Inculcating Institutional Infrastructure to Support International Collaboration

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Abstract

Prior literature on international collaboration has focused on the management and coordination between participating organizations. Research is lacking regarding how to improve academic institutions’ social, organizational, and technical infrastructures to support their members’ participation in international collaborations. We use two projects as case studies to exemplify how infrastructural components were developed in individual projects and identify the organizational practices that facilitated embedding these components into institutional infrastructures. Based on the findings, we developed a model to inculcate institutional infrastructures that support international collaboration. This model can help improve academic institutions’ understanding of how to better support their members’ participation in international collaboration.

1. Introduction

Advances in science and healthcare are increasingly reliant on international collaboration. In 2008, over one third of scientific publications resulted from international collaborations and enlisted authors from more than one country [27]. International partnerships allow researchers and educators to leverage talent and creativity distributed across different geographical areas, while also applying locally-based scientific and educational resources [27].

Prior literature on international collaboration has focused on the management of collaboration efforts and social coordination between different participating organizations (e.g., [1,7,14,15,16,19]) or within a virtual organization [8]. However, virtual organizations are not so virtual. Concrete local organizations – and the resources and services they provide – are crucial for efficient and productive collaborations [13]. Researchers have pointed out the importance of incorporating the support for collaborations in virtual organizations into infrastructures of individual institutions in order to achieve the sustainability of virtual organizations [17]. Despite its importance, research is still lacking regarding how participants in international collaborations are enabled or constrained by their home institutions, and how academic institutions should develop institutional infrastructure to support their members’ participation in collaborative projects.

In this paper, infrastructure is defined and conceptualized as consisting of interrelated infrastructural components—“technical, social and organizational arrangements” that enable an organization to function in certain ways [11] (p.380). Developing infrastructures involves generating governance and funding, developing and designing technologies, and managing organizational arrangements [24]. Moreover, infrastructures emerge and evolve over a long period of time. Infrastructures are developed on an “installed base” and are limited and strengthened by that base [26]. When researchers and educators from an academic institution participate in collaborative projects, they consciously and unconsciously develop an “installed base” by generating and preserving infrastructural components. For example, over the course of a project, participants may develop a new software tool and an organizational structure that supports the use of that tool. This tool and organizational arrangement can become part of an institutional infrastructure which will benefit future collaborations.

However, disruption in infrastructure development is often observed, which results from the reality that an individual project usually concentrates on efficient and...
effective practices that produce favorable outcomes for that particular project. Little attention and effort are directed to sustaining and integrating infrastructural components developed by individual projects for the benefit of future projects. In addition, academic institutions are loosely coupled [28]. That is, individual departments preserve their own identities and physical and administrative separateness, and connections between different departments tend to be limited, infrequent, and weak. This makes locating, connecting and embedding infrastructural components developed from various projects into institutional infrastructures more challenging.

In this paper, through the analytical framework of synergizing [3], we examine how institutions can inculcate infrastructures to support international collaborations, that is, how institutions sustain infrastructural components, embed them into existing infrastructures, and incrementally develop institutional infrastructures. We use the African Health Open Educational Resources (OER) Network (Network) and a collaborative platform (CP) developed by medical schools of a US and a Chinese university as case studies to exemplify the opportunities made possible and challenges inherent in inculcating an institutional infrastructure. We seek to answer the following research questions:

- What are the infrastructural components developed through individual international collaboration projects?
- How can we synthesize added values from each project and incrementally develop institutional infrastructures to support international collaboration?

After first answering the research questions, we propose a model of inculcating institutional infrastructure, which can help improve academic institutions’ understanding of how to better support their participation in international collaboration.

2. Literature review

2.1. Developing infrastructure

Adopting the analytical framework by Star and Ruhleder [26], many researchers explored how infrastructure is developed (e.g., 3,4,10,11,22). Infrastructure is not one single event, and thus infrastructure development involves ongoing processes [11]. Infrastructure is relational, and thus infrastructure development involves integrating heterogeneous social and technical relations such as “aligning the end-goals of multiple participants, motivating contribution in the face of competing reward structures and designing novel technologies that are usable and stable” [25] (p. 234).

Lee et al. [13] particularly theorized human infrastructure to magnify the social aspect of infrastructure development. Human infrastructure is defined as “the arrangements of organizations and actors that must be brought into alignment for work to be done” (p. 491). Infrastructure development involves complex interaction among a multitude of collaborative structures including teams, networks and place-based traditional organizations. Thus, for researchers of collaboration infrastructures, a focus on a single unit of analysis such as a cross-institutional collaborative team or a research network cannot reveal the whole picture of all the interweaving factors.

Ribes and Finholt [24] observed inherent tensions across the three scales of action in infrastructure development. These scales include enacting technology, organizing work, and institutionalizing. They also pointed out three concerns in infrastructure development, including motivating contribution, aligning end-goals, and designing for use. Nine tensions were identified at the intersection of the scales and concerns. For example, at the intersection of “motivating contribution” and “organizing work” is the tension of “development vs. maintenance,” which accounts for the challenge of developing technologies beyond a specific research system and incentivizing people to continuously maintain, support and upgrade these technologies. Other tensions include “project vs. facility,” “planned vs. emergent,” “inclusion vs. readiness,” “individual vs. community,” “research vs. production quality systems,” “communities vs. constituencies,” “research vs. development,” and “today’s requirement vs. tomorrow’s users” (p. 380).

While Ribes and Finholt [24] pointed out the concrete tensions in the process of infrastructure development resulting from the interaction of diverse social and technical entities across social contexts and temporal dimensions, Bietz et al. [3] developed the theoretical framework of “synergizing” to capture the daily activities of “creating and maintaining productive sociotechnical relationships” that “accumulate into infrastructural embeddedness” (p. 252). Synergizing is defined as a “strategic collaborative undertaking in pursuit of greater combined effects than individuals, groups, or organizations could effect on their own” (p. 252). It is “the work that developers of infrastructure do to build and maintain productive relationships among people, organizations, and technologies” (p. 245). Two key sub-processes of synergizing are aligning and leveraging. Aligning emphasizes coordinating relationships among people,
organizations, and technologies to make them productive and functional within a specific infrastructure. For example, agreements should be established regarding intellectual property of research findings when a collaboration involves different institutions with various policies. Leveraging means “using an existing relationship with a person, artifact, or organization to build or strengthen a productive relationship with another person, artifact, or organization” (p. 253). For example, a university in Africa may use an existing relationship with one university in the US in order to connect with key individuals from another university in the US. Thus, “leveraging” and “synergizing” are premised on people’s awareness of and the ability to align different relationships generated by individual projects. Prior research, however, directed little attention to how relationships developed by previous projects are sustained, leveraged, and ultimately integrated into the institutional infrastructure.

2.2 Sustaining infrastructure

Sustaining infrastructure entails maintaining productive alignments of multiple relationships to respond to changes in organizational arrangements, technologies, and user needs [4]. Adopting a relational view of infrastructure and using synthesizing as analytical lens, Bietz et al. [4] examined how developers of a cyberinfrastructure understand and respond to changes in order make the infrastructure continuously meet the needs of its users. They found that infrastructure development involves tight coupling of human and technological infrastructures, which determines that change in one area requires adjustments in another. Aligning infrastructural relationships includes readjusting existing relationships, cultivating new relationships, and terminating some unproductive relationships. Leveraging existing relationships helps alleviate the burden of aligning organizational, individual, and technological relations.

Randall et al. [22] further explored how the theory of synergizing works “on the ground.” Through examining the evolution of a cyberinfrastructure, they demonstrated that sustaining infrastructure entails leveraging existing relationships to enroll new participants and cultivating new relationships when developing and using infrastructures. Through identifying new users’ needs and negotiating the changes with infrastructures to meet the new users’ requirements, alignment of the new and old stakeholders is achieved.

Like previous studies on sustaining infrastructure, our research also adopted a relational view of infrastructure and used synergizing as our theoretical lens. However, previous studies focused on the adaptation and scaling up of infrastructures to meet the changing organizational, technological, and user needs. Our research concentrates on understanding how to sustain infrastructural components developed from individual projects, incrementally embed these components into existing infrastructure, and accomplish inculcation of institutional infrastructure.

3. Research sites, approach and methods

We studied two international collaboration projects, the African Health OER Network (Network) and a collaborative platform (CP) between medical schools of a US and a Chinese university.

The Network aims to create and promote OER by African academics to share knowledge, address curriculum gaps, and support health education communities. OER are open-access teaching and learning materials that are free, publicly available, and openly licensed to allow anyone to view, download, copy, translate, adapt, and redistribute the content [2].

The Network involves collaboration among University M (in the US), University K and University G (both in Ghana), University C and University W (both in South Africa), and an educational non-governmental organization (NGO). In each participating university, there are numerous players including faculty members, project managers, instructional designers, OER enablers, and technologists who fulfill a variety of roles to contribute to OER production [15].

During the Network project, from 2008 to 2012, we performed participant observation to understand how each institution supported their faculty and staff members’ participation in the Network and how individuals contributed to institutional infrastructure development while they worked on accomplishing goals for the Network project. The lead author was invited to join the project as a social scientist to study the sociotechnical factors leading to the success or failure of the Network. One author was the Principal Investigator of the Network project. Two authors were project managers from two African universities.

At the end of the Network project, we conducted 34 semi-structured interviews with key stakeholders including faculty members, technologists, communication officers, OER enablers and project managers. Each interview lasted for about an hour. Our questions focused on how participants felt that their local institutions supported their participation in the Network, the challenges encountered by them, and how their participation in the Network could be sustained after the project funding ended.
Another collaborative project we studied, the CP, is a collaborative platform between University M from US and University P from China. The CP supports various clinical research collaborations. We performed participant observation between 2010 and 2011. Two authors of this article were invited to join the project to study the collaboration dynamics within CP and to provide recommendations to the management teams to formulate strategies related to communication, project management, and coordination based on the research findings. Participant observation was complemented by observations of both virtual and collocated executive committee meetings and annual joint symposiums. Semi-structured interviews were carried out through the time when the two authors were involved in the project, and 32 interviews with principal investigators and researchers that averaged about 40 minutes were conducted in total. Participants were asked questions about the challenges in their collaborations, the success factors leading to their collaboration, and how their institutions supported their collaborations.

Participant observation enabled us to study threads of activity that affected the success of collaborative projects over years, to gain insights that were only discernible to project participants, and to develop contextual knowledge that helped us interpret interview data with confidence. A limitation of participant observation is its subjectivity, which may be biased by the researchers’ experiences and roles in the projects [12]. Observer bias was mitigated in this study by data source triangulation—the authors of this paper took different roles in the projects and were from different institutions [20].

Data in this study consisted of transcripts from the interviews, field notes and documents posted on various websites about the interview participants and the projects studied. We reviewed each interview transcript for accuracy and fidelity to the audio recordings. Completed transcripts and field notes were then imported into Dedoose software for qualitative analysis [9]. We first coded the data for content, and then analyzed the codes for emergent patterns, which were organized into conceptual and thematic categories [18]. While the focus of our analysis was inspired by theories of infrastructure development [3,5,26] and Weick’s [28] theory of the loosely coupled system, we also remained alert to emerging ideas. We particularly paid attention to social, organizational, and technical arrangements that supported individuals’ participation in international collaborations. This analysis generated a set of recurring themes that referred to infrastructural components and organizational practices to sustain and embed these components into an institutional infrastructure.

4. Findings

Adopting the analytical lens of synergizing, we identified a repertoire of infrastructural components developed by the projects studied. As shown in Table 1, these components include knowledge in individuals, joint efforts between organizational units, organizational practices to create synergy between projects, social capital, and tools and technical systems. We also explored how institutions created and maintained relations among people, organizations, and technologies to sustain infrastructural components and embed them into institutional infrastructures.

4.1. Knowledge in individuals

Participants in international collaborations learned about new resources, acquired new knowledge, and amassed new skills for dealing with a variety of challenging situations. For example, in the Network, project managers gradually learned to become the transactive memory conduits [23] in individual institutions--they located and integrated resources distributed across various individuals, departments, and institutions. For example, one faculty member at University C created educational materials using 3-D images. Some other members were interested in the technology but did not know how to use it. The project manager at University C identified and connected these two groups of participants so that they could learn from one another. Project managers in participating institutions in the Network also gradually learned about the strengths of each institution and identified opportunities for forming complementary collaboration among institutions.

Participants also honed their abilities to deal with unfamiliar situations and improved their cultural competencies. For example, a US participant in the Network mentioned that he learned that when discussing potential collaboration opportunities, the African partners tended to say “yes” to most proposals. However, there were indeed different types of “yes.” Some institutions were so resource constrained that they would say “yes” in order to eventually obtain the resource they needed, regardless of the immediate project’s programmatic aims. The US participants learned that it was necessary to put themselves in their African partners’ shoes and over time understood their real needs.

It can be seen that individuals acquired skills, experience, and knowledge while participating in different projects. However, these skills, experience, and knowledge can be easily lost with staff turnover if they are not integrated into institutional infrastructure.
What we observed from the Network and CP projects also echoed findings from previous studies that participants in individual projects tend to focus on specific project goals and often lack incentives and capability to document and reflect on their experiences [6]. This demonstrated a challenge in infrastructure development—“transcontextual syndrome” [26]. That is, while participants in the Network and CP projects direct their attention to the requirements within the project context, institutional infrastructure development requires the vision and capability to contribute in the institutional context.

Collaboration between communication officers and project participants also enabled the knowledge and experience that individuals gained from participating in the Network project to be recorded in the institutional websites and to be accessed and used by people who are interested in learning about international collaborations. For example, an OER technologist from University C shared in one blog entry about collecting data using Google Analytics (http://oldblogs.uct.ac.za/blog/education-development-unit-fhs/oer); and a blog entry of University M talked about how Network participants explored Raspberry Pi as a model to share digital learning materials “at institutions with no or limited bandwidth, no or limited electricity, and limited on-site support for technology” (http://openumich.com/).

The Network also adopted open practices to share documents and publications, which made knowledge accumulated through the project more discoverable, reusable, and redistributable. For example, the Network administered regular internal and external evaluations during the project. All of the evaluations, which documented the lessons learned from the project at different stages, were Creative Commons licensed so that all the participants and people who were interested in learning about international collaboration experiences could access, disseminate, reuse, and remix the materials. A central service department on open publishing from University M assisted all Network participants in publishing their materials openly if they wished.

It is also important to connect people who possess knowledge and those who need to access and use it in the process of embedding individual knowledge into an institutional infrastructure. The CP project established an informatics core that brought together faculty and staff members in informatics at both participating universities to support various clinical research projects. This arrangement enabled the informatics core members to leverage knowledge, skills, and experience they learned from one project to other projects. For example, the core members first worked on customizing a clinical research data management system, Open Clinica, for a research group targeting Hepatitis C. The informatics core members reported that during the process they accumulated experience in

### Table 1 Infrastructural components and organizational practices to inculcate institutional infrastructure

<table>
<thead>
<tr>
<th>Infrastructural components</th>
<th>Organizational practices to inculcate institutional infrastructure</th>
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<tbody>
<tr>
<td>Knowledge in individuals</td>
<td>Providing venues to externalize individual knowledge and make it shareable and accessible (e.g., databases, blogs, newsletters, publications, etc.)&lt;br&gt;A adopting open practices to make knowledge more discoverable, reusable and redistributable&lt;br&gt;Connecting individuals who possess knowledge and who need to access and use it</td>
</tr>
<tr>
<td>Joint efforts between organizational units</td>
<td>University K routinizing collaboration between OER and Communication and Design Department&lt;br&gt;CP ensuring mutual benefits for the bioinformatics core and researchers to sustain joint efforts</td>
</tr>
<tr>
<td>Practices to create synergy between projects</td>
<td>Facilitating sharing of grant and project information to identify opportunities for synergizing resources</td>
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<tr>
<td>Social capital</td>
<td>Aiding the development of social networks through information sharing (e.g., overlapping participants and visit calendars of different projects)</td>
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<tr>
<td>Tools and technical systems</td>
<td>Aligning tools and technical systems with existing technical infrastructures</td>
</tr>
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The synergizing lens allow us to understand how participating institutions in the Network and CP aligned relationships across project and institution contexts and enabled inculcation of institutional infrastructures. In the Network, communication officers from University M’s central service department collaborated with the project participants to write and archive newsletters and social media content about the project. Participants in the Network reported that communication officers’ assistance relieved their workload. They reflected that they would not have written some of the blog entries without the help of the communication officers.
developing a multi-lingual research data management system for international collaboration. They learned using database design to assist data quality control, for example, setting up ranges for data entry for specified variable parameters. They also gained understanding of clinical researchers’ requirements for designing survey questions taking into consideration cross-cultural issues. As the CP funded the informatics core to serve different clinical research projects, the informatics core later was able to apply what they learned from the group targeting Hepatitis C to other projects that focused on lung and cardiovascular diseases. Without the investment in the core and the CP platform, each cross-institutional clinical study would not have built on the knowledge and tools of previous studies, and the informatics core members would have limited opportunities to apply what they learned from one project to another.

4.2. Joint efforts between organizational units to support international collaboration

Another infrastructural component relates to joint efforts between organizational units within an institution to support an international collaboration project. In a loosely coupled academic institution, where departments are less interdependent and projects are funded by term-constrained grants, these inter-unit support efforts tend to be provisional and end when the projects are completed. Viewing with the lens of synergizing, we understand the importance of maintaining these inter-unit collaborative efforts and integrating them into an institutional infrastructure. Both the Network and CP have demonstrated that institutions should carefully plan organizational arrangements to sustain the joint efforts developed by individual projects.

In the Network, the OER management team at University K from Africa found that most health science instructors who worked on OER production were not familiar with using technologies, and thus required consistent and continuous support. At the same time, students from University K’s Department of Communication Design needed projects in which they could apply the design skills they were learning in the classroom. Thus, the Network project management team worked with the Department of Communication Design to set up a process to enable and sustain their joint efforts. This process included providing training for both faculty and students in the Department of Communication Design in areas such as instructional design, open publishing, and intellectual property and assigning the students to work with health science faculty members on OER production. By building this inter-unit collaboration in a sustainable way that met the ongoing interests of both parties in University K, the health science faculty members working on OER production could obtain continuous technical assistance and support even after the external grant was completed.

The CP endeavored to sustain collaboration between the informatics core and the clinical research teams by promoting mutual benefits of the parties involved. When establishing the informatics core, researchers and staff members who agreed to serve in the core emphasized that they were motivated to participate because they perceived that supporting the CP could lead to their own innovative research. The informatics core members have since regularly identified research opportunities. For example, they published papers on designing a multi-lingual clinical management system. They also researched using technologies to collect diet data that accommodate cultural differences between the US and China. As the Chinese dishes tended to mix a small amount of meat and vegetables, it was extremely difficult for Chinese patients to reflect and quantify in a survey response how much of each kind of food they consumed for a meal. The informatics core has been working on an image recognition system using dish images to assess the amount of food intake.

4.3. Organizational practices to create synergy between projects

International collaborations, which have high demands in terms of travel and communication expenses, consequently generate high resource needs. Synergizing resources—that is, identifying, coordinating, and consolidating different funding resources on a project—enables project participants to overcome barriers caused by limited resources and to increase project sustainability.

For example, in the Network, University C received multiple grants related to open access, all with different focuses—one grant focused on open content, one on health sciences OER and one on OER technologies—and all at different times. All the grants were managed by an educational technology department and an office responsible for and promoting the opening up of scholarship. In this way, stakeholders could concentrate on the efforts of people who shared similar interests and made long-term plans to ensure the sustainability of open initiatives across the portfolio of projects.

At University M, when the Network was underway, another granted project supporting collaboration between University M and Ghanaian government
agencies, academic institutions, and non-profit organizations started (hereafter called MG in this paper). Perceiving the common goals, the respective principal investigators set up plans to create synergy between these two projects, with approval of the sponsors. The Network could use MG funds to purchase and ship equipment for OER production to Ghanaian institutions; participants in MG could learn from those participating in the Network, leveraging and building on lessons learned about technical and organizational arrangements leading to successful collaboration.

In loosely coupled academic institutions, the major challenge of synergizing resources from different projects lies in that people working on different projects may not be aware of which projects share similar goals. Thus, it is important to set up organizational processes that allow people to be alerted about funded projects that may be of interest to them. For example, at University K, a project manager was strategically assigned to multiple international collaboration projects, including the Network, which enabled her to identify opportunities to synergize resources from various projects. In this way, practices to create synergy between projects became part of the supporting infrastructure for international collaboration at University K.

4.4. Social Capital

Putnam [21] defined social capital as “connections among individuals—social networks and the norms of reciprocity and trustworthiness that arise from them” (p. 19). When participating in international collaboration, individuals develop their social networks with collaborators from other institutions and thereby accumulate social capital. For example, as a result of the involvement of so many units and people with diverse expertise in the Network at Universities K and M, the relationship between these universities, which was initially limited to the medical schools, later expanded to several other units across the universities. International collaboration, however, also imposes challenges for developing relationships as there may be fewer opportunities for participants to engage in face-to-face interactions and fewer chances for online communications due to both geographical and time zone differences. Retaining the social capital developed in individual projects and turning it into part of the institutional infrastructure is thus crucial.

Viewing through the lens of synergizing, developing and sustaining social capital involves the process of enabling participants in international collaborations to create and maintain relationships within and across projects, as the existing relationships can be leveraged to create new relationships in future projects. Leaders and participants in both the Network and CP strategically created opportunities to establish and maintain relationships. Leaders of both projects learned that several of their participants were simultaneously engaged in other formal and informal collaborations with the Network and CP participating institutions. It was thus helpful to share information about site visits and social events with a broad number of stakeholders. In this way, when a participant traveled for one project, his or her collaborators on other projects might find opportunities to meet with that participant on the same trip, thereby increasing travel efficiency and creating more opportunities for project participants to interact with each other. During the Network project, the project manager at University M tracked information about the visitors to University M from the four African universities involved, even when they visited University M for other projects. When she knew about the travel schedules of the African visitors, she would schedule meetings and social gatherings for participants from University M and the African universities. The CP website also listed all the participants who were visiting other institutions.

When we wrote this paper, University M’s medical school was planning a shared calendar with information about site visits for all international collaboration projects that the medical school members are involved in. Participants in the Network also recorded the previous relations developed in individual projects so that social capital accumulated previously could be potentially leveraged in other ventures. For example, University C created a database of faculty and staff members who were involved in international collaboration and listed all their collaborators and their roles in each project.

4.5 Tools and technical systems

International collaboration relies heavily on information technology for interpersonal communication, project coordination, and information and data sharing. Individual projects not only employ the existing technical infrastructure, but may also develop new technologies that can become part of an evolving institutional infrastructure.

Synergizing theory allows us to see the importance of “coupling human and technical infrastructure” [4] (p. 908) in order to sustain tools and technical systems developed by individual projects. When the newly developed tools and systems are aligned with the existing infrastructure, it is easier for institutions to provide consistent support for the use of these technologies and embed them into an institutional infrastructure. In the Network, a technical team at
University M partnered with a third party vendor to develop a Drupal-based publishing platform, known as OERbit, for sharing learning resources with the world. Drupal was selected because it had had an active online support community and an active community of practitioners across University M. Consequently, University M had an adequate amount of technical support for OERbit, resulting in its campus-wide adoption. However, OERbit was not as widely adopted by all Network participating institutions, even though OERbit was released as open source software and intended for use by all the participants. Some of the universities within the Network lacked resources for the technical support necessary for troubleshooting the platform and assisting user interactions.

In the CP project, the shift of support for OpenClinica from the informatics core to a central institutional service department of University M demonstrated how a system developed by and for an individual project can be integrated into institutional infrastructure through aligning relationships across different organizational contexts. At the beginning of the CP project, when intensive work was needed to customize OpenClinica, frequent communication between informatics support and research teams was required so that system customization could reflect researchers’ needs in a timely fashion. At this stage, it was challenging for a central institutional service department to provide support for the CP project because of staffing constraints and a lack of bilingual skills, but the informatics core of the CP project could meet the need because of the team’s agility. After the customization of OpenClinica was completed, only occasional support for troubleshooting was required. The support for OpenClinica was then handed off to a University M central service department. Meanwhile, the customized OpenClinica became part of University M’s institutional technical infrastructure and started to serve a wider community of clinical researchers at University M.

5. Conclusion and discussion

In this paper, we first identified infrastructural components developed by two international collaboration projects. Adopting the analytical framework of synergizing, we then examined organizational practices to inculcate institutional infrastructure—to align social, organizational, and technical relationships to sustain infrastructural components and embed them into an institutional infrastructure that is usable by future projects. Based on the findings, we developed a model to summarize the processes involved in inculcating institutional infrastructure as shown in Figure 1. This study bridges the gap in the literature on “how to support virtual organizations that have components of traditional organizations.” [25] (p.241).

While previous studies focused on aligning relationships to enable infrastructures within virtual organizations, our study directed attention to developing and sustaining infrastructures within local institutions. We found that one of the major challenges in inculcating institutional infrastructure results from “transcontextual syndrome” [26]. That is, participants in international collaborations focus on the goals and activities within the context of individual projects. However, to integrate their work into an institutional infrastructure requires the vision and capability to contribute in the context of an institution. Aligning social, technical, and organizational relationships across individual projects and different organizational units within an institution enabled the institution to sustain the infrastructural components developed by the projects and embed them into their institutional infrastructures. For example, with the assistance of communication officers of participating institutions, participants in the Network could record and share what they learned from the project through social media; with the funding and the arrangement of a cross-institutional platform of the CP, the informatics core could apply what they learned from one clinical research project to others.

Our research findings echoed Bietz et al.’s [4] finding about the importance of coupling human and technical infrastructures for developing and sustaining infrastructure. However, our research provided a more nuanced understanding of the sociotechnical processes underlying the interaction between human and technical infrastructures within an institution and between local and virtual organizations. Different organization units, which constitute part of a human infrastructure, demonstrate their unique strengths and provide support for technical infrastructure in various ways at different stages of infrastructure development.
Thus, inculcating institutional infrastructure requires an understanding of the strengths and weaknesses of different forms and parts of human infrastructure, and continuously aligning social, organizational, and technical relationships accordingly. For example, at the beginning of the CP project, the informatics core provided the researchers with agile support for a clinical research data management system. After the system became stabilized and after it became part of the institutional technical infrastructure, the support was handed off to a central service department of University M because the need for support became less frequent and long-term support was required.

Our study also revealed the importance of broad information sharing in inculcating institutional infrastructure, which was not discussed in previous literature on infrastructure development and sustainment. Information sharing is a prerequisite for aligning relationships to sustain and embed infrastructural components into an institutional infrastructure, especially in a loosely coupled academic institution, where connections between different departments tend to be limited. In the projects studied, sharing information about funded projects in a structured way allowed people to identify opportunities to synergize resources between projects; sharing information about previous collaborations and current campus visit by collaborators during a project allowed institutional members to leverage the existing social capital and make full use of opportunities to develop and retain social networks among project participants.

Information sharing is, in turn, supported and sustained by aligning relationships across projects and organizational units. In the projects studied, collaboration between communication officers and project participants enabled information sharing about individual projects. A campus visit calendar maintained by a central service department could inform people about opportunities to enhance relationships with previous collaborators or to develop relationships with potential collaborators.

Our study demonstrates that there are many opportunities to sustain infrastructural components developed by individual projects and embed them into an institutional infrastructure. We hope the model we developed on inculcating institutional infrastructure will serve as a template for academic institutions that are interested in providing systematic institutional support for international collaboration.

As with many studies on infrastructure, an inherent limitation of our research lies in what Ribes and Lee [25] called “historical myopia.” That is, while the units of analysis of our research is on projects and institutional support for these projects, the functioning and influence of institutional infrastructure can only be observed and evaluated over a time frame that is much longer than the term of a project. In the future, we intend further examination of other international collaboration projects supported by the involved institutions and validate findings from the current study—to understand whether the infrastructural components are sustained in the institutional infrastructure over years and whether they continue supporting international collaboration projects. In future research, we will also compare how the process of inculcating institutional infrastructure differs between well-resourced and less-resourced institutions. This comparison will enable us to further identify institutional factors that impact infrastructure development.

6. Acknowledgment

This paper is based in part upon work supported by the William and Flora Hewlett Foundation under Grant Number 2009-4796 and National Science Foundation under Grant Number 1025618.

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