# DCS 4As

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How can a curriculum support and sustain both critiques and creativity with digital and computational tools in the context of a classical liberal arts education? Within that broad intellectual challenge, what can a student or scholar of languages and literatures, or biology, or anthropology contribute to complex problems and questions of the common good that involve computation and the liberal arts and sciences? Since 2011, groups of faculty members, administrators, librarians, technologists, and students at Bowdoin College have been working to answer these questions, with particular attention to the role of the liberal arts in shaping technology for knowledge production. Working under the title of Digital and Computational Studies (DCS), these collaborators understand the digital broadly as screen-based media and platforms, while computation refers to both algorithmic processes and the tools for quantifying and visualizing data. In order to create a program of study that outlasts the latest tool, app, or device fad, we have developed a proto-epistemological framework for analysis of our objects of study. The framework's foundational principles are twofold: technologies affect not only the world itself (objects of study) but also how students and scholars need to use and criticize technologies in order to make sense of this technological world properly.

We accept that digital humanists, computational social scientists, computational physical scientists, and digital artists may use the same software, sensors, and digital scholarship workflows in their disciplinary practices. Willard McCarty has called this the "methodological commons," a theoretical space shared by disciplines that adopt formalized computational processes to answer their scholarly questions. (*Humanities Computing* 114-57) Yet, (and McCarty's body of work addresses this), without common goals, the common ground is insufficient for developing a sustainable, creative, or interdisciplinary practice of critical inquiry around the contexts and consequences of developments in digital and computational technologies. When seen in this light, the analytical approach at Bowdoin also answers and expands upon a call by Tanya Clement from 2012 to determine a role beyond skills-based learning for digital humanities in higher education (372). The goal is not merely exposure to a given tool in the methodological commons, but the ability to identify and access the questions that can make the tool's use, refinement, and outcomes more accessible, ethical, and empowering.

Those social justice goals are informed and necessitated by the institutional mission of Bowdoin and draw deep inspiration from the work of Data & Society co-founder and scholar danah boyd. In a 2015 talk that remains a frequent touchstone of our current curriculum, boyd reminds the audience that these technologies are made by people and applied to or by people, with all of the positive and negative consequences of human behavior. ("What World Are We Building?") Given Bowdoin's commitment to climate studies, we also recognize that our objects of study are developed and deployed in physical environments, use natural and manmade resources, and capitalize on material properties of their component parts. As such, DCS is a transdisciplinary commitment that has benefitted from the contributions of faculty members, students, and staff from across the divisions of the College. Given the youth of the program, we have attempted to build access, inclusivity, and ethics into the structure of the curriculum in order to avoid challenges of representation and equality that many established programs now face. As such, we argue that DCS at Bowdoin is an intellectually responsible, sustainable approach to analysis and creative possibilities in the face of rapidly changing digital environments and computational practices.

After a short history of DCS at Bowdoin, we present the intellectual framework that drives the curriculum. We provide a story of the genesis of this epistemological model, an explanation of its core structure, and an example. The conclusion connects the framework to the liberal arts and aspirations for successful DCS students.

## The History of DCS at Bowdoin

In 2011 Bowdoin's President, Barry Mills, asked a group of faculty in Math and Computer Science to conceive of a new program at Bowdoin that would help make the College a leader in the rather vaguely defined area around the idea that computation was becoming increasingly important across most disciplines in the liberal arts and that this trend was likely to accelerate going forward. The faculty involved in that first meeting were asked to envision what a unifying program might look like. These faculty resisted the temptation to roll out a computational science or big data initiative, recognizing that the long-term success of the program would require general acceptance from the faculty at large. It was at this stage that Bowdoin's small size, about 200 tenure-line faculty, was an advantage. The initial group first invited faculty to a series of meetings to solicit ideas and concerns. Based on those meetings a first steering committee was formed, carefully chosen to include participants from across the College. Since then a diverse group of faculty, spanning a significant fraction of the College's departments and programs, have served on steering committees and working groups all designed to define and refine DCS' core mission.

The result is an initiative with a bidirectional goal: to integrate computation into other disciplines rather than merely trying to bolt it on, as is being done in many programs across the country, and to integrate those disciplines into a study of computation. Put another way, students that encounter DCS from other disciplines should be able to enhance the understanding of their major through the critical lens of DCS and vice versa. By establishing DCS as a meeting point for the Liberal Arts around questions of the place of technology in experience, expression, and environmental impact, Bowdoin's program differs from other academic models for Digital Humanities and the Digital Liberal Arts. Many schools received three-year Andrew K. Mellon grants to establish Digital Humanities programs, which created horizontal pathways across humanistic disciplines in courses that adopted computational tools, or created temporary postdoctoral fellow or new support staff positions to assist faculty and students with research or course projects. Staffing choices, coursework and research outcomes were largely driven by the applicability of the software to the course content. These efforts and the broader Digital Liberal Arts landscape represent the trend of integrating technology into the curriculum through its application rather than through a centralization and specialization in interrogation, critique, and developing habits of mind for the knowledgeable user.

DCS, therefore, operates in *two fundamental directions*. First, DCS builds on theoretical frameworks from a range of academic disciplines to promote critical reflections by students on how human beings and contemporary societies transform and are transformed by the different technologies. To do so, DCS proposes the development of a set of knowledge, critical apparatuses, and skills that will allow students to recognize deeper problems of the technological aspects stemming from an inside perspective of how the diverse technologies are created and structured in their varied digital and computational manifestations. Thus, as students learn more about computer programming languages, algorithmic thinking, artificial intelligence models, and the like, they create new perspectives and dispositions to perceive assumptions and consequences that remain opaque to simple users of technologies lacking such background.

Second, DCS, by exposing students to the creation of computational and technological artifacts, allows students to develop new ways of exploring the various areas of their intellectual formation through a collaboration between computational analysis tools and the conceptual interpretation of the different areas of knowledge. With this, the student will learn, for example, how the use of machine learning techniques can help research in other fields; opening up an extensive corpus of classical literature, government documents, or texts produced by various social media. In this second direction of its pedagogical movement, DCS empowers students to learn from digital artifacts and apply them in a contextual and integrated way to their diverse areas of knowledge.

The original multi-disciplinary steering committee was instrumental in shaping this bidirectional core DCS philosophy of use combined with critical engagement. For the first several years DCS was driven by a College-wide steering committee. Members came from a wide cross-section of departments. After the first iteration of the committee Eric Chown, a computer scientist, and Pamela Fletcher, an art historian, were made co-chairs and in turn co-taught the first DCS course in 2013. The shared perspective gained by that course, that engaging with technology should be a conversation between two sides seeking to understand each other through common intellectual ground, has shaped everything that has come since.

**The DCS Epistemological Framework**

Initially the critical apparatus of DCS was stated in terms of the three central questions that DCS courses and research should address with regard to digital artifacts: **why**, **how**, and **what**. Elaborating on these three questions would take several pages, but we will summarize them briefly.

The “why” teaches students to think critically and contextually about digital and computational tools. It also prepares students to imagine alternatives to current computational methods and assumptions in the context of clearly articulated intellectual, aesthetic and/or ethical goals. Notably it is the lack of asking “why” that has drawn so much criticism to Silicon

Valley. That same lack of asking “why” has led to the current discourse of screen addiction, aptly anticipated in the body of research by Sherry Turkle and outlined in Nicholas Carr’s *The Glass Cage*.

The “how” has to do with how the underlying methods of the digital and computational revolution. Students are taught “computational thinking,” not merely to program or do statistical analysis, rather how to solve problems generally with applications that stretch far beyond work with computers. Importantly, the “how” isn’t just about solving problems, it is at least equally essential to understanding the artifacts created by others.

The “what” has to do with the ways that digital artifacts are embedded in the world. Networks, for example, have become the fundamental means of communication in our world and have given individuals the power to scale communication to previously unseen levels. Only now are we, as a society, coming to grips with the implications of this change. In line with Catherine D’Ignazio and Lauren Klein’s *Data Feminisms* (2019), Tara McPherson’s scholarship, Safiya Noble’s *Algorithms of Oppression* (2018), and Zeynep Tufecki’s *Twitter and Tear Gas* (2017), the “what” question recognizes that digital artifacts like networks are not simply abstract entities defined by their efficiencies and scaling, but are instantiated in the world with many potential consequences.

As we began to think about how these questions would translate into an academic discipline we realized that what bound all of what we were doing together were digital artifacts and that these artifacts formed our area of inquiry.

Thus, we moved from a series of questions and topics to a series of scaffolded interpretative frameworks that were sufficiently abstracted to allow the topics to shift over time. “What” became **artifacts** and **architectures** (both moving targets with changing identities) that scale in terms of their creation, composition, expression, rhetoric, questions, and interactions. “Why” became the **agency** priorities of the liberal arts and sciences: history, culture, power, representation, aesthetics, ethics, assumptions. “How” became activities of **abstraction** such as computational thinking, statistical analysis, computation through programming, and modeling.

To accomplish the bidirectional movement that we articulated as a priority, DCS organizes its epistemological sphere around those four aspects of our interaction with the technological world that emerged from initial coursework and research: *artifacts, architecture, abstractions,* *and agency (DCS 4As)*. These four aspects provide a rich infrastructure so that complementary angles of digital and computational phenomena can be explored from the two directions that guide DCS.

By **artifacts** we understand anything that contains digital or computational components, for instance, personal computer, Facebook application, car with onboard computer, smartphone, Firefox browser, smartwatch, robot, Google search application. Each artifact engenders a set of questions regarding the problems it tries to solve; the values it fosters or inhibits; the historical, social and economic contexts of its creation and use.

In turn, these artifacts communicate among themselves and with society through **architectures** from which DCS proposes a critical analysis of their assumptions, premises, intentionalities, stakeholders, and consequences. Architectures, such as the internet, can create possibilities, in part by structuring and orchestrating how artifacts work in conjunction with each other, but these same architectures also impose limits and generate tangible implications for technological societies. Importantly, many objects of study in DCS can be understood as artifacts and as architectures.

The third aspect we want to explore about technologies are the **abstractions** underlying technological artifacts so that we can analyse the processes of creating new artifacts or new architectures. All artifacts and architectures are based on models and abstractions of certain functionalities or information. In order to understand the implications of abstraction, the scholar (or the students in the class) must discuss the real-word phenomena modeled by the technology and how these phenomena are impacted by the modeling choices and decisions behind a given technology. Understanding these abstractions also requires an exploration of data used by artifacts, how this data is collected, what it represents, and how it affects the outcome of the artifacts or architecture that use and transform it.

The fourth aspect, **agency**, recognizes that it is necessary to explore how artifacts and architectures impact users and entire societies, changing their capacities to act in, and impact the world. Understanding this requires looking at a number of questions, including who uses the artifact, and for what purposes? Who is unable to use the artifact and why? What is the relationship between the artifacts and the physical, emotional, social, civic, and economic aspects of the people who interact with them? What can people do with the artifact or with the product of its use based on its architecture? How are the impacts (in)consistent across populations?

The DCS 4As is therefore a proto epistemological model to analyze and criticize how technologies are impacting personal, social, and environmental contexts. The goal of the model is to provide a deeper understanding of how technologies affect our lives by exploring multiple angles of such technologies in a methodological yet flexible and creative-prone way. By focusing on contexts, multiple disciplines' priorities, and processes, we have designed a preliminary interpretative structure that is responsive to the rapidly moving target of digital and computational development. In turn, this proto-epistemological framework can perhaps be capacious enough to operate in the conditions of rapidly accelerating change in which we find ourselves.

## Looking at Whatsapp from the 4As Perspective

### *Artifact*

Whatsapp is a messaging application. It works mainly on smartphones and provides functionalities to exchange text, audio, and video messages. It also allows phone calls and video calls among its members.

It was developed as an alternative for the high costs of mobile services of short messages (SMS) in some countries. Its user base grew exponentially, and in 2019 it has more than 1.5 billion people in over 180 countries, according to the WhatsApp website.

One of the key features announced by Whatsapp is that it provides end-to-end encryption, which means that besides the sender and the receiver no one can read the data transferred. This functionality reduces Whatsapp's potential for doing targeted advertisements based on message content and should theoretically increase users' privacy.

In 2014 Facebook purchased WhatsApp for $19 billion. This acquisition made the fastest growing worldwide independent social network part of Facebook, which can now integrate data from both user bases, potentially negating the value of end-to-end encryption.

If we only study Whatsapp as an economic artifact, we miss the potential and significant change to privacy posed by the computational aspects of the app. Likewise, seeing the app's development as an historical event, rather than connected to a social and physical infrastructure, risks overlooking important global distinctions in mobile device access and use.

### *Architecture*

Two main physical architectures are supporting the Whatsapp artifact when considered in its typical implementation as a smartphone application. The first one is the wireless network that provides the primary communication channels among phones, the wireless cell towers, and other routing equipments. The second architecture is the internet itself that provides communication from the wireless infrastructure to internet servers that can store and route messages between users, store contacts and groups information, and be accessed directly from other web applications through internet browsers like Firefox, Chrome, and Safari.

Whatsapp uses an internet connection to transfer messages, so it relies on data connectivity of the internet architecture rather than SMS (short message service) that is part of the wireless architecture. It means that the bulk of the application functionalities lies outside the wireless operator infrastructure that is used only as the basic bearer of wireless data. It has important implications related to the debate on net neutrality, for instance. Understanding the implications of architectural aspects like this is a good example of the deeper analytical layers with their assumptions and consequences that DCS wants to investigate with the 4As framework.

Less obvious architectures include the social and cultural architectures that encourage and regulate the app's uses, as well as the economic conditions that facilitate or deny access and motivate the development and use of the app. Whatsapp's initial monetization model was based on subscriptions. Users from certain countries would pay $1 per year to have the app. In 2016, Facebook announced the app would be free of subscriptions, and the monetization strategy shifted to provide business accounts so that businesses and organizations would have a direct channel with their customers by paying a premium subscription.

Although the end-to-end encryption provides some level of privacy regarding the content of messages, it is essential to remember that all metadata as user names, locations from and to messages are sent, time and date in which messages are sent, and mainly the network of connections based on messages exchanges is not encrypted and it becomes an important asset for information extraction. It is particularly concerning if one considers scenarios in which users from Facebook and Whatsapp are cross-referenced so that data from both platforms can be mined in conjunction. This is another aspect of this technology that only surfaces through a deeper and nuanced investigation of the underlying architecture and how it affects the artifacts itself, and user's agency.

### *Abstraction*

Whatsapp creates a model for one-to-one and group conversations via text and voice messages that make real-world synchronous conversations, asynchronous. It also allows asynchronous communication via voice and video calls.

As the service is still free of charge, except for the data plans required for mobile devices, users can communicate much more frequently, including with long distance and international interlocutors. It seems to change the dynamics of video conference since it made it available to a broader public that would otherwise have financial and technological barriers to access this type of service.

On the other hand, due to its ubiquity in some countries, WhatsApp became another source of the digital divide as some services can only be accessed through WhatsApp. It is also unclear how long Whatsapp will be free of advertising and provide end-to-end encryption. Given the dependency level created by the application, it may impose changes that users will have to cope with at least for some time to keep their regular forms of communications and business running.

### *Agency*

The impact of Whatsapp on people's lives is enormous. According to a report by Facebook at its developers' conference in 2018, every day, WhatsApp users send approximately 65 billion messages, and more than 2 billion minutes of voice and video calls are made via the app. The numbers gives a sense of how this new technology impacts interpersonal communication. People rely on Whatsapp to keep their personal connections, participate in groups, organize events, and to establish new relationships.

On the positive side, it allows for new ways of communication bridging geographical gaps and opening the internet era for low-income users since some of the biggest Whatsapp markets are in countries under development such as India and Brazil. On the not so bright side, this new communication mechanism may decrease other forms of interpersonal contacts, enclosing its users in this digital communication bubble, and impacting in negative ways how social agents develop and enhance their real-world relationships and communication skills.

## Translating the 4As to a Curriculum

In our curriculum we strive to balance the critical against the creative. That is, on the one hand we believe that criticizing a computer program requires having some experience programming, and on the other that it is crucial to think about the context and consequences of one’s creations. We require all of our courses to focus on more than one “A” and most involve at least three. Thus, just because a course is “computational” does not mean that we would include it in our curriculum.

At the base of our curriculum are two introductory courses that aim to both introduce students to the four As and also to begin teaching them many of the skills, such as programming or network analysis, that are central to further study. Our intermediate courses focus either on deepening experience with a technique such as text analysis, or on unifying themes, such as ethics or cognition. At the advanced level students are expected to do projects related to their own interests. An advanced course could easily have a student do a large-scale text analysis project working alongside another who work involves extensive use of GIS, both of which engage with the questions of the 4As in order to develop a thorough critique and informed application of the tools. Alternatively, a project could focus on one of the As, with less emphasis on the application of a specific computational method. This culminates in a year-long senior capstone course where students are required to do a substantial project related to their coordinate major.

Finally, we would note that many interdisciplinary programs are built by collecting courses from around the curriculum. A DCS-like program could be built starting with introductory CS courses, a philosophy course on ethics, etc. It is our belief that such an approach is fundamentally flawed. To "do" DCS is not like using a swiss army knife where one chooses one skill at a time and deploys it in isolation. The power of a DCS-like approach is in blending and integration. To be able to seamlessly and fluidly cross boundaries requires experience and practice. This is why we require all of our courses to integrate multiple parts of our framework. Indeed courses like introductory CS are not counted as DCS courses.

The affordances of DCS mitigate, but do not claim to solve, challenges facing the Liberal Arts and Higher Education more generally. The 4As framework helps students to constantly acknowledge the scalable, global, and constantly versioned system of knowledge production, expression, and human behavior in which they exist. Since we accept that specific content will likely change, we have focused our pedagogy on practices and habits of mind that resist computational automation and provide agility, informed to a large extent by Cathy Davidson's work. (*Now You See It*, *The New Education*) The availability of content means that transfer of knowledge cannot be a direct goal of such a pedagogy, but rather training in methods for selection and validation. Moreover, the automation of skills-based tasks shifts pedagogical attention to knowledge application. Accordingly, DCS embraces multiple types of knowledge as part of the investigation of abstraction and agency: embodied, material, scientific, local, indigenous, social, archival, and experiential. Given the scalable nature of artifacts and architectures, and the complexities of global agency, the analytical questions related to the 4As emphasize inclusion and diversity with the recognition that one solution does not fit all. As a result, the program has an intellectual imperative, as well as an opportunity, given its youth, to avoid the challenges established curricula now face with histories of marginalization, colonialist legacies, and representation.

## Conclusion

This article is premised on our belief that what a student needs to learn in the 21st century has fundamentally changed. In turn, we have laid out an intellectual framework that aims to update what a liberal arts education should look like. As we noted in discussing our curriculum, the integrated thinking required by DCS requires practice. In active learning terms, students need to “do DCS” to really learn DCS. As we have noted, all of the courses in our curriculum aim to do this to one degree or another, but it is still a reasonable concern that, given the limitations of individual courses, students might not have sufficient time with individual topics to gain a deep understanding of how they fit together. We address this in our curriculum in a number of ways. At the highest level our courses are designed to let students go deeper, but in a method independent of any particular computational approach. E.g. in one of our upper level courses, “Computation in Context,” students are expected to do substantial projects related to their coordinate major, but the methods are up to the student. One student might do a text analysis project whereas another might do a mapping project. The course content provides scaffolding for answering the questions of the 4As and evaluating their impact on the use or design of a tool and evaluating the results of its use.

Ultimately we are arguing that knowledge can no longer always be broken down into disciplinary size chunks. Students need to take on projects that would not be possible, except under unusual circumstances, under the old liberal arts boundaries. These projects necessarily require a scope that is larger than a single class. Thus we require all majors to do a year-long senior capstone project. This capstone captures the essence of what we are trying to accomplish. Our curriculum is grounded in a belief in integration. For students to be able to analyze and understand they must also be able to do. And, while many of our courses are project-based, a year-long project enables students to immerse themselves in every aspect of a large-scale digital project from data collection and representation, to critical analysis and interpretation, to visualizing, contextualizing and explaining the final results. Even if a student ultimately becomes an expert in a single aspect of the process they will have gained experience with the whole range and thus will be better prepared to engage and collaborate with other experts. In this way, students master the foundational principles of DCS: the ways in which this technology is shaping the world and how critique can shape the use and creativity with that technology as it changes ever more rapidly.

**Terminology Appendix**

DCS 4As is a proto epistemological model to analyze and criticize how technologies are impacting personal, social, and environmental contexts. It is a method of analysis that comprises four main axes, the 4As.

The goal of the model is to provide a deeper understanding of how technologies affect our lives by exploring multiple angles of such technologies in a methodological yet flexible and creative-prone way.

Artifact - Anything that contains digital or computational components.

Architecture - Anything that mediates the use of artifacts, and the interaction among artifacts.

Abstraction - The process of creating new artifacts or new architecture.

Agency - How artifacts affect people's capacity to act in the world.

Artifact results - Any physical or digital product of artifacts.

Intentionality - Motivations and reasons for creating new artifacts and architectures through the abstraction process.

- Cultural Intentionality - Intentionalities related to expected impacts of artifacts and architectures on the creation and sharing of customs, expressions, arts, and institutions held in common by a population.

- Economic Intentionality - Intentionalities related to expected impacts of artifacts and architectures on the production and distribution of financial resources.

- Social Intentionality - Intentionalities related to expected impacts of artifacts and architectures in personal and social relationships.

Interdisciplinarity - The 4As approach brings to the forefront the interdisciplinary characteristics of DCS, and it demands a collaborative and multifaceted research effort to discuss technical questions related to artifacts and architecture, but also social, psychological, political, and economic (just to name a few) perspectives to explore premises, consequences, and contexts of agency and abstractions.

DCS 4As analysis - It is the description, analysis, and critique of a given technology using the DCS 4As model. Its starting point or object of study is either an artifact or an architecture.

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