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Developing a CS+X Major: Computer Science + Society

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Digital Humanities has always been an interdisciplinary project. Positioned at the juncture of the Humanities, Social Sciences, and Computing, the field has fostered fertile collaborations. The archived course offerings from the Digital Humanities Summer Institute at the University of Victoria document the venerable annual community event's evolution from a 2001 gathering focused on Text Encoding Fundamentals and DH Pedagogy and Curriculum, to the multifaceted 2019 event featuring courses on specific tools, theoretical frameworks, digitization, international culture, and more. DH work can be done by lone scholars on a shoestring budget, but the complex projects on view at DHSI are often better suited to well-resourced institutions replete with research labs and dedicated staff.

This paper surveys the work humanists and social scientists at a small university have done with our colleagues in the School of Computing and Data Science to launch a new undergraduate major in Computer Science + Society. Designed to provide graduates with foundational training in both Computer Science (CS) and the Humanities and Social Sciences (HSS), the program will equip them for meaningful careers in a range of fields. Inspired by the principles of open exchange central to the DHSI ethos, we hope to model radical interdisciplinarity for our campus and beyond.

After more than a decade of strident calls from American politicians and regulatory agencies for a narrow focus on STEM education, computer scientists are joining their liberal arts colleagues in pushing back against this rhetoric. Computer Science professor Lior Shamir recently observed:

> I learned that scholarly questions can also be approached in ways that do not necessarily have to come down to a number and a P value, a formal proof and a protocol that can be replicated. I also learned that these paradigms can be effective in many cases where the hard sciences do not always have answers—questions related to social justice or to underrepresented minorities. The lab mind-set comfort zone that I believed to be the only way in which the universe could be understood was replaced with awareness that we can approach questions in other ways and through other methods that aren't necessarily part of the STEM toolbox (Shamir, "A Case Against the STEM Rush").

The ubiquitous role assumed by Computer Science, in particular, in recent decades has elevated individuals like Facebook CEO Mark Zuckerberg and Amazon CEO Jeff Bezos and the teams they lead to positions of massive political, social, and economic power. Having a strong background in STEM fields will not prepare tomorrow's leaders for

the complex social issues they will navigate. Broad, rigorous training in the liberal arts will meaningfully complement Computer Science education. As Shamir noted, liberal arts education offers much more than the “soft skills” and “empathy” often cited in contemporary defenses of the humanities. Multidisciplinary training in a variety of methods of research and interpretation prepares graduates to tackle complex problems with the humility and confidence to conceptualize their investigation in a nuanced and comprehensive manner.

Background

Wentworth Institute of Technology is a small, private university in Boston enrolling approximately 4,000 students. The Institute offers degrees in Computer Science, Engineering, Architecture, Design, Construction Management, Applied Sciences, Applied Math, and Business Management. The curriculum includes two mandatory full-time, one-semester co-ops that students complete while pursuing their degrees. During these co-op semesters, students do not pay tuition to the Institute. Instead, they work for area companies and organizations, mostly in paid positions, gaining experience that leads, often directly, to jobs after graduation. The Institute remains extremely focused on job market preparation and offers no humanities degrees.

In 2013 the Department of Humanities and Social Sciences planned a minor in Digital Humanities. This evolved into the “Media, Culture, and Communication Studies minor”, which the department hoped would serve as the springboard for an undergraduate major in the field. This six-course minor offered selections ranging from “Shakespeare on Film” to “Video Production” and “Pictures, Media, and U.S. Politics.” In support of the minor and planned major, several faculty members invested time and effort in becoming proficient with a range of Digital Humanities techniques and I was hired through a search for a specialist in Digital and Public History. Four faculty members have attended DHSI, while others have developed courses centering on projects using Omeka, Scalar and other digital tools.

Despite the commitment of this dedicated team, the major proposal stalled, in part due to the difficulty of procuring paid co-op placements for humanists in the competitive Boston market, where many students from other universities can afford to complete unpaid internships. We debated seeking authorization for unpaid co-op positions but did not want to buck the industry trend away from requiring unpaid student labor. We paused the proposed major, while continuing to offer the minor.

In 2017, the Dean of Computing and Data Science (then Chair of Computer Science) proposed developing a CS+X major with those teaching Humanities and Social Sciences. Despite initial reservations about ceding curricular control to another department, we proposed a B.S. in Computer Science + Society in 2020, and plan to launch the program in Fall 2021. The sections that follow outline the curriculum, the strengths of this type of major, and present an environmental scan of similar programs of study at other universities. This information is presented in hopes that it may be of use to others considering developing similar programs.

Computer Science + Society Curriculum

The major in Computer Science + Society combines two distinct fields of study—Computer Science and Science, Technology, and Society. In so doing, it follows the growing educational trend to pair training in Computer Science with work in another academic discipline. Called “CS+X” majors, such programs were initially focused on Engineering and Math, where they also sometimes take the form of Data Science. In recent years, however, some universities have begun to expand such programs into the Humanities and Social Sciences.

Skepticism toward such programs often stems from limited understanding of the nature of Computer Science, which encompasses far more than programming. Skuse et al. observe, “Computer Science is the study of algorithms, i.e., of processes for solving problems. […] Learning to program, itself, is not Computer Science any more than learning French is the study of French Literature; a computer scientist may have to learn a programming language to implement an algorithm” (48). According to the Association for Computing Machinery, Computer Science graduates should have not only the fundamental competencies central to the field, but also familiarity with common themes and principles, appreciation of the interplay between theory and practice, system-level perspective, problem solving skills, project experience, and commitment to life-long learning (The Joint Task Force on Computing Curricula Association). CS+X programs effectively provide training in practical Computer Science, offering students an opportunity to master relevant skills through work on real-world problems.

The coursework for the degree at Wentworth is grounded in our existing minor in Science, Technology, and Society, which draws on the strengths of the disparate areas of specialization of the Humanities and Social Sciences faculty. An introductory course in Science, Technology, and Society, together with an introduction to ethics, orient students to the ways in which decisions are (and should) be made around science and

technology policy and development. Coursework in Social Science Research Methods and Statistics and Applications ensures students have the foundational training in quantitative and qualitative research methods needed for analytical work in the social sciences. A course in the History of Technology and Society, a Political Science class in Science and Technology Policy and an Economics course in Technology and Economic Development offer students a strong background in the ways in which technology and society have influenced each other.

On the Computer Science side of the curriculum, students will complete seven courses from the discipline's traditional foundational sequence: "Computer Science (I and II)", "Introduction to Networks", "Computer Organization", "Data Structures", "Databases", and "Algorithms". They will also take two electives chosen from among "Data Science Fundamentals", "Mobile App Development", "Assembly Language", "Programming Languages", and "Operating Systems". This rigorous nine-course sequence ensures that students will master the fundamental skills of Computer Science.

Computer Science + Society: Major Bridge Courses

The program centers on four courses co-taught by one faculty member from Computer Science and one from Humanities and Social Sciences. These "bridge" courses will link the two fields, offering students a rare opportunity to learn from the collaborative efforts of faculty from wildly different disciplines working toward a common goal. These courses are carefully sequenced to complement the other coursework students are completing each year.

The sequence begins with "Introduction to Computer Science + Society", which students take as a co-requisite with "Computer Science I" during their first semester. The course offers students an orientation to sources and data in the Humanities and Social Sciences and an overview of varied areas of intersection between the fields. While a traditional Digital Humanities course targeting humanists might emphasize the ways one can employ digital tools, this course also considers aspects of how such tools function. This course is geared toward beginner students with enthusiasm for Computer Science and interest in its widespread uses. Core skills emphasized include fundamentals of programming with Java, library research, data visualization, and written and oral communication.

Students then take two Studio courses focusing on the use of a tool or application on a problem or scenario in the Humanities or Social Sciences. The topics will vary with the

instructional teams, covering anything from textual analysis, spatial analysis, image analysis, quantitative analysis and data visualization to web technologies, mobile technologies, and 3D printing. Some of our Literature faculty plan to offer courses grounded in digital poetry and graphic novels, broadening the program's interdisciplinary potential.

In the capstone "Senior Project" course, students work in teams on a semester-long project of their own choice and design, incorporating research and analysis from areas of the Social Sciences, Humanities, and Computer Science. Surveys of area employers indicate that project management is a highly desired and marketable skill. Teams will also practice using the principles of agile project management as they navigate this large, interdisciplinary project.

At its core, this program embraces the shift in many fields toward macroanalysis, defined as "a transdisciplinary intellectual concept offering opportunities to engage students in the role that large-scale computer modeling and simulation play in complex decision-making" (Thomas Lombardi 87). Across the Humanities and Social Sciences, there are ample opportunities for student learning grounded in macroanalysis. A class taking a Literature lens might use digital tools to analyze a corpus of literary texts. A class focusing on Sociology might analyze U.S. Census Data to create data visualizations about social inequality.

Broader thematic approaches can also be employed to encourage students to think across multiple disciplines through macroanalysis. In a course focusing on climate change, students might analyze large data sets of global temperatures, water levels, pollution measures, and so on. The scientific challenges of climate change have long been eclipsed by those posed by human behavior. Students could evaluate and propose steps to mitigate climate change while considering the fundamental insights provided by Psychology, Sociology, Economics, History, and Political Science.

Similar approaches can be taken toward the study of Epidemiology. The COVID-19 pandemic has demonstrated that scientific and medical insights into public health can be deployed effectively only when the broader social context is considered. Social inequality, politics, economic trends, and individual and group psychology all inform both how the virus is spreading and how we might limit its reach. Students can use macroscopes like GLEAMviz, a free tool, to model disease spread and mitigation strategies (Lombardi 93; GLEAMViz). Students at other universities have used this tool to study the 2009 H1N1 crisis and the 2014 Ebola outbreak. In the CS + Society

program, this tool can be used and analyzed in courses grounded in History, Sociology, Economics, or Political Science.

A Studio course might focus on the ways in which individuals and groups are observed in contemporary society for the purposes of marketing and surveillance. Students could read some of the literature on the ethics of surveillance which will be even more relevant in the aftermath of the Covid-19 pandemic, watch and analyze some of the recent films portraying such themes in often dystopian settings, and research the methods companies such as Google, Facebook, Amazon, and others use to monitor and predict consumer behavior. The course would transcend the limits of a typical Ethics of Technology class since students would also engage the Computer Science aspects of the topic through exercises and activities exploring the mechanics of such systems of surveillance. Final projects could be prototypes of the core concepts of such a system, combined with research and analysis of potential deployment methods.

Spatial analysis is a key area of overlap between the fields of Computer Science and Humanities and Social Science. A Studio course in digital mapping would provide excellent opportunities for students to experiment with various systems of data visualization (Ian Gregory and Alistair Geddes; Anne Kelly Knowles). Basic concepts of cartography, its history and ethical considerations could form the first module. Students could then experiment with spatial analysis in R, creating basic analytical maps. In another module they could utilize GIS software such as ArcGIS or QGIS to create maps. These programs are especially compatible with Python and include consoles for such programming inside the main menu. Coding—using Python or more advanced languages if the student is familiar with them—allows students to go beyond the traditional limits of the software, customizing more fully the analyses carried out. Final projects could allow students to research topics of their choice, locate appropriate data sets, develop analytical maps, and present their findings.

A Studio course surveying humanistic data analysis could use the textbook *Humanities Data in R: Exploring Networks, Geospatial Data, Images, and Text* by Taylor Arnold and Lauren Tilton and apply those skills to a source-rich topic such as urban renewal. One emphasizing textual analysis could center on Python and the Natural Language Toolkit (Teddy Roland). CS + HSS courses offered at other universities further extend the possible course offerings. Courses at Union College using modeling and simulation include “Economics of Technological Change” (using Mathematica), “Quantitative Economics”, “Contemporary Problems in Macroeconomics”, “Study

Abroad in Egypt" (using 3D models of ancient sites) and Literature courses focusing on Romanticism and using the Blake Corpus Browser (Valerie Barr 208-209).

The courses discussed above will teach skills in problem-solving, research, data analysis and communication that graduates will bring to their careers. This curriculum reflects a significant innovation when compared to the traditional course of study in either Computer Science or the Liberal Arts. In adopting this approach, we hope to address some of the challenges faced by our institution and by other institutions focused on undergraduate education.

Strengths of CS+X Programs

CS+X programs are rising in popularity, revitalizing discussions of interdisciplinary computing pedagogy. S.B. Fee, Amanda Holland-Minkley, and Lombardi classify such work into four main areas: introductory courses with an interdisciplinary bent, CS courses tackling interdisciplinary projects, non-CS departments teaching interdisciplinary computing, and "computing curricula designed around interdisciplinarity." CS+X programs fall into this latter category and offer students the chance to study across the boundaries of individual colleges.

Advocates of such programs include Jim Kurose, Assistant Director for Computer and Information Science and Engineering at the National Science Foundation, who described CS+X degrees as providing valuable training for "those who want to use data collection to analyze topics such as politics, society, and the environment" (Corinne Ruff, "Computer Science, Meet Humanities" A19). We anticipate high demand for students who have both computing ability and the research training and relevant contextual knowledge which can be learned through HSS, since many graduates of other majors and other institutions possess one of those skill sets, but few possess both.

CS+X programs also help to diversify the demographics of those studying Computer Science. According to the Association for Computing Machinery, women, and under-represented minorities each made up less than 25% of the bachelor's degrees awarded in Computer Science in 2018 (Stuart Zweben et al. 44). In 2015, Professor Maria Klawe, President of Harvey Mudd College, noted that the National Science Foundation and the Computing Research Association had both reported steep drops in the number of women pursuing Computer Science degrees at the undergraduate level since the 1990s, even as women's presence in other STEM fields (most notably Biology and Chemistry) had increased (Klawe). At Harvey Mudd, Klawe made diversity a priority and increased the proportion of women majoring in Computer Science from 10% to

40%. Klawe cited team-based projects and research opportunities as helpful in this regard. Our CS + Society program is grounded in team-based and research-oriented projects in part to emulate this aspect of Harvey Mudd's success.

Klawe also noted, "They (the faculty) redesigned their introductory Computer Science courses to focus less on straight programming and more on creative problem-solving. They included topics to show the breadth of the field and the ways in which it could benefit society." Wentworth's CS + Society program will offer precisely this curricular space for practical Computer Science that Klawe describes. We are optimistic that seeing the real-life potential for their skills from their first semester at Wentworth will help students from underrepresented groups maintain focus and develop a strong sense of purpose as they complete the degree.

The rapid rise of data science education warrants discussion here. In 2012, *Harvard Business Review* called data science "the sexiest job of the 21st century" (Thomas Davenport and D.J. Patil). By 2017, *Forbes* called the field not just "hot," but also, "the highest paid field to get into," due to demand outpacing supply (Iliya Valchanov, "Why Data Science is Such A Hot Career Right Now."). There have been recent signs of that market beginning to level off, but it remains strong (Nick Kolakowski, "Data Science Market").

In response to this highly-publicized job market, many universities have launched Data Science graduate programs, encouraging applications from individuals from a wide range of backgrounds. The transition into a master's in Data Science can be difficult, however. As data analyst Meta S. Brown observed,

> Interdisciplinary learning and diversity in the workplace are good things, but some of the stuff I see is ridiculous. Yesterday, someone asked me if it would be hard to transition from a degree in art to an advanced degree program in analytics. Yes, yes, it would be hard. If you've had no training in statistics, or even college math, and no experience with databases or programming, you should take some of those classes and see how it goes before considering a career in data science (Brown, "4 Reasons Not To Get That Masters in Data Science").

Interdisciplinary undergraduate degrees offer a potential bridge between such disparate fields by affording students space to engage deeply with both Computer Science and subjects of humanistic inquiry.

Interdisciplinary education can add meaningfully to computer science education. Lombardi says that "we have missed something in computing education: a cohesive approach to a style of thinking that is changing how humans process language, organize knowledge, understand space and time, and grapple with the complex systems at the heart of civic life" (95). Grounding computer science training in real-world applications can help students maintain an outward-facing approach to the field, enhancing their awareness of the broader effects their work will have.

From the Humanities and Social Science side of the campus, such programs afford students a remarkable opportunity to carry out original research and data analysis at the undergraduate level. They also respond to contemporary critiques of the career preparation provided to students in such disciplines through the addition of complementary training in Computer Science. Graduates will be prepared for further study and employment in the broad range of fields now shaped by big data and communication networks, in a world where Computer Science has become ubiquitous.

Environmental Scan

In developing this major, we surveyed the landscape of Humanities and Social Science-based interdisciplinary computing programs. Unfortunately, such programs are not tracked in a systematic manner by the Association of Computing Machinery.[1] Below are descriptions of the relevant major programs we identified.

- Gonzaga University offers a B.A. in Computer Science and Computational Thinking which allows students to pursue interests in Arts, Economics, and other fields.
- Washington & Jefferson College houses a department of Computing and Information Studies in which students work with Digital Media and other interdisciplinary approaches, such as Data Science.
- Bates College offers a Digital and Computational Studies program that brings together Computer Science faculty and those teaching Art, Philosophy, Economics, and other areas. Bates faced challenges here because, as a liberal arts college, it does not have a Computer Science department (Straumsheim, "Computer Science as Liberal Arts 'Enabler.'") This situation makes the program relatively expensive to run and limits the depth of student learning.
- Caltech has pioneered programs pairing Computer Science with Economics, Sciences, and Mathematics.

- Northeastern University has developed a robust roster of CS+X programs as part of the thirty-seven Computer Science-related majors currently offered by the university. Those programs include CS + Communication Studies, CS + Media Arts, CS + Journalism, CS + Linguistics, CS + Cognitive Psychology, CS + Environmental Science, CS + Criminal Justice, CS + Economics, CS + English, CS + History, CS + Philosophy, CS + Political Science, and CS + Sociology.
- Northwestern University hosts several events and campus programs highlighting the links between Computer Science and fields such as Communication, Journalism, and Marketing, including speaker series, colloquia, and seminars. Northwestern is currently hiring to expand their Computer Science faculty, including a cluster hire looking for faculty especially interested in supporting the CS+X programs.
- Occidental College has three paths for students of Computer Science: the traditional Computer Science major, a math-intensive track, and then CS+X, a path in which students have the freedom to design their own interdisciplinary program of study.
- University of Colorado Denver offers a CS + program in which students are encouraged to pursue a minor in a wide range of fields or choose from a select list of majors, including Chemistry, English Writing, Rhetoric, and Technology, and Math.

The University of Illinois has developed a wide range of CS+X programs in order to meet increasing student demand for diverse training in Computer Science (Wurth). Elsa Gunter, Research Professor and Director of Undergraduate Programs in the Department of Computer Science, notes “CS + X is a recognition that today, computing touches nearly everything, and as a result, the arts, science, business, medicine and engineering are all changing” (Rhee, “CS+X degree programs cater to growing job demands for technical skills”). The University of Illinois’ interdisciplinary programs combine Computer Science and Music, Philosophy, Linguistics, and Economics, which build on earlier majors joining Computer Science with Math and Statistics. Graduates pursue a range of career paths, depending on their interests and training. CS + Linguistics has proven one of the most popular CS+X degrees at the university, drawing 80 majors, some of whom have found employment with Apple, Google, Microsoft, and Amazon.

A sobering lesson is offered by Stanford University’s failure to sustain their CS+X program. The program began with a bold launch structured around fourteen possible “X” partners, including several liberal arts options. Unfortunately, the program struggled to gain and keep enrollment. The closure of the program led to the

publication of a blog post from Daniela Gonzalez, a student in the program who shared her insights into the challenges the program faced. Key problems she identified included a bloated program of study, a lack of opportunities for real interdisciplinary exploration, and departments that did not effectively collaborate (Gonzalez, “The End of CS+X”).

We are too early in our program development journey to claim expert knowledge of best practices. Interdisciplinary cooperation across schools seems the greatest barrier to success that we have so far identified. In part, this challenge is inherent to the disparate fields occupied by CS and HSS, which might at first appear to have little in common. Institutional structures and incentives pose the bigger hurdle, however. The surge in enrollment in Computer Science programs in recent years has left many departments understaffed and many faculties overwhelmed. Balancing a heavy load of teaching and service, few Computer Science faculty have time and energy to invest in interdisciplinary partnerships, even if they are interested in such work. University budgets and administrative structures also rarely provide meaningful incentives for the development and support of such programs.

Building an Interdisciplinary Community of Practice

In developing this program, we are attempting to practice radical collaboration rarely seen on university campuses. Interdisciplinary initiatives between various Humanities fields have long been common at many universities, fostering programs in American Studies, African American Studies, and Women’s and Gender Studies, among others. Similarly, interdisciplinary programs bridging areas of the Sciences and Engineering are also standard fare, as evidenced by Wentworth’s existing undergraduate majors in Electromechanical Engineering, Biomedical Engineering, Biological Engineering, and Interdisciplinary Engineering. Collaborations bridging the STEM fields and the Liberal Arts, however, remain almost non-existent.

Our approach to curriculum development for this program has been deeply influenced by the philosophy and practices embraced by the DHSI community. As many have observed, Digital Humanities requires practitioners to adopt a position of conscious humility. Even senior scholars, accustomed to occupying a position of authority, must admit gaps in their knowledge and position themselves as beginners in some activities. At DHSI, efforts are made to foster an atmosphere of nonjudgmental collegiality, in which traditional academic ranks fade and graduate students teach courses to tenured professors. English professors teach classes in Python, History professors teach classes in R, and software developers teach classes to intellectually diverse groups. In

a classroom next door, courses focusing less on technical processes and more on cultural theory, ethical frameworks, and digital accessibility receive equal respect and attention. From DHSI we have borrowed some of the specific approaches to interdisciplinary computing education embodied in our program's curriculum. More importantly to the genesis of this program of study, our summers in Victoria have inspired us to believe that truly interdisciplinary communities can be built through a conscious commitment to humility, open communication, professionalism, and patience.

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Footnotes

1. Email correspondence to author from Association of Computing Machinery Member Services, 29 July 2020, indicated that the ACM does not even track undergraduate degree programs in Computer Science. ↩