Building a Distributed Virtual Laboratory Adjacent to Academia

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Abstract

A number of contemporary forces have conspired to drive highly-competent academics away from the academy. The vagaries of departmental hiring, institutional conservatism, and growth in the number of researchers versus available positions have displaced talent and innovation. Enter the alt-academic institution: small-scale institutions engaged in academic research in niche areas that are not viable at conventional institutions. I will introduce the reader to a specialized type of alt-academic institution by discussing their economics, organizational structure, and approach to collaboration/mentorship. Additionally, innovations such as infrastructural innovation, open access pipelines with version control, heterarchical organization, and a flexible contribution philosophy have made such institutions possible. The main subjects for this point of view article will be the OpenWorm Foundation (<http://openworm.org/>) and the Orthogonal Research and Education Laboratory (<https://orthogonal-research.weebly.com/>). Readers are also provided with an account of institutional challenges, from article/book access to encouraging collaborative participation. As recent financial crises and pandemics have made clear, we need robust alternative institutions to overcome challenges to the pure research enterprise. Distributed virtual alt-academic institutions can also serve to increase diversity and overall participation in the research enterprise. This has positive consequences for science literacy and discovery more generally.

Introduction

As a response to the challenges of doing academic scholarship and research over the past decade, a number of alternative (alt-) academic institutions [1] have emerged. The mission of alt-academic institutions has focused on niche activities in the scientific community. For example, the Pacific Science Institute [2] opened in 2014, and caters to the development of theory in an exotic locale. Alt-academic institutions have been further enabled by advances such as internet access and the proliferation of open data. In this article, we will focus on a certain type of institution: one that promotes distributed and virtual collaboration in the service of interdisciplinary science. Aside from enabling technologies, four infrastructural innovations make distributed virtual institutions attractive to a wide variety of potential adopters. These include infrastructural needs, open access pipelines with version control, heterarchical organization, and a flexible contribution philosophy.

While alt-academic institutions are relatively new endeavors, they are hardly poor imitations of the traditional academic variety. We can look to the Ronin Institute [3, 4] as an example of how the alt-academic model serves independent scholars by providing basic

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institutional support for researchers in the social sciences, natural sciences, and humanities. Ronin is particularly interesting because they have introduced a new working paradigm called *fractional scholarship* [3], which allows affiliates to pursue research at their own pace and provides work-life flexibility not afforded by traditional institutions. Yet these models of open scholarship and collaboration also require new and sustainable models of participation and economic viability.

The primary barrier to academic research outside of academic institutions is the mode of production. Until recently, the only sustainable models for pursuing an independent institution were industry-funded labs and think tanks. Yet with the rise of open-source software, new collaborator-centric models of production have emerged. Yochai Benkler has proposed such a model from the perspective of *peer production* [5], which involves achieving academic milestones such as papers, conferences, and workshops in terms of individual contributions. Peer production requires more than a culture of contribution and attribution, which already exists to some extent in academic contexts. It also requires both non-proprietary infrastructure and coordinated efforts resulting in flexible collaborative groups. The latter have value over traditional hierarchical collaborations, particularly when organized around new problems or emerging fields of inquiry [6].

Traditional institutions are also slow to respond in the face of societal challenges. By contrast, our type of institution can be more robust to events such as pandemics and economic downturns. In addition, technology has been moving us in this direction for a number of years, but pieces need to be put together. We have seen this type of change with respect to proposed changes to scientific conferences [7]. As the number and diversity of scientists has increased, so has the demand for flexibility of traditional modes of practice surrounding the research enterprise. In this article, I will assemble these pieces using examples from my own affiliations.

Distributed virtual alt-academic institutions might also mitigate participatory barriers to academic research. Over the past several decades, traditional barriers to academic research have fallen as broader access to credentials, open-sourcing of instrumentation, and open access to academic papers no longer limit scientific participation to only a few groups of elite individuals. Furthermore, the open and citizen science movements have demonstrated that people are willing to invest time and energy in scientific scholarship for purposes such as sustaining human knowledge and societal well-being. These trends and needs can be met by our type of institution, engaging the casual scientist as well as scientists who are displaced from traditional institutions due to economic austerity or a lack of fit.

Infrastructure

Our type of institution's infrastructure should share common traits: geographically agnostic, project management at minimal cost, and minimizing the challenges of making both

short-term and long-term investments. To accomplish this, the Orthogonal Lab is organized around a series of working groups. While these groups vary by topic, they typically revolve around enabling various approaches to core intellectual questions. DevoWorm [8, 9] brings together developmental biologists, computer scientists, and physicists at various career stages. By contrast, Representational Brains and Phenotypes is largely student-driven, and is a place where they can explore a common theme in various ways. To enable collaboration and project development, Open Access pipelines, version control documents, video conference, and messaging tools such as Slack are used to bring together many minds, all at relatively low cost to both the individual and the institution.

Encouragement of self-directed education and a broad cross-disciplinary perspective results in research-guided educational opportunities. These experiences are internal, external, and self-generated. Internal: collaborators engage in formal coursework through the institution, either in the form of hosted lectures, tutorials, or digital badges. External experience comes from collaborators attending webinars or short courses hosted by external institutions such as the Santa Fe Institute, Cold Spring Harbor Lab, and MetaCell. Self-generated experience is exemplified by collaborators learning as they seek knowledge, and so educational resources are designed with the understanding that casual contributors must rapidly get up to speed as to the intellectual landscape of their research problems.

One advantage of building an organization around working groups is the ability to build diverse teams with multiple areas of expertise. This results in an alternative to the traditional hierarchies that define the social structure of most research groups. Networks of shared responsibility and shifting contribution called *heterarchies* best define the type of structure we strive for in our working groups. Heterarchies define both project management [10] and the fostering of new ideas from birth to completion [11] in our type of organization. In terms of research culture, heterarchical organization has more fundamental consequences. It tends to break down the linkage common in the biomedical sciences between lab names and the possessive, for example “work done in the Smith Lab”. This cultural shift will have a consequence on authorship patterns as well. The Orthogonal Research Lab has advocated for the use of an authorship tree [12], which provides a new way to represent the complex relationships between academic production, influence, and substantive feedback.

We also embrace what Michael Nielsen [13] calls a *dynamic division of labor*. This can best be demonstrated by community data from another example of a distributed virtual alt-academic institution, the OpenWorm Foundation. A rank-order graph demonstrating one indicator of the contribution structure of the OpenWorm Foundation is shown in Figure 1. While much of the coding labor is done through Github commits, the number of messages posted to the organizational Slack team is a more inclusive indicator of all community activities. There are three general trends to note. Senior Contributors, or formal leaders in the community, contribute

the most messages overall. Casual contributors, with only a few contributions per person, make up the long-tail of the distribution presented in Figure 1. Major collaborators (people who run traditional physical labs) and board affiliates both exhibit high variability in their message contributions. Overall, while there is a diverse core of collaborators who do a lot of the work, casual contributors also provide a robust source of technical expertise.

Figure 1. Log-transformed rank-order graph of OpenWorm Foundation contributor message posting to the organizational Slack channel. A subgroup of 228 out of 346 Slack team members were used in this analysis (members who contributed at least one message to the team).

In terms of a flexible contribution philosophy, distributed virtual alt-academic institutions must make an investment in social media, supplementary education, and interdisciplinary modes of investigation). This makes research accessible to people from unconventional career paths, in addition to enabling a diversity of lifestyles. The dynamic division of labor model mentioned in the previous section relies upon microcontributions, which lowers the barrier to entry for a given collaborator. The question is how useful are microcontributions to academic pursuits and scientific projects more generally. Clues to this effectiveness come from the collaboration structure in the OpenWorm Foundation, which is a distributed, collaborative, and virtual group interested in building the first digital organism [14]. In this context, Coase’s Penguin (or in this case Worm) proves to maintain long-term collaborations and attract potential collaborators.

Yet one of the most important facets of making distributed collaborations work, namely the transformation of new collaborators into long-term leaders, remains elusive [but see 15 for potential strategies]. Therefore, a core participation pathway (Figure 2a) for our type of

institution must involve establishing oneself in the group and building upon this momentum. This can be viewed as something akin to an iterative design process [16], and is intended to retain contributors who would otherwise not be retained in the organization (Figure 2b).

Figure 2. Example of the open mentorship model. A: basic layout of the model, B: model layout including the iterative design process, Inset: highlight of what constitutes the redefined contribution, C: example of feedback between contributions and mentorship/learning opportunities.

As with the OpenWorm Foundation, Orthogonal Laboratory likewise encourages an open mentorship model in which there is no single path to collaborative success (Figure 2c). An early contribution based on a passing interest or casual interaction might result in a larger-scale contribution down the road. As such, this covers the shortcomings of academic environments with respect to participation of peoples typically underrepresented in conventional teams.

In Figure 2, this larger-scale contribution is coupled with mentorship and learning opportunities. The relationship between casual small-scale contributions and formal large-scale contributions is reinforced through peer feedback (revisions to previous contributions) or serial mentorship (successfully scaled-up collaborations bringing in new contributors). This encourages an intellectually and socially diverse team of contributors. The small-scale to large-scale contribution pathway is formally defined in Figure 2 as the redefined contribution. In this model, a small contribution is made initially, such as a blog post or a small literature review. This initial contribution can then be converted into a series of derivative outputs, or contribution x can be converted into a series of y s. Research derivatives (multiple y s) also provide valuable feedback in making the original contribution better.

Summary

Ultimately, the new and innovative types of institutional activities featured in this article requires even more momentous cultural shifts. This includes both financial and sociotechnical norms. One recommendation to funding agencies is to support a number of these institutions with a funding mechanism that combines a small business grant and a research center grant. A secondary recommendation for people who wish to start their own distributed virtual alt-academic institution is to reevaluate your standards for group membership, inter-dependencies between collaborators and projects, and how to progress towards specific goals [17]. These standards are undergoing great change, and will lead to new ways of thinking even for the most traditional of organizations.

Certain types of research that are well-suited to a distributed virtual alt-academic institution. Research involving relatively small investments in instrumentation such as data science is a particularly suitable area of investment. This includes the analysis of existing open datasets, as well as the creation of tertiary data sets (fusion of multiple secondary data sets). Integration and visualization of the existing literature is also needed, particularly in the form of review articles and knowledge maps [18].

A concern about the viability of distributed virtual alt-academic institutions is their sustainability over many years, particularly with respect to the natural turnover of research projects and personnel. One challenge for our type of institution involves library resources, particularly subscriptions to journals and the purchase of books. This is solved by drawing from the personal libraries collaborators, encouraging resource sharing and exploiting open access

resources such as Unpaywall [19] and Green Open Access [20] papers. For the long term, university libraries might offer special types of subscriptions to more specialized resources.

A more substantial challenge is to develop an educational mission without formal accreditation. As distributed virtual alt-academic institutions do not operate at the same level of student volume and degree of formality as accredited institutions, they can find a niche by appealing to underserved training needs of collaborators and students in the organizational community. This further contributes to community-building and getting participants up to speed on specialized topics. This has positive consequences for science literacy and discovery more generally.

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