muster.

A number of our students have already worked in the labs at Colonial Williamsburg, either as an extension of their research in our chemistry department or with an eye toward entering one of the five major conservation programs in North America. The two most recent to aim for careers in conservation have earned their M.A.s and are working as conservators in the capacities they sought. The aims now are to provide much clearer and established tracks for future students without having to rebuild them each time, strengthen perpetual connections with partnering institutions, and create opportunities for collaboration and longer term projects.

Rationale

There are five major art conservation M.A. programs in North America. Four of them are in the U.S. (University of Delaware’s Winterthur Museum, Buffalo State University, New York University, and UCLA which partners with the Getty Museum) and one in Canada (Queen’s University). Admission is highly selective and most of the programs explicitly require...
experience in conservation laboratories that will not be available as part of most undergraduate students’ education.

Most of the resources necessary for William & Mary to develop a highly competitive undergraduate focus in art conservation are either available within the college or at least potentially within our reach. The courses necessary to satisfy the expectations of the five programs are all available here. Below is a list that will meet the requirements of all of them.

The other major requirement of the conservation M.A. programs is laboratory experience. Only Winterthur specifies a number of hours—a minimum of 400 hours in a conservation lab. That seems like a lot of hours, but two five-week full-time summer internships, to name one possibility, would meet the minimum requirement.

If William & Mary can build a cooperative understanding with the conservation laboratories at Colonial Williamsburg, we may be able to build a regular path toward lab hours for our students. In fact, the students’ success will be greatly enhanced by the variety of laboratories Colonial Williamsburg operates. Duplicating the success of our previous graduates in the future will depend on making a collaboration with William & Mary clearly beneficial to Colonial Williamsburg. It should be possible to prepare our students to contribute maximally while requiring minimal investment from Colonial Williamsburg. If the conservation lab at Colonial Williamsburg is amenable to our proposal, we will have to ensure that the collaboration benefits both institutions. Preliminary inquiries appear to be fruitful.

Preparing students to contribute will mean giving them training even before they interview with Colonial Williamsburg conservation lab personnel. If they can be shown some basic skills, including how to handle various kinds of objects and tools, how to operate some instruments, and how to make suitable photographic documentation of works, they may be accepted for lab work. Getting students to such a level of readiness might mean establishing a tutorial or small class (depending on the number of students who take an interest in this focus) that reviews some techniques in chemical analysis, brushwork, woodworking, handling objects, photographic documentation, and color correcting.

Looking beyond Colonial Williamsburg, this model could function in multiple venues, the organization of which will allow us to approach outside partners with a clear plan and goals. Any form of material artifact – stone, wood, paper, plastic, tortoise shell – would lend itself to
analysis and preservation, even the digital. Uncountable numbers of pages of data sit on hard drives and floppy disks, magnetic tape and punch cards needing to be cataloged and conserved. The original tapes containing the raw unprocessed Apollo 11 moon landing footage were erased and reused by NASA in the early 1980s because they faced a major data tape shortage at that time. Collaborations between members of this program, librarians, data scientists, and others may yield novel and interesting approaches that have not yet been tried.

**Learning Objectives**

- Develop Art Conservation as an academic discipline.
- Prepare students for graduate study in a variety of conservation fields.
- Facilitate interdisciplinary learning.
- Research the historical context and material culture of a wide range of artifacts.
- Motivate diverse groups to pursue technical studies.
- Perform and disseminate research on art conservation in multidisciplinary education.

**Advisory Board**

This Focus will be overseen by an Art Conservation Advisory Board that will be empaneled by the Department of Art & Art History and its partners and may include interested faculty from other departments, programs, and institutions under the advisement of the Cohen Career Center. The Advisory Board will cooperate in determining which courses will be taught over a given 2-year period, in consultation with the Registrar, and all affected Department Chairs or schedule coordinators.

**Resources**

Art conservation will take advantage of the plethora of resources available throughout the William & Mary ecosystem in partnership with outside institutions, including A&AH, Chemistry, Physics, Biology, Anthropology/Archeology, and the laboratories available at W&M and also through Colonial Williamsburg.
Core classes:

Chemistry

CHEM 103  General Chemistry I
CHEM 103L  General Chemistry Laboratory I
CHEM 206  Organic Chemistry I
CHEM 206L  Organic Chemistry Laboratory I
CHEM 209  Organic Chemistry II
CHEM 305  Inorganic and General Chemistry II

Plus another class of clear relevance, such as:

CHEM 309  Instrumental Analysis

Studio Art

ART 211  Drawing and Color
ART 212  Three-Dimensional Design: Form and Space
ART 309  Life Drawing I or ART 311  Drawing
ART 315  Painting: Basic Pictorial Structure
ART 340  Introduction to Photography

Art History

Specializations in anthropology, archaeology, art history or museum studies. Courses in these fields can be mixed together, but no more than two should be at the introductory level. Only art history will satisfy the requirements of all the programs.

Up to two of the following:

ARTH 251 or ARTH 252  Survey of the History of Art I and II or
ARTH 255  Art of East Asia or
ARTH 267  Greek Archaeology and Art
ARTH 268  Roman Archaeology and Art

Four to six upper-level electives (ARTH 3xx or ARTH 4xx) in various cultural traditions or historical periods.
Sustainable Design

Introduction

Whereas the proposals for Digital Gaming and Art Conservation follow the model of a standard pre-professional track, Sustainable Design presents an even more ambitious challenge. Students and practitioners in the engineering fields are increasing placing environmental and social sustainability at the core of their practice and professional responsibilities. The three pillars of sustainability <Social, Economic, and Environment> are also central to the design process, requiring the talents of multiple disciplines in order to minimize negative environmental impact, while recognizing the interdependence between all people and the natural world.

This concept can be applied to the fields of architecture, landscape architecture, urban design, urban planning, engineering, graphic design, industrial design, interior design, fashion design and human-computer interaction. Here again, William & Mary is wonderfully situated to take a leading role in education and research.

Rationale

Ventures such as the Mercury Project (started 2005) led by Dan Cristol (Biology) and Sharon Zuber (American Studies), have demonstrated the impact a multidisciplinary team could
have throughout the William & Mary community. The same leaders along with Dorothy Ibes (Environmental Science) and Ed Pease (Art & Art History) have received seed funding from the Center for Energy and the Environment to study “third places” on campus, which are defined as social spaces separate from the two usual social environments of home (“first place”) and the workplace (“second place.”)

Elizabeth Mead’s (Art & Art History) proposed “Improbable Building Project” and, more recently, Rob Hale’s (VIMS) “Plastics in the Environment” group, also seed funded by CCEE, typify the dynamic potential inherent in these multidisciplinary studies and demonstrate the conceptual basis for this Focus.

Course of Study

The common core course of study for this Focus will be in Environmental Science, Art & Art History, and Business. The Art department presently has three architects on its faculty: Ed Pease, Sibel Zandi-Sayek, and Xin Wu all of whom are conversant with environmental design issues and theory at great depth.

The Business School offers a concentration in Sustainability through the following courses:

BUAD 441 Social Entrepreneurship
BUAD 453 Sustainability Inspired Innovation & Design
BUAD 464 Sustainability/Green Supply Chain
ENSP 101 Introduction to Environmental Science and Policy

In addition to natural tie-ins with COLL 100, 150 and 200 level courses, many opportunities exist to work and study internationally within the COLL 300. Partners such as the Center for Ecological Living and Learning (CELL) have already shown interest in working with William & Mary faculty to tailor custom short course field programs in Central America, East and South Africa, Middle East, Scandinavia, Iceland, and Scotland.
Business and Entrepreneurship Pillar

Design & Deliver Concentration

Introduction and Historical Perspective

Educational experiences that involve innovation, design, engineering, and other creative activities exist throughout William & Mary. Recently, the number of these initiatives has increased and as we have noted the centrally supported infrastructure has grown (e.g., Makerspaces), and efforts have been underway to establish a system of open access to these spaces for all interested parties. In business and industry, creative problem solving has been cited as one of the top 10 criteria for employers’ hiring decisions [Zupek, 2011]. Moreover, as we noted in the introduction the widespread availability of resources for creative activities that has spawned coalitions of artists, architects, engineers, educators, students, and designers engaged in creative activities is becoming prevalent in commercial ventures such as Alphabet, X, Tesla, Ford, GM, and elsewhere. The interested reader may find local examples at http://www.757makerspace.com.

While opportunities for students to engage in creative activities exist at W&M, we still have a long way to go to provide all of our students, graduate, and undergraduate with access to the full set of tools, and exposure to the entire range of processes they are likely to encounter when they leave us. The Business and Entrepreneurship Pillar seeks to better coordinate those activities to “connect the dots” and to broaden the range of activities to provide the exposure to the range of creative activities we foresee growing over the next decade. As part of the highly desirable promotion of multidisciplinary work among students and faculty, this Pillar brings a valuable perspective to framing problems and an alternative point of view for their solution, reinforcing the various skills needed to develop teamwork and leadership that is also critical to workplace success. The Raymond A. Mason School of Business (hereafter “Mason” or “Mason School”) is a very natural place for this effort; there are nearly two dozen faculty members in Mason with terminal or advanced degrees in engineering specialties, and it is home to a set of
very quantitative business graduate specialties including finance, logistics, data science, and more. So, it is expected that this Pillar will become a pivot around which much of the organization will come, especially for students from other schools around the campus, whose knowledge and skills vary.

This cross-campus collaboration will engender the individual’s respect for their own skills and contributions, as well as respect for others with skill sets differing from their own. It is also anticipated that students will gain an understanding that solving hard problems to achieve satisfactory solutions requires a very high degree of cooperation and teamwork among people with very diverse skills. This is as true for a creating and launching a rocket as it is for designing and constructing a building, or a large piece of art to occupy the atrium of such a building. The confluence of science, art, and engineering has creativity and cooperation at the nexus; this is a requirement for success in the coming world.

Benefits of coordination also come in the form of economies of scale in sharing the investment required for the assets necessary for this program as well as ongoing expenses, such as course development, course instructions, and administration. Faculty from one school, who interact with faculty from other schools and departments will similarly grow in their motivation to look at problems, instruction, and endeavors in general through a broader lens as they move via “design stage failures” from success to success

Description of the Design and Deliver program

Curricular Content

The Design Concentration provides students with the experience of rendering ideas, devices or objects that are intended to solve specific problems to create physical or functional forms. These potential forms may be products, software, an educational program, artwork, a robotic device, or an object, system of objects, or other created output. Although the physical prototype of a solution may be the most tangible manifestation of students’ efforts, in the Mason Design and Deliver studios the process for developing those solutions is a primary focus. The initiative leverages the Design Thinking framework that has been developing in the Mason School for the last two years. This framework is depicted in Figure 1. The Design Thinking
framework is characterized by two distinct phases: identifying problems and solving problems. Each is extremely important. A great solution to a badly posed problem can do as much or more damage as a bad solution to a well-posed problem. Furthermore, no solution is likely to survive in the marketplace for long unless it is a “good-enough” solution to a well-posed problem. It goes without saying that the only businesses will survive in the marketplace will be those that can depend on the ability of their employees to do both parts effectively.

The two phases consist of four modes:

- **Discover** - uncovering needs and insights through customer relations and research
- **Define** - synthesizing the data from that research to reframe broad challenges into specific problems
- **Create** - developing concepts for user testing and iteration
- **Evaluate** - testing prototypes and assumptions to determine next steps to iterate

While Figure 1 appears as a straightforward, predetermined sequence, the modes are often executed in a sequence different than implied in Figure 1 depending on the needs of the project. Furthermore, multiple iterations through the four modes are frequently required based on emergent findings. Utilizing this Design Thinking framework to arrive at a feasible solution is what we are calling a *design cycle*, or *cycle*, for short.

![Figure 1: Design Thinking Process](image)

A primary feature of the Design Concentration is that it is generically applicable to multiple interest areas, including: the development of Products, Apps, Physical Computing, Design, Education Programs, and Project-based learning. For the purpose of this proposal we call
these interest areas “threads.” These threads provide many ways to introduce students from diverse backgrounds to this program.

The content of the Design Concentration as an academic program consists of two distinct phases. These structure and intent of these two phases are shown in Table 1. *Students who complete both phases earn 12 course credits, and are awarded a Concentration in Design.* Demonstrated competency or completion of all Phase 1 requirements are a prerequisite to participating in Phase 2 activities.

<table>
<thead>
<tr>
<th></th>
<th>Phase 1</th>
<th>Phase 2</th>
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</thead>
<tbody>
<tr>
<td><strong>Credits</strong></td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td><strong>Timeframe</strong></td>
<td>Summer (pre-enrollment) or Freshman through Junior years</td>
<td>Upper Division/Senior year</td>
</tr>
<tr>
<td><strong>Focus</strong></td>
<td>Design process and skills</td>
<td>Ambiguous challenge</td>
</tr>
<tr>
<td><strong>Cycle Format</strong></td>
<td>Online learning modules for skill building and concept literacy</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hands-on labs for application practice</td>
<td>Challenge-centric with the goal of leveraging the skills and concepts learned through 1st cycle.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Online modules and labs can be used to supplement</td>
</tr>
<tr>
<td><strong>Project format</strong></td>
<td>Specific to a particular focus area</td>
<td>Highly ambiguous</td>
</tr>
<tr>
<td></td>
<td>Narrow scope</td>
<td>Crosses multiple disciplines</td>
</tr>
<tr>
<td></td>
<td>Requires execution of a newly learned skill</td>
<td>Constitutes a complex, wicked problem</td>
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</table>
Students may fulfill Phase 1 requirements over their Freshman, Sophomore, and Junior years. Phase 1 competency can be acquired through combination of online learning modules and hands-on labs which, taken together, cover all of the modes of the Design Thinking framework. The learning modules teach theory, principles, and concepts, whereas the labs constitute the hands-on application of those concepts to a problem. The online modules for Phase 1 are investments that can be leveraged by others at W&M, whether these offerings are in undergraduate and graduate programs, or are satisfied by other online programs such as continuing education programs. Phase 1 requirements may optionally be completed prior to enrollment in the Design and Deliver program by completing a summer bridge program – which we envision to occur as an intensive course exposing students to the necessary concepts and providing equivalent hands-on experiences. The precise details will need further elaboration, but we believe the structure that is likely to emerge will look like that in Figure 2, showing a sample depiction of Phase 1 curricular content. As noted in Figure 2, all students will take the learning modules and labs in blue for a total of 3 credits. Students will then choose other learning modules and labs relevant to their chosen thread for an additional 3 credits.

<table>
<thead>
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<th>Team-based</th>
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<td></td>
<td>Requires multiple process iterations</td>
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</table>

Table 1: Cycles through the Creative Process
We envision Phase 2 to be a 6-credit project, taught across two semesters, suitable for Coll400 or senior-level students. The intent of these projects is to have students work in multidisciplinary teams composed of students who have completed Phase 1 in differing threads. These diverse, and inclusive teams will solve a Phase 2 problem (see Table 1) by iterating through the Design Thinking process. Phase 2 projects would not have clear, precise problem statements, but instead would be ambiguous in nature and require the tools of the Discovery & Define modes to resolve that ambiguity to define the challenge in sufficiently explicit terms to seek a potential solution for design. Such problems would be selected to lie at the very diffuse boundary between very hard and extremely hard; but we would expect this experience to illustrate some of the feature of “wicked problems.” As we mentioned in the introduction, wicked problems are not on the spectrum of difficulty; they are in some sense the opposite of a hard problem [Camillus, 2008]. Wicked problems therefore are not “problems” as such, rather they are “conditions” or “circumstances” that evolve over long-periods of time, or that represent fundamental limitations of a system. An analogy in the realm of computational science is the difference between problem statements that are known to have a unique solution and those that cannot be proven to have any solution at all. Although we want our students not to shrink when confronted with wicked problems, we also want them to understand the peril of rushing headlong into one, especially if they are betting the company on finding “a solution.”
As an example of the types of problem structures that might given to upper division students in Phase 2, student teams could be challenged to design a service or device that could **enhance** the desirability or feasibility of “aging in place” for older individuals (see [http://www.ageinplace.org/](http://www.ageinplace.org/)), as compared to transitioning to managed care facilities, or other options. The solution for such a problem lends itself to a multi-disciplinary approach, as a solution to this problem could be a product, an App, a device with embedded Physical Computing, an Art object, or, preferably, an amalgam of multiple solution modalities. Allowing broad problem definitions allows and encourages multidisciplinary interaction among team members. In addition, such problems encourage creativity by allowing for many different type of solutions. Other potential Cycle 2 project themes includes, improving middle school public school education, encouraging physical activity for youth, or improving quality of life in developing countries.

This experience will be divided across two semesters as are Physics Department Senior Projects. The intent would be that this 6-credit sequence will qualify for a COLL 400 designation and as major-related electives for many programs across William and Mary, which increases the feasibility that students can participate in this activity while satisfying other curriculum requirements.

**Inclusion**

This concentration aims to promote mindsets and skills that are inclusive to all students across all schools and from all majors. Traditionally, programs that feature engineering and technology principals have found recruiting and retaining women to be challenging (National Center for Women in Information Technology; NCWIT, 2007; National Science Board, 2010). This proposal acknowledges this challenge and naturally extends to majors that are significantly populated by women such as the life sciences and education among others (NCWIT, 2015). Based on recommendations of programs that have been successful in recruiting women to similar majors and minors, the concentration will be promoted through messages of using creativity and problem solving to address relevant societal problems [Bouville, 2007]. Toward that end, the problems posed to students will often involve solving a problem provides societal benefit, such as is the case for the sample topics previously mentioned for Cycle 2 projects. Further, faculty
members will be advised on how to personally recruit students into the concentration, shown the applicability of the concentration to students’ specific future trajectories, and will be advised as to how the concentration will connect students to diverse peers across campus as well as to their community [Knight, Novoselich, & Trautvetter, 2014].

**Other planned activities**

**Orientation and Immigration Assistance to the Certificate Program.**

Elements of Phase 1 content, in particular, the Design stage are taught through web-based materials. To build a vibrant community of designers it will be important to attract other students into the concentration. Building a community and to facilitate and encourage in-person contacts and interactions between them while the web-based elements are in progress. Also, because this concentration may consist of students who do not move along a fixed or predictable schedule, working at their own pace, a very careful orientation and early counseling will be needed is required to help students navigate. We plan to take advantage of those counseling sessions others who may be interested in the concentration.

We plan to develop a web site to serve as an information portal for the program and a place to organize the activity. Primary functions and uses of the site include: discussion of activities in various threads, announcement of project opportunities for Phase 1 and Phase 2 projects, initial recruiting and sign-up sites to help in forming multidisciplinary teams for credit-bearing and non-credit-bearing projects to include connections to the entrepreneurship center efforts.

The site will all be a useful repository on which we can maintain a calendar of all design-related activities, talks, and meetings on campus including clubs such as makerspaces and shops, and the Mason School Design Thinking Club. It will also be a useful central repository of descriptions, photographs, and the location of existing artifacts from design efforts, and to maintain a database of previous projects which might serve as a basis for projects in courses across campus.

The Design & Deliver initiative activities are complementary to various entrepreneurial efforts at W&M, including some activities that are entirely student led, such as hackathons and
other events leading to interesting designs. There may be occasions where directed student projects, either associated with the Design and Deliver activities, or other activities at W&M, and most especially designs coming from Phase 2, where students could strongly benefit from further commercial exploration Patent and other technology transfer initiatives that students may wish to pursue through W&M, can be referred to the Alan B. Miller Entrepreneurship Center (ABMEC), where close coordination of IP and other issues will be maintained for student (and faculty) benefit. Students may wish to participate in business modeling workshops or submit proposals for seed funding which we hope to have available in ABMEC to help them to further pursue their ideas. The Center provides mentorship and external networking support to help students to move ideas forward.
The App School

**Goal:**

The App school is focused on the need for liberal arts students to understand the digital world, to create value and deliver that value digitally. Using today’s tools, students can acquire the necessary knowledge to use those tools quickly enough to focus on the Design and Deliver paradigm discussed earlier in the document.

**Description:**

The focus of the maker school is on making an app, computer or phone based, or webapp that improves performance or solves a problem for the user. It might be a business solution, a medical solution, a communication solution or etc. The problem the app/website and students address would require Design, Render, and Abstraction, and perhaps would be part of an approach to a Wicked Problem. The app program would be very much engaged in the ideas of Design and Deliver. The App Program focuses primarily on implementation of solutions. The minimum goal of the App School is to design and deliver a minimum viable product (MVP) in an area of interest of the student. That is, a product that can/will be taken to market, without frills or “nice to dos.”

The students would develop the app from conception to design to delivery. Many students across the curriculum have been inspired by individuals like Mark Zuckerberg of Facebook, who have built such applications while in their undergraduate curriculum. Students have found the current path at William & Mary, perhaps dual degrees in business and computer science, to be daunting.

While it is possible for a student to complete an App School project, the intention is for students to work in teams of two to five students. We would encourage students from all App School projects to meet periodically to socialize and exchange ideas. Speakers would also be a focal point of these periodic meetings.
Courses:

Students would learn to code, as necessary, test applications for functionality and customer usability and features. Students would learn about performance metrics, regarding app performance, as well as market performance.

There are five proposed courses required for the App School:

- Lean Startup and marketing – In this course the students would learn about the lean startup, lean/agile project management, MVP’s, and the advantages and necessity of quick product-customer feedback loops.
- Programming Frameworks – The programming frameworks would concentrate on what the student needs to know to develop and deliver applications quickly. There are several frameworks available that abstract and automate much of the work required to bring a site online. Access to appropriate web-based resources will also be taught.
- User interfaces and design – It is safe to say that a bad user interface will kill an application. As part of the Design and Deliver ideas, good user interface design will be taught and encouraged.
- Application architectures - Making decisions about where the work gets done in a running application is important for performance reasons as well as security reasons. Performance measures, metrics, will be discussed with respect to application speed and in respect to the data required for marketing analysis. Digital ecosystems will also be considered, i.e. what services can be used in the applications that are available from other companies.
- App Development – This is the course where students would actually develop their app. As currently envisioned, it would be taken concurrently with the other courses, in order to immediately apply the knowledge gained.

Optional courses: There has been much excitement about incorporation of artificial intelligence into phone and web apps. The premier neural network technique is called Deep Learning. Machine learning is related, although without the neural networks. These techniques are the essential ideas behind voice recognition on the phone such as Siri, face recognition on Facebook, and many other domains of pattern recognition discussed in earlier sections of this document.
Program Length:

At a pace of 2-3 courses per semester, this program could be completed in through the course of a single academic year. It might also be possible to complete in a 10-11 week summer intensive experience. The graphic below is for a one-year program format.

Relation to new curriculum

There are a number of possible ways that the App School courses would fit into the new curriculum; we expect the largest contribution to be in providing COLL 200 and COLL 400 opportunities.

COLL 200

COLL 200 requires that those centered in the Natural World and Quantitative Reasoning (NQR) knowledge domain that also considers aspects of the Culture, Society, and the Individual (CSI) and Arts, Letter, and Values (ALV) domains. Since the problems/projects students would work on are inherently multidisciplinary, we would expect that courses would fit into the requirements for COLL 200 easily. Examples would include User Interfaces and design, and Lean startup/marketing.

COLL 400

COLL 400 can be completed through upper-level seminars, independent study and research projects, and Honors projects that are specially designated by departments, programs, or schools. We would expect that App School courses would fit into the requirements for COLL 400 easily. One example would be the course in which the project is completed, App Development.
The App School

Courses

Semester 1
- Lean Startup/Marketing
- Programming Frameworks

Semester 2
- User Interfaces and design
- Application Architectures

Optional
- Deep Learning
- Machine Learning

App Development
References for Business and Entrepreneurship Pillar


Infrastructural Pillar

Maker Spaces

In anticipation of moving forward into engineering and design activities, W&M has invested in the development of a number of spaces suitable for such activity. These spaces have been outfitted with sets of tools to allow individuals with ideas for products to attempt to rapidly prototype those ideas and to enter the iterative process of debugging and improving performance at a minimal cost. These “maker spaces” have been created with the idea that they can be accessed by any member of the W&M community without respect to department, school, or employment status, and that they are essentially “IP-free zones” where W&M will not generally assert claims of any type to the products developed there unless those products are the result of a direct and “specific assignment” that might need access to maker space resources for execution. Maker spaces therefore resemble “play grounds” or “recreational facilities” in the way municipal recreational fields or school playgrounds are intended to promote health and social bonding activities, maker spaces are intended to hone the urge to solve problems creatively.

The following is a list of centrally supported maker spaces, containing a variety of equipment that is available for use by any member of the WM community, and for occasional use by partner institutions or members of the local community

- **Applied Research Center** at Newport News: maintains a small make space comprising multiple 3-d printers, and other light machining, electrical bonding, microscopes, and characterization tools suitable for small prototyping work.
- **ISC – BioMaker Space**: supports molecular genetic activity for development of BioBricks or other modular biological component devices. PCR, Sequencing, Labelling, and other necessary equipment is available for WM use only.
- **Mason School Innovation & Design Center** – limited equipment for rapid prototyping including multiple 3-d print and additive manufacturing tools. Extensive design facilities also exist.

- **Morton Hall Humanities Maker Space** – prototyping 3-d print, 3-d display, game development, design studio activities, autonomous vehicles.

- **Small Hall Maker Space** – an extensive set of tools for electronic device development, prototype manufacturing including multiple 3-d print, joining, electronic measuring tools, vacuum forming, laser cutters, computer controlled milling and routing, extrusion, robot and autonomous vehicle development, and 3-d display. This set of facilities is allied with an extensive full-scale metal-working Student Machine Shop capable of all aspects of ferrous and non-ferrous metal forming at scale.

- **School of Education Maker Space** – 3-d additive print prototype manufacturing, heavy emphasis on electronic device development and custom printed circuit board development. Training for local high school lead teachers.

In addition, W&M operates a number of spaces where curricular activity for academic credit, faculty/student research and other regular activity occurs where specialized equipment is available that can be made accessible for engineering activity related to uses of the maker spaces. These spaces include

- **AidData** – extensive data handling, storage, analysis, and display. Applications development from smart phone to large-scale cloud computational systems.

- **Art & Art history Studio Spaces** – 2-d and 3-d media spaces, wood working, paper forming, clay shop and ceramics studios with kilns, full scale photographic studios, metal working, welding, coating, paints, conservation media.

- **Applied Science Robotic and Engineering Spaces (Hinders)**- various engineering design tools for autonomous vehicles and advanced sensor development

- **Alternative Energy Engineering Laboratory**- MS Hall- full scale micro- and nano-scale engineering processes laboratory for battery, capacitor, fuel cell and
other applications. Connected to Small Hall Engineering Labs and Applied Research Laboratories for plasma and photon processing.

- **Club Environments**  Engineering activities that also occur in rapidly growing “club environments:” Rocket club, Robotics Competitions, NASA drone competitions, computer hackathons, Mason School Entrepreneurs Club.
Learning Centers

The Center for Innovation in Learning Design

William & Mary is dedicated to world-class teaching and remains at the forefront of innovations in teaching and learning. The faculty within the School of Education (SOE) are committed to this bold vision of innovation. The SOE’s strategic planning process identified the need to develop a Center for Innovation in Learning Design to capitalize on significant opportunities for instructional innovation that span wide-ranging constituencies within the SOE. In addition, these opportunities will provide motivation for creating and sustaining interdisciplinary relationships with other departments and schools at William & Mary. This focus on interdisciplinary relationships, combined with innovations in instruction, fits within the scope and purpose of the Committee for Engineering and Design’s goals. In addition, the Center for Innovation in Learning Design (CILD), much like the Engineering and Design Committee, intends to utilize the design thinking process to define and approach relevant problems in both local school systems and higher education. For example, the CILD has in combination with the Mason School, provided local school personnel with design thinking training intended to allow secondary schools to tackle policy, administration, curriculum and instruction issues.

In addition, the faculty within SOE plans to expand the reach and application of engineering design in education through the establishment of the CILD. The CILD can serve as a tool to prepare administrative and teacher candidates to rethink the current methods of approaching curricular and structural issues within the K-12 environment. In addition, the CILD will emphasize the use of engineering design techniques within the K-12 environment itself, that is, instilling within K-12 students the critical thinking skills required to solve interdisciplinary, multi-faceted problems.

Innovations in Learning Design

The Center for Innovation and Design will provide a means for teachers and administrators at all levels of education with a vision of teaching practices that differ substantially from traditional emphasis on the routine use of facts and procedures.
approaches to authentic inquiry include design thinking, inquiry-based learning, and project-based learning, all philosophies consistent with goals for instruction established by Committee for Engineering and Design. The Center aims to establish partnerships between faculty, in-service teachers, teacher candidates, and other schools and centers within William & Mary to facilitate the creation of curricular and instructional designs centered on relevant, contextually-based problems. For example, a problem faced by local and national school districts is student engagement, and providing learners with problem-based classroom experiences that are relevant to individualized career paths will simultaneously engage students, as well as provide the future workforce with relevant skills and dispositions. To assist with solving this problem, CILD will work to offer professional development activities and teacher candidate preparation that will include instruction on effective interdisciplinary collaboration to bridge connections between concepts. In addition, such professional development will also provide instruction to allow teachers to develop lessons through the use of maker spaces. The center will allow teachers to build partnerships to industry professionals and university researchers to demonstrate multiple pathways to learning and career possibilities for K-12 students. Finally, center activities will include the use of design thinking strategies both as a means to instruct students at the high school and post-secondary level.

Faculty within the SOE are well positioned and qualified to operate the Center because they are committed to exploring, prototyping, and testing new learning designs. SOE faculty has also established deep and wide networks campus-wide, locally, and globally. The CILD will leverage these networks to apply diverse perspectives to issues facing teaching and learning. In addition, the Center’s interdisciplinary focus will create rich opportunities for faculty and student research, training, and practice and will expand research endeavors as well as contribute to intellectual capital.
Center Goals and Objectives

The purpose of the Center for Innovation in Learning Design is to envision, develop, implement, and assess innovative learning designs for students and educators. Specifically, the Center will:

1. Promote collaborative research and development activities around issues of learning
2. Incubate and develop new projects focused on innovative approaches to learning
3. Consolidate support for external partnerships and funding opportunities
4. Disseminate outcomes through research, workshops, and evaluation studies

Core Center Functions:

The director or co-directors will help to catalyze new initiatives related to learning design through a range of strategic efforts summarized below.

- Foster a culture of innovation and collaboration within the School of Education and between schools across the William & Mary campus.
- Coordinate new and emerging initiatives to prepare for formal research grant proposals and other external funding opportunities with a particular emphasis on innovative, cross disciplinary approaches to education.
- Provide support for research and evaluation efforts related to Center projects and initiatives (research design, interdisciplinary partnerships, assistance with data analysis, etc.), in concert with the Associate Dean for Research.
- Strengthen SOE-school division partnerships through collaborative and innovative initiatives that address macro and micro levels of education policy, curriculum, and instruction.
- Develop and offer innovative and unique training institutes, curriculum materials, and learning designs that can be used to generate revenue to support Center initiatives and strategic initiatives throughout the SOE and William and Mary.
Example Project Foci:

The Center would support a range of projects which would include

- Engage in creative, critical and design thinking process that lead to potential solutions of long standing PK-16 educational issues such as:
  - Instructional relevance
  - Student assessment

- Create emergent teaching and learning initiatives in PK-16 education, such as:
  - College Teaching Certificate
  - Virtual world and simulation

- Generate big data that can be used to understand complex learning challenges via learning analytics and subsequently develop research questions based on these analytical tools

- Offer experiential learning in design thinking and project-based learning (e.g., mentoring/coaching in PD) to educators in K-16 settings.

- Develop collaborative research initiatives across the School and William and Mary with the goal of securing external funding support.

- Design and deliver professional development for education professionals (e.g., Design Thinking for PK-16 Educators)

Long Term Plans for the Center

- Become a national leader in innovative learning design through outstanding work, major funding through grants and contracts, and wide and diverse dissemination of results through professional conferences and publications

- Install a leadership structure capable of securing external funding and leading large scale, high yield initiatives focused on innovation and learning design.

- Develop and host professional conferences and institutes on innovations in learning design in the Center and the SOE Professional Development Center
• Develop a partnership with the Mason Business School Entrepreneurship Center to work with venture capitalists to create products to support teachers and students in PK-16 education.
Center for the Liberal Arts

The Center for the Liberal Arts (CLA) grew out of faculty discussions held during the recent curriculum review. The CLA was eventually chartered to “…support a robust liberal arts education through the continual organizing and infusing of content, integration, creativity, and innovation throughout the undergraduate College Curriculum.”

The CLA, through its affiliated Faculty Fellows, is charged with being a kind of vanguard for the new curriculum. CLA Fellows commit to being out in front, leading the charge, creating new courses and taking responsibility for anticipating and proposing solutions to problems that always emerge during the implementation of something as complicated as a new curriculum. They do this in a very open and collaborative manner, by helping other faculty along the way, by providing models for courses and assignments, by answering questions in department meetings and retreats, by counseling faculty one-on-one who may be nervous about taking risks, by reminding our colleagues that it’s by taking risks, experimenting, and learning from our mistakes, that William & Mary will continue to be one of the leading liberal arts universities in the country.

The CLA is a home for faculty who are hungry for meaningful interaction with colleagues from across campus, faculty who are outstanding scholars, artists, and researchers, and who have a demonstrated commitment to general education. The CLA is a kind of ‘skunk works’ or ‘enterprise zone’ for the liberal arts, a place where faculty support one another, a safe place for a physicist to seek insights from historians and artists about effective teaching methods or to form team-teaching partnerships, to brainstorm with like-minded colleagues across fields and domains of knowledge in a mutually respectful manner.

After two and a half years with no fixed home, the CLA occupies space in Morton Hall as of summer of 2016. Longer term, current plans are for the CLA to take up residence as part of a newly-renovated ground floor in Swem Library. Initial conceptual discussions with architects are underway. These new spaces would be highly collaborative and should include a maker space.
Swem Library Central Data Visualization Lab

The research and teaching areas described above, including digital humanities, geographic information systems (GIS), modeling and simulation, and the use of big data in high performance computing has a great deal of momentum across campus. This work will benefit from developing a central large-scale visualization space suitable for multiple purposes. Earl Gregg Swem Library (Swem) has managed partnerships and shared spaces including the Tribe Tutor Zone, the Writing Center, Academic Advising, the Omohundro Institute of Early American History and Culture, and the Center for Geospatial Analysis. Swem recently completed a $1.8 million dollar renovation of a high technology digital media center, and is collaborating with the Center for the Liberal Arts (CLA) on a faculty- dedicated space to support the new college curriculum. We propose to house a necessary central data visualization and digital imaging display space in a 4000 square foot location currently occupied by government documents in Swem.

The facility would enhance student and faculty research and learning by connecting users with unique visualization hardware and software and the latest online research tools and services. This lab will engage students and scholars from the sciences as well as those in the humanities and allow them to take advantage of a variety of technological tools in one shared space. The lab will be staffed by librarians and IT experts with specialized skills, who support work in the digital environment.

The centerpiece of the planned lab is a large, touch-enabled, high resolution digital canvas that will enable students and researchers to display and analyze data of all kinds, and engage the community with visual representations of their research. Flexible, hands on spaces are planned where faculty will teach students concepts and demonstrate the use of modeling, data and visualization across the curriculum. The lab will enhance research, modeling, and visualizations by providing technology and services that promote interdisciplinary engagement, collaborative investigation, and innovative inquiry.
References

Swem is taking much of our inspiration for this project from the Curve Wall at Georgia State University- https://youtu.be/7tp_vyiQNC