PERSPECTIVES ON THE ADOPTION OF RESEARCH AND EDUCATION NETWORK TECHNOLOGIES: A Q METHODOLOGICAL STUDY

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ABSTRACT

The critical need for access to network technology resources supporting advanced tools of academics and research is evident across disciplines and locations around the world. As research conducted by and in partnership with higher education institutions continues to increase in demand, it is incumbent on institutions to ensure the resources for this work are available as standard features for their faculty and students.

The purpose of this study was to identify opinions of end users on the challenges to adoption of research and education (R&E) network resources at their local higher education institutions. The intent is to inform the R&E community about these challenges and to consider them when planning for the life cycle of network design and deployment.

Study participants represented Information Technology (IT) leadership at 23 higher education institutions located within a regional R&E network consortium. Q methodology was applied to an established technology adoption model, the Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh, Morris, G. Davis, F. Davis, 2003) and informed by Rogers' (2003) theory on the diffusion of innovations. The UTAUT model was modified to address attitudes toward technology resources enabled through access to R&E networks.

Statistical analysis of the Q-sort data and examination of additional qualitative data were completed on data collected in this study. The combined methods served to identify factors based on the most prominent characteristics of each group and interpreted in alignment to the study framework.

Results demonstrated the diversity of institutions and locations represented. Salient viewpoints expressed by respondents implied themes related to the value of a collegial

environment within which to develop and deploy new projects, the critical need for institutional capacity and support, and the challenges of accessing and use of network resources.

Theory can benefit from these results as a resource for exploring further modification of the initial UTAUT model to include technologies and audiences not previously included. Practitioners will benefit through reference to the findings when planning for the human and technological infrastructure capacity needed to support research and academic at their institutions.

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DEDICATION

To Christian, Mary and Steven, who revere and strive passionately for the richness in life that comes with the continued journey of learning. I dedicate this work to you.

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CHAPTER 1. INTRODUCTION

This study was designed to identify salient and compelling opinions of end users on the challenges to adoption of research and education (R&E) network resources at their local higher education institutions. Study participants represented Information Technology (IT) leadership at higher education institutions across the footprint of the Northern Tier Network Consortium (NTNC), a regional network that connects to the larger national U.S. R&E network infrastructure. To achieve this goal, Q methodology was applied to an established technology adoption model, the Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh, Morris, G. Davis, F. Davis, 2003). For purposes of this study, the UTAUT model was modified to specifically address attitudes and opinions toward technology tools and applications enabled through access to R&E networks.

A regional R&E network, the NTNC serves local institutions by connecting them to the U.S. Internet2 backbone, the nation's largest and fastest coast to coast R&E network built to deliver advanced, customized services dedicated specifically for research and education purposes. Internet2 is established, operated, and governed by the nation's leading research universities and is dedicated to advancing the adoption and use of a collaborative environment that enables development of innovative solutions supporting their educational, research and community service missions. As part of this larger community, the NTNC membership footprint spans across states in the Upper Great Plains and Pacific Northwest, from Michigan to Washington and including Alaska.

Figure 1.1

Geographical map of the Northern Tier Network Consortium as of 2017 (excluding Alaska).

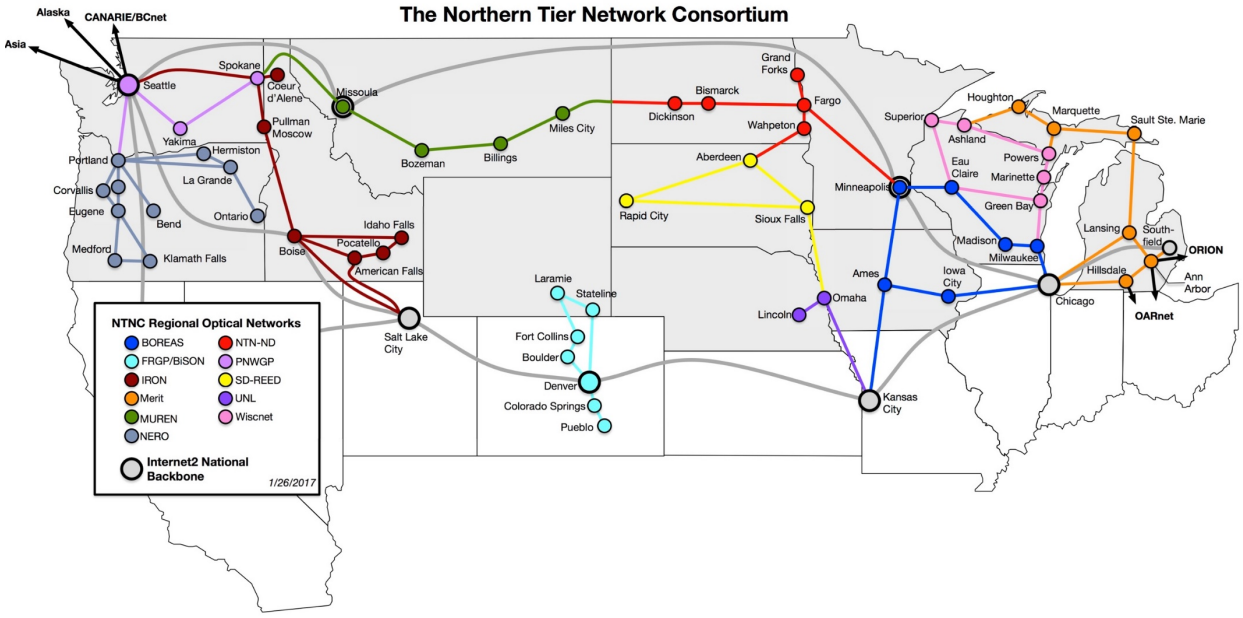
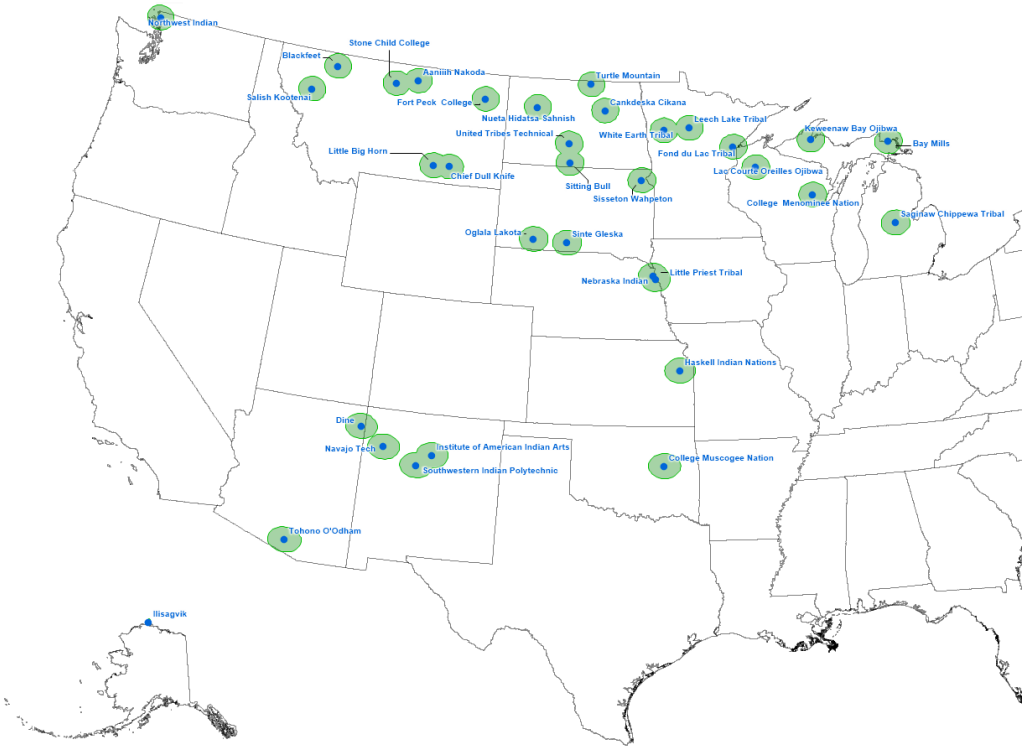


Figure 1.2

Tribal Colleges and Universities in the U.S. (AIHEC, 2018).



An inspection of Figures 1.1 and 1.2 shows the significant geographical overlap of Tribal Colleges and Universities (TCUs) on the map of the NTNC footprint. Because the NTNC member states are home to approximately 75% of the accredited TCUs in the United States, it is important for this study to include TCUs as key representatives of higher education in our rural and remote areas of the country. It is not a focus or the intent of this study to compare adoption rates of R&E resources across cultures.

Statement of the Problem

The critical need for access to resources supporting advanced tools of academics and research is evident across academic disciplines and in locations around the world. The foundational processes supporting teaching and learning in classrooms, as well as the research laboratory, look much different than they did just decades ago. The expanding ability to digitize most every process and product of contemporary life has impacted expectations for how students learn and how research is conducted. The tangible walls of classrooms and laboratories have melted away as access to digitized repositories of every data set, image repository and remote operation of advanced research hardware becomes normalized. Digital communication affords students and researchers the ability to partner and collaborate with peers in real time regardless of their location across a country or the world. For as much as the feel of a hardbound book pulled from stacks in a library emotes strong sentiments by so many, the speed at which global knowledge continues to advance demands equal capacity by research to disseminate findings relevant to solutions for today's critical issues. The time required for discovery and innovations to hit the bookshelves in the form of an edited, printed hard copy book that must be searched, found, and checked out is rarely a practical option in contemporary life and society. Our global society increasingly demands real time solutions to the most challenging issues, and those

demands translate into a requirement for almost immediate transparency of research methodologies and results. The skill set needed to support this environment will not develop on its own. Today's students cannot hope to enter a workforce embedded in digital knowledge and processes unless they themselves are raised to live and work in that environment. The educational systems through which today's students proceed must be equipped to train a future workforce that embodies these skills. As research conducted by and in partnership with higher education institutions continues to increase in demand across the globe, it is incumbent on an institution to ensure the resources and support for this work is in place as a standard feature for all faculty, students and activities engaging in public/private partnerships.

Cost savings are no less of a concern in the field of technology networks. While R&E networks are able to provide segregated and secure networks to foster networking and application research that enables the timely mobility of very large point to point data transfers securely and reliably, they also serve to relieve pressure on institutional commodity internet resources through such features and Netflix and Akamai caching. This practice offsets commercial internet traffic draws resulting in overall cost savings on internet use. Networks supported by the R&E community are part of multi-state regional partnerships that provide shared network services across user communities as well as diverse options for backup and connectivity. Perhaps one of the singular and most important characteristics of the R&E network infrastructure is that its business model is built on member-driven collaboration, as opposed to a vendor/customer relationship, thus strengthening the return on value to the member for dollars spent on resources of highest value to the collective partnership (The Quilt, 2017).

The benefits of a tech immersive environment and how it supports transformative applications are pervasive across contemporary culture, and no less so for teaching and research.

Universal access applies to more than just a fiber optic network. It also describes the doors that open to a learning and research environment that is without walls and without barriers, enabling every participant with the same access to global knowledge and opportunities as their peers in the next county or country.

Contemporary research is conducted globally, through remote access to scientific tools and data repositories enabled by collaboration among colleagues regardless of their location. Exemplary uses abound, frequently functioning and perceived as a standard resource, expected as a basic tool with access available when and as needed. Advanced technological tools required by contemporary research across disciplines may not always be available at each institution. Leveraging the capacity of R&E networks for remote uses such as simulations, visualizations, and data mining enables researchers to complete their work at their own institution and also allows them to virtually collaborate with colleagues around the world.

One very relevant example, the Wiley Publishing Company, a global company specializing in academic publishing for more than 200 years has recently launched its Digital Archives project (Wiley, 2017) with a goal to make primary source content available for use in everyday research, and also restore and preserve it for generations to come. Foundational to this project is the work to conserve and restore physical documents, scan high-resolution images, perform Optical Character Recognition (OCR) on printed works, add searchable terms to handwritten content, and enhance or create new metadata, cataloging records and subject indexing to ensure the highest level of discoverability. The results will be to make this historical global content available for use in everyday research and restore and preserve it for generations to come. A more detailed description is provided by Kubelka (2017), where further discussion describing this resource allows us to see science through a humanistic lens:

> In order to effectively understand and respond to the current challenges we face as a modern society, it is critical that researchers have access to the holistic scholarly record—one that goes beyond an article or its conclusions—encouraging deeper understanding or even reinterpretation of findings through the lens of historical context. Only by placing the sciences within history and cultures can researchers truly understand the interdisciplinary nature of the subjects they strive to advance, ultimately yielding positive research and educational outcomes. (Kubelka, 2017, p. 2)

A second exemplary use case is evidenced by the quiet but industrious United States Geological Survey Earth Resources Observation and Science (EROS) research center located just outside of Sioux Falls, South Dakota which annually provides illustrative examples of increasing demands for data worldwide. Each year, EROS ingests and distributes data sets to global audiences at progressively higher volumes. The NTNC provides significant network capacity in support of the ongoing data and research collaborations between EROS, national laboratories, weather data stations and higher education around the world.

Across the span of 2018, EROS ingested and distributed more than 17 petabytes (PB) of data to end users, with 5.5 PB of that traffic being transported on the NTNC circuit. EROS campus network supports 40G interfaces and routers that enable 20G transport capacity between EROS and a network interchange point in Chicago. As both a primary and backup circuit to EROS data traffic, the NTNC and the national R&E backbone is integral to the functions of the critical work and research conducted at this federal facility (USGS, 2018).

For the region of the United States that encompasses the Upper Great Plains, Pacific Northwest and Alaska, access to and responsibility for the connection to these national and global R&E resources is achieved through a partnership among higher education institutions that

govern self-funded and state-owned network segments collectively referred to as the Northern Tier Network Consortium (NTNC). While the primary results of this study will highlight the challenges to adoption of R&E network resources specific to the NTNC region, it is also hoped that the outcomes will serve to inform and potentially provide a framework for future planning suitable for use by other R&E networks in the U.S.

As regionally based organizations, R&E networks are located geographically closer to the institutional communities and populations they serve, and because of that proximity are better positioned to understand the specific needs of the academic and research drivers in their region. Proffered by Monaco et al. (2016) in a report to the National Science Foundation, regional R&E networks have the ability to foster and enable collaborations at a number of levels, across institutional, disciplinary, state, and regional boundaries. By nature, a collaborative partnership also affords member institutions economies of scale when it comes to contracts for network leases, equipment, and licensing. In addition, the research community benefits from the significant value that results from the collective technical knowledge base and skill set garnered through these partnerships.

Now, with the view of the successes of early efforts to deploy and expand R&E network access in the rear-view mirror, the work is not yet complete. Parallel to the challenge of overcoming rural broadband access, efforts must continue to provide access to the full community regardless of location or population where institutions are located. Too many areas across the country still experience delayed adoption rates. This deprives the local population of the tools and resources needed to support contemporary academics and research, potentially sacrificing contributions to national and global efforts aimed at expanding a workforce with the knowledge base and skills necessary to support this work.

Challenges to adoption identified by the R&E network community exist on several fronts, emerging both through formalized case studies and informal anecdotal experiences provided by community members. A summary of key themes for these challenges identified by the researcher and based on more than two decades of work in this field include stakeholder awareness, perceived adequacy of service and access for the end user, perceived accessibility to the resources, and adequacy of IT support for these services. Similar themes surfaced as findings in a widely recognized technology adoption model, the Unified Theory of Acceptance and Use of Technology (UTAUT). Four constructs were identified in the UTAUT study that were determined to play a significant role as direct determinants of user acceptance and usage behavior. These constructs include performance expectancy, effort expectancy, social influence and facilitating conditions. For purposes of this study, challenges identified by the R&E network user community were aligned with those found in the UTAUT study that play significant roles as direct determinants of user acceptance and usage behavior. These were used to develop a framework that serves as the basis for a broadly representative Q-set reflecting contemporary challenges specific to R&E network resource adoption.

An initial alignment of the two groups of determinants and challenges are indicated in Table 1.1. The items are identified based on emergent common themes identified by R&Es in the U.S. at the time of this study. They are further confirmed through findings identified as limitations to the current configuration of advanced cyberinfrastructure resources (Monaco et al., 2016).

Purpose of the Study

This research study applied the use of Q methodology to a modified UTAUT technology adoption model in order to identify opinions of end users regarding challenges to the adoption of R&E network resources for teaching and research at their local institutions.

Research Questions

The study was guided by a focus on the following research questions:

- What are salient challenges to adoption of Research & Education network resources experienced by higher education institutions across the Northern Tier Network Consortium?
- How can knowledge of these challenges serve to inform those who advocate for the use and expansion of these resources, both in the NTNC and peer networks across the U.S.?

Theoretical Framework

Several models related to innovation adoption and acceptance have been developed since the early twentieth century. The origin of contemporary innovation diffusion research is credited to a notable study on adoption of farming innovations initiated in the 1930s. Efforts through the decades have been made to refine and extend the models to fit specific disciplines and fields, the results of which have sometimes generated concerns within the field about the level of chaos this has caused, due to lack of extensive use of any model extension (Bagozzi, 2007). The focus of this literature review was to identify theories and methods that appeared to be the best fit for the research topic. Along with a brief overview of foundational theories, three models served as the basis to this discussion and are compared for their perceived fit to the field at the heart of the current study. They included the Diffusion of Innovations by Rogers (2003); the Technology Acceptance Model (TAM; Davis, 1986), and the Unified Theory of Acceptance and Use of Technology (UTAUT; Venkatesh, Morris, G. Davis, F. Davis, 2003).

A key model that served as the foundation for this research was the diffusion of innovations as developed by Rogers (2003). Rooted in the anthropology research tradition, Rogers' theory is one of the most popular models for exploring diffusion and adoption of new technology innovations (Sahin, 2006). Anthropologists often show that the planners and officials in charge of diffusion programs failed to account fully for the cultural values of the expected adopters of an innovation. As a result, the diffusion program often failed or at least led to unanticipated consequences (Rogers, 2003).

Several aspects of this model confirm it as a good fit for this study. One such element is the articulated description of the change agent and their role in the success and failure of innovation adoptions. The frequent inability of a change agent to see beyond their own perspective of an adoption they perceive as one that holds just as much value for everyone else all too often serves as a barrier to the communication element of the diffusion process.

The diffusion model is built on a conceptual process that is distinguishable in all diffusion research studies. Occurring in order, Rogers defines them as the basis of the diffusion process where 1) an *innovation* 2) is *communicated* through certain *channels* 3) over *time* 4) among the members of a *social system* (Rogers, 2003). Not all innovations are equal, however, and the perception of the attributes of an innovation by the potential adopter, whether an individual or a system, also plays a key role in the rate of adoption.

While the diffusion research studied by Rogers (2003) was initially developed to describe adoption of ideas and innovations in a broad sense, including technology, the TAM, developed several decades later had the specific adoption of technology tools and resources as its primary context. As stated by Davis (1986), the goal of his research was to develop and test a theoretical model of the effect of system characteristics on user acceptance of computer-based information

systems. The results from use of the TAM was to improve understanding of user acceptance processes, providing new theoretical insights into the successful design and implementation of information systems. In addition, the TAM would provide the theoretical basis for a practical user acceptance testing methodology that would enable system developers and implementors to evaluate proposed new systems prior to their implementation, maximizing an efficient product development process by allowing providers the ability to focus their efforts on the tools and resources deemed to be most valuable to the end user community.

Credited with much of the foundational development of this model, Davis (1986) aligned the concept of self-efficacy, an element of social cognitive theory as described by Bandura (1986) with one characteristic of TAM, the perceived ease of use. Several authors, including Adams, Nelson, & Todd; Agarwal & Prasad; and Lippert & Forman (as cited by Straub, 2009), reported that another characteristic of TAM, perceived usefulness, was also incorporated into the theory as a result of previous research that found it to be a consistent influence of future individual use of technology. Davis' work is also credited for launching a renewed interest in spotlighting the importance of individual perceptions of a technology. Both Davis (1986) and subsequent studies on mandatory information technology implementation by Massey, Montoya-Weiss, and Brown (as cited by Straub, 2009), report findings that highlight the value of addressing how subgroups within a system may hold different attitudes on perceived ease of use and perceived usefulness. These echo the message by Rogers (2003) and others who note that a frequent misstep by change agents and the researchers in this field, is to completely ignore the impact of culture and social connections on both individual and organizational rates of adoption.

A successor of TAM, the United Theory of Acceptance and Use of Technology (UTAUT; Venkatesh et al., 2003) is one of the more recent extensions of TAM. Because

explaining user acceptance of new technology is considered to be a mature research area in the field of information systems, a wealth of research in this area has been completed, resulting in the development of several models that extend and refine the original theories and models. Much of the research is based not only within the field of information systems for business and commerce, but also psychology and sociology.

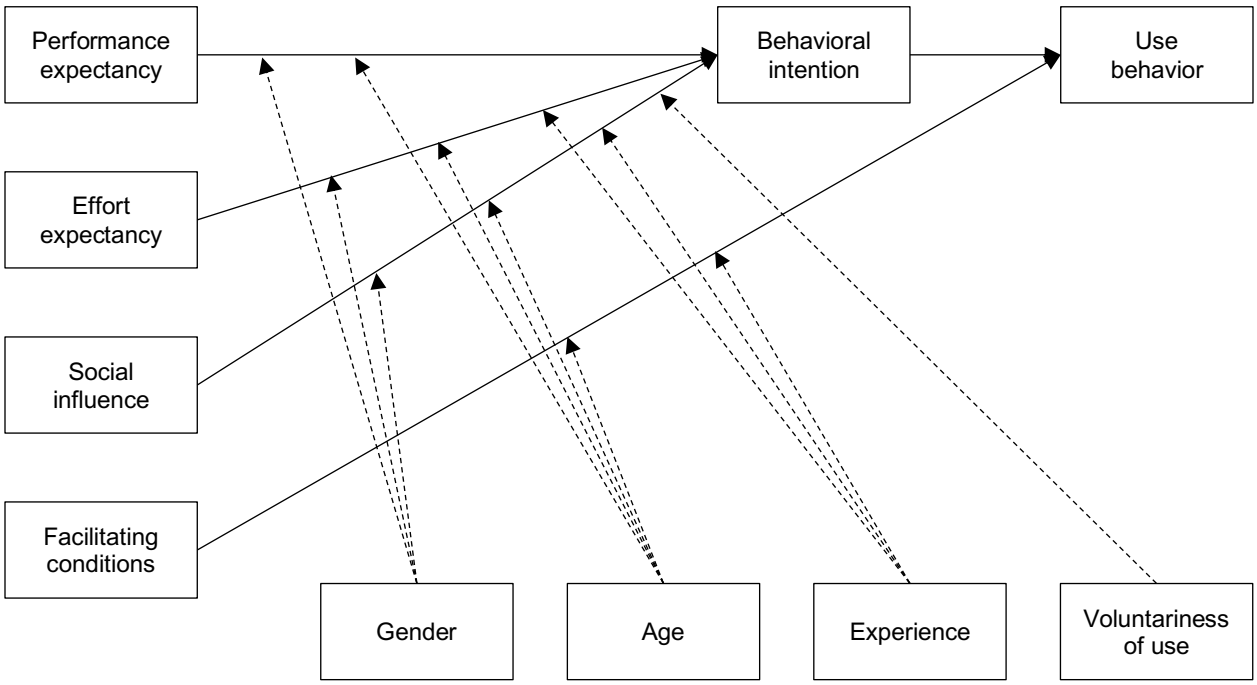
Developed and tested by several researchers who authored both the original and modified versions of TAM, primary goals of UTAUT research were to empirically compare eight of the most widely used existing models of adoption and acceptance in order to arrive at a baseline assessment of the explanatory power of the individual models against which a new unified model could be compared, and then to develop and empirically validate the new model, UTAUT. These objectives operate under a larger vision, identifying a model that is more unified, more parsimonious, and yet accurately assesses the likelihood of success for new technology innovations and supports understanding the drivers of acceptance in order to proactively design interventions targeted at populations of users that may be less inclined to adopt and use new systems (Venkatesh et al., 2003).

Successful in demonstrating a more parsimonious model, UTAUT reduces the number of constructs from seven identified in the numerous original studies, down to four that the researchers believe play a significant role as direct determinants of user acceptance and usage behavior. As indicated in Figure 1.3, these consist of performance expectancy, effort expectancy, social influence, and facilitating conditions. The researchers note that the labels applied to these constructs are independent of any theoretical perspectives. The role of key moderators is included in the model and include gender, age, voluntariness, and experience and provide the theoretical justification for the UTAUT hypotheses (Venkatesh et al., 2003). The four constructs

identified in the UTAUT model were used to develop the concourse and set design, aligning Q statements to the constructs within the framework of the study. Table 1.1 shows the alignment of identified technology adoption challenges for the R&E network community to the usage behavior determinants established by the UTAUT model.

Figure 1.3

Research model for the Unified Theory of Acceptance and Use of Technology (Venkatesh et al., 2003)



Note: the dashed lines denote moderating (interaction) effects.

Table 1.1

UTAUT Model Showing Alignment of Research Themes

Construct	Description	R&E adoption challenges
Performance expectancy	The degree to which an individual believes that using the system will help him or her to attain gains in job performance.	Performance expectancy relevant to the benefits for work/research is often at low levels for both researchers and IT personnel.
Effort expectancy	The degree of ease associated with the use of the system.	Users (of R&E resources) frequently believe the level of effort required to access and obtain the service will be higher if they are located at smaller, more rural institutions.
Social influence	The degree to which an individual perceives that important others believe he or she should use the new system.	Institutional/discipline/collegial influences impact motivation of individual researchers to seek out these resources at their home institution.
Facilitating conditions	The degree to which an individual believes that an organizational and technical infrastructure exists to support use of the system.	Adequacy of IT resources to support advanced scientific research.

Significance of the Study

Findings are intended to inform the field of adoption theory and the R&E technology network community across several areas. First, the study applied Q methodology to the UTAUT framework by developing a concourse that explores challenges to adoption rates of research and education (R&E) network technologies. At the time of this proposal, no existing published research has been identified that is similar in context. In relevance to the identified user community from which the participants (known as the P-set in Q studies) will be chosen, providing an understanding of attitudes and opinions held by end users on the value of these resources can help decision makers determine plans for expansion and upgrades in terms of ongoing investment of technical and human resources. Especially relevant to these decisions is the ability to understand the specific resources and their characteristics of highest interest to

potential end users. Study findings may also be helpful for the academic community as they work to strengthen elements of degree programs, research experiences, curriculum, training and workforce development initiatives intended to increase interest in research areas and increase the number of students going into research across disciplines and across institutions. And finally, certain elements identified for inclusion in the Q-set may provide useful information about the relative likelihood of success of proposed systems early in their development, where such information has greatest value.

Results of the study will serve to inform providers / change agents within the R&E network community of salient factors that determine intention and behavior (UTAUT) toward the use of the resources.

With close ties to the contemporary issues related to broadband access in rural and remote areas of the country, the findings of this research are also pertinent to similar efforts by the U.S. federal government and numerous public and private entities. Included in these efforts is the focus on serving tribal lands that are spread across the country. All of these groups continue to dedicate significant levels of time and resources to expand Internet connectivity to residences and businesses in rural and remote areas in an effort to ensure universal access to a resource on which today's economic, educational, public service and entertainment industries are dependent.

Definition of Terms

Change Agents: An individual who influences clients' innovation-decisions in a direction deemed desirable by a change agency. Typically, a change agent attempts to implement change within a system that results in adoption of the innovation. The opposite also applies, where the change agent works to slow down diffusion or adoption of an innovation deemed by the change agency as undesirable. Change agents are most often perceived as heterophilous to a system

since they frequently attempt to integrate from the outside (Rogers, 2003). This can result in attitudes of initial mistrust by those in the system, impacting the speed and level at which an innovation is adopted. For purposes of this study, the change agents are characterized as IT Leadership at the institutional, state, and national level who advocate access to R&E network technology and the resources for academics and research they enable.

Network Resources: For purposes of this study, the full term or shortened term of resources implies discipline specific technology hardware, software, cloud applications and storage, including advanced scientific tools with the capacity for remote access and remote instrumentation, the activities and data of which can be used for visualization and analysis by researchers regardless where they are located.

Opinion Leaders: Those within a system or community who are able to influence other individuals' attitudes or overt behavior informally in a desired way with relative frequency. Leadership is considered to be informal in nature and not a function of an individual's formal position or status within a system (Rogers, 2003). For purposes of this study, opinion leaders are characterized as faculty and researchers at institutions located across the region of the NTNC. This includes public and Tribal Colleges & Universities that are identified as two-year, four year, and graduate/doctoral institutions.

Limitations of the Study

The structured development of the Q statements may not adequately represent perspectives of all participant roles invited to participate in this study. Since the researcher is embedded in the role of the provider (i.e. the change agent, in this case, the IT leadership responsible for deployment and ensuring diffusion of the innovation) it may be difficult to ensure

that the Q statements are written to accurately reflect context and opinions of all participant roles.

This research study does not intend to identify any correlations between culture or race and the attitudes and opinions toward the use of R&E resources. Because the NTNC region encompasses more than 75% of the accredited U.S. TCUs in its footprint, it is critical to include the viewpoints of these institutions in this study as representatives of the larger higher education community, however it is not the focus of this study to use the results to compare attitudes and behaviors across cultures in the region.

Organization of the Dissertation

This dissertation begins with an initial introduction to the context, purpose, and significance of the study. Chapter 2 provides an overview of the scope of background on the specific topic of research and education networks and how the chosen theoretical framework and methodologies were identified and selected for conducting the study. Chapter 3 provides a more detailed view of the methodology and the process to modify the identified theoretical framework for purposes of the study. The collected data and the process and results of analysis are the focus of Chapter 4, followed by a discussion of the findings and potential impacts and implications of the study in Chapter 5.

CHAPTER 2. LITERATURE REVIEW

The objective of this literature review has been two-fold as preparations were made to implement this research study. First, it addressed the need to conduct a comparative review of the existing theories and research models of technology adoption for the purpose of understanding the theoretical roots of this field, and to determine which of the models provided a better fit for the study. Second, using those models identified to be best aligned to the intent and scope of the study, modifications are proposed for use in the current study in order to adequately address the specific context of the research.

According to a recent report by the Center for Digital Education (2016), today's global community increasingly looks to higher education to facilitate and perform leading-edge scientific research. Universities investing in advanced technology research infrastructures receive more funding, are more competitive at recruiting top talent and are often at the forefront of some of the most impactful scientific breakthroughs. Much of the important research conducted at universities today depends on the ability to process, store, and share massive volumes of data (Center for Digital Education, 2016).

Across the country, and in the region of the upper Midwest and Pacific Northwest, regional technology networks serve as arms of the national R&E technology network interoperating to form a larger whole, the U.S. national R&E backbone, Internet2.

As a member-owned organization whose mission is to operate an advanced technology network intended for research and academic activities of its membership, Internet2 provides services to more than 90,000 community anchor institutions, 305 U.S. universities, 70 government agencies, 42 regional and state education networks, 84 leading corporations working with the member community and over 65 national R&E networking partners representing more

than 100 countries. The technology that creates regional networks and the larger interoperable network fabric encircling the globe is the foundation for distributed education and research activities across the higher education community (Internet2, 2018).

Close attention to ongoing operations and maintenance of this now global network has justifiably taken on a life of its own. Too frequently, however, the very reason behind all of this work is lost in the shadows and concerns for high bandwidth, low latency, zero downtime and high security needs that demand ongoing and immediate attention.

Regardless of facts related to miles of fiber and various other indicators, there continue to be areas across the United States that have failed to adopt the tools and resources available to support contemporary academics and research. This lack of access can significantly impact local populations in their efforts to grow a workforce with the knowledge base necessary to support contemporary society's growing dependence on technology tools and resources of all kinds. Throughout this discussion it is the intent of the researcher to balance the perspectives of both the change agent who promotes the adoption of these resources, and the end user in an effort to accurately reflect the elements at play in this environment.

A critical component of the success of the national and international R&E networks, and subsequently the regional networks that serve as connectors between the national network and the local institutions is the need to incentivize groups across each region to work together to ensure the developed infrastructure is dependable and resilient. A broad representation of partners serves as a catalyst in the ability of regional partners to collaborate and leverage resources that no single entity could achieve on their own.

The debate concerning net neutrality for populations across this country justifiably plays a role in this discussion. Evidence points to data indicating dead spots in access to basic

connectivity, not just for educational institutions, but also anchor institutions that serve a variety of community needs. From the local to the federal level, there exists a lack of urgency and motivation to dedicate the resources required to improve these conditions, all with negative impacts on the ability of a community to expand its economy and grow its workforce. What are the elements that serve as impediments to adoption of these critical resources? Where do the barriers exist and how can change agents address them in order to most effectively dedicate resources toward the challenges that stand in the way? And what can be done about the challenges that exist external to the system, so external that they seem too far away and too removed from the area in need to have any hope of improvement? Searching out and highlighting the use cases that illustrate the value of this highly recognized technology communication and collaboration resource results in valuable messages to stakeholders both internal and external. Often the perspective of a change agent does not adequately focus beneath the surface of a given situation to uncover the clues to challenges in adoption rates. From the perspective of the change agent or agency, the resource should be easily perceived as valuable for every institution and surrounding community.

Context

For the context of this study, an understanding of where current and future end users are in their beliefs about the value of these resources and the challenges that exist to their adoption may be helpful to decision makers as they work to determine plans for expansion and upgrades in terms of ongoing investment in technical and human resources. Especially relevant to these decisions is the ability to understand the specific resources and their characteristics of highest interest to potential end users. Study findings may also be helpful for the academic community as they work to strengthen elements of degree programs, research experiences, curriculum, training

and workforce development initiatives intended to increase interest in research areas and increase the number of students going into research across disciplines and across institutions. And finally, certain elements identified for inclusion in the methodology may provide useful information about the relative likelihood of success of proposed systems early in their development, where such information has greatest value.

Several key themes can be identified to help frame this challenge. The following concerns are based on emergent common themes identified by those who operate or are engaged with R&Es operations in the U.S. at the time of this study. They are further confirmed through findings identified as limitations to the current configuration of advanced cyberinfrastructure resources (Monaco et al., 2016).

- *Stakeholder awareness*: Lack of adequate awareness and knowledge of available resources limits expectations by users. Lines of communication tend to be limited across personnel who perform technical and administrative tasks for R&E operations, resulting in information that is disseminated and shared in less detail with a more limited audience of stakeholders or end users, and in a less timely manner. This environment has the potential to negatively impact advancement and use of the resources for academic and research activity.
- *Lack of user expertise:* Due to awareness issues and perceived adequacy of support needed, users are often unsure of how to request and implement the resources available to support their research activities. This unintentionally creates an existence of achievement glass ceilings in research activity and further limits use and awareness by both end users and those in support roles. They combine to limit the opportunity to learn, and in turn, to mentor others on the use, both scholarly and technically. The "I-know-a-flash-drive-works-for-this-so-I'll-just-continue-to-do-it-that-way" syndrome becomes a self-imposed default option.

- *Adequacy of service and access to the end user*: Researchers are located at institutions of various sizes and at locations often at a distance from central points of presence where major communication network backbones interconnect. They have the interest and skill to conduct data-intensive science and to train their students to learn these skills, but often face the challenge of not having access to the appropriate technologies needed. The availability or perceived lack of availability by a campus to provide access to these supporting resources can negate interest and motivation across user groups. Ultimately this can challenge an institution's ability to attract and retain faculty and researchers whose work depends on resources that can provide the capacity needed for research data mobility, data security and the knowledge base and skill required for effective use. Improved awareness of how technology related challenges faced by researchers regardless of discipline are addressed directly by the infrastructure of R&E networks is just one of several challenges to adoption.
- *Adequacy of IT resources to support advanced scientific research*: The needs of technology resources for any higher education institution continue to increase. The day to day business of addressing critical needs of the campus can significantly limit the attention dedicated to advancement of resources for scientific research that require support by the local information technology department. While the technological skills exist, it is frequently a challenge of information technology units to devote the time and resources needed to support research when local campus needs dictate how and when those resources are provided. Critical contemporary technology challenges requiring increased skilled support include research data mobility, cybersecurity, and assurance of advanced information technology knowledge and skills attainment and transfer.

Since the key elements of the this research focus on challenges to adoption of innovations made accessible via the R&E network, it is important to clarify and articulate the definition of successful adoption in a way that is useful across stakeholder groups.

Tracking the miles of fiber and points of presence of the physical R&E technology network indicates a consistently positive trend in connectivity, but that is only one data point in the adoption scenario. Actual user evidence at the local and regional level exemplifies that unique characteristics and success within that scenario is much different than simply counting miles of lit fiber. Foundational to this study is the ongoing challenge of the provider to articulate the definition of success within this context. How can the definition be refined in order to provide the most accurate and useful tool for stakeholders to reference when making decisions regarding improvements, services, and expansion?

Numerous assumptions on the challenges to adoption rates of R&E network innovations exist. While perceived as anecdotal, they are well-founded, based on personal experience and evidence from numerous scenarios. Across the sources, three themes frequently surface as key challenges. The first relates to money. As discussed by DiMaria (2016), financial resources are needed to engage in R&E network activity both at the time of deployment, and also ongoing in order to ensure institutional technology is able to stay in step with the advancements at the network level. For some schools, inadequate financial and human resources needed to support that effort make it difficult to take full advantage of the innovations available. In addition, even though funding may be available, demands for technological resources exist across many levels of an institution's IT infrastructure making it easier to give priority to more tangible and urgent daily needs over the relatively unseen infrastructure of R&E technology. Schools are scrambling to move more

of their investment into their IT delivery systems and to make their capabilities as robust as possible, but sometimes the funding does not match the desire (DiMaria, 2016).

A second theme of the mechanisms that can serve as challenges to adoption of these innovations relates to promotion of its value and benefits. DiMaria (2016) reports that R&Es need to do a much better job of marketing and promoting their resources. R&Es are typically comprised of engineers and entrepreneurs collaborating across institutions and networks where the focus is to build network capability because of its benefits to both the local network and the greater network community. However, their objectives are on technical operability and not on marketing in a language that is meaningful to the end user community of researchers and educators. At the heart of the R&E technology network innovation is its genesis in the public higher education institution, with a mission to serve its state and region. Thus, the for-profit element has not been a key driver in strategic communications. In general, R&Es are exceptional at providing technical and financial transparency to their members and focusing on service delivery, but as a general rule, most do not actively promote their services and potential (DiMaria, 2016).

Yet a third theme of challenges to successful adoption speaks to the nature of the community in question. While large research institutions with more extensive budgets are able to take full advantage of the high-performing research capacity offered by R&Es, others with less access and less resources may miss out on services such as security, advanced end-to-end applications, instructional design, professional development support, multimedia treatment and ADA compliance resources (DiMaria, 2016). In addition, small institutions with less focus on research are awarded grants at lower rates and again miss out on R&E services due to less engagement in the broader community of network innovations along with the funding that comes with grant

initiatives. And still for others, regardless of size or location, there is a basic lack of awareness of R&E network technology innovations.

Continuing the discussion on defining evidence of successful adoption naturally includes a review of the perspective of others in the community. Reports by McMullen et al., von Oehsen & Hauser, and Wang (as cited by Monaco et al., 2016) indicate that regional organizations occupy a key strategic position between campuses and national computational resources. These organizations have a significant role to play in assisting potential users of computational resources at the local level to learn about and use national resources. To better illustrate this role, three examples of advanced computing resources reliant on the resources and capacity offered by a national and global R&E network fabric are described here.

- Genomic sequencing is expanding: Genomics research is rapidly becoming one of the leading generators of big data science. University-based researchers collaborate with counterparts and access data repositories across the nation and around the globe. A live demonstration in 2012 witnessed 24 gigabytes of genomic data being transferred from Beijing to University of California, Davis via Internet2's 100G network in 30 seconds. A file of the same size sent via the public internet took more than 26 hours. In contrast, transporting this data via a hard drive by airplane would take 17 hours (Jones, 2012).
- National Library of Medicine: As part of the National Institutes of Health, the National Library of Medicine (NLM) is the world's largest biomedical library and the developer of electronic information services that deliver trillions of bytes of data to millions of users every day. Scientists and health professionals around the globe search the Library's online information resources more than 1 billion times each year, resulting in the transfer of biomedical research into practice. According to the National Institutes of Health in their

annual report (2014), to support these resources, the NLM/NIH information technology (IT) network infrastructure is designed to be reliable and secure in order to support interconnections for the exchange of large data sets between NLM and its external partners, including the NIH campus network and researchers around the world, the public Internet, and the Internet2 national research network.

- Earth Resources and Observation System: An exemplary illustration of reliance on global R&E network resources is presented by the U.S. Geological Survey Earth Resources and Observation System (USGS-EROS) located just outside of Sioux Falls, South Dakota. EROS (2018) is one of the largest land remote sensing centers in the world, housing the longest and most comprehensive record of Landsat images of earth's conditions ever assembled. Images include aerial photography, cartographic, topographic and satellite image collections. With satellites in orbit, USGS is capable of collecting data for any location on earth's surface every eight days. Two of the newest satellites each have daily capacity to ingest 1.6 TB of data and distribute 3.2 TB data to users.

With services that are technologically ahead of the curve, R&E networks enable communication and collaboration on a high-speed network free of the noise and friction found on most commercial provider networks (DiMaria, 2016). R&Es also have enormous capabilities and potential for all schools, small and large, to realize new capabilities in teaching, learning, research, and administration (DiMaria, 2016).

For purposes of this research, the targeted community in question are anchor institutions located within the footprint of the NTNC, where rural is more consistently common than urban, and where adherence to the local culture is strong. The cultural norms frequently characteristic of rural and less populated areas can sometimes pose more of a challenge to innovation diffusion, in

contrast to more highly populated areas where access to more diverse approaches and cultural acceptance are likely.

A brief discussion on the terms and definitions relevant to this research is needed at this point. Beginning with the history of theories and models in this field, terms such as acceptance and adoption are frequently interchanged. A term requiring clarification is innovation. Defined by Rogers (2003), innovation is an idea, practice, or object that is perceived as new by an individual or other unit of adoption. It matters little if the innovation has been around for a while or is simply new to the individual. Newness of an innovation may be expressed in terms of knowledge, persuasion, or a decision to adopt (Rogers, 2003). As his research evolved, Rogers (2003) realized that the primary focus of innovations in his work had to do with some kind of technology or technology application. In similar fashion, the term innovation will also be used in this context to reference a technology tool or resource enabled via access to the R&E network and community.

For the majority of this discussion the term adoption will serve to reference technology innovations specific to the network resources of the R&E community. Also relevant is the term community, defined as the human network of those engaged in using, supporting, and engineering the technical and human capacity of this infrastructure. The specific R&E community that is central to this research is located in a region spanning across the upper Midwest from roughly Michigan westward to Washington and Oregon, including Alaska. The end users of the resources afforded by access to the R&E networks are faculty, students, researchers, and staff at the higher education institutions located in this region. The rural nature of many of these states means that end users experience frequent challenges to commodity internet access for a variety of reasons. Due to the rural and remote characteristics, along with

the relatively high concentration of Tribal Colleges and Universities (TCUs) also located in the region, local populations place high value on the resources available from anchor institutions in their communities that can support access to critical resources needed for daily life. Along with access to education and advanced research tools, online resources required for a significant portion of daily life include those related to employment, access to job training, access to basic health care and many others.

The local institutions and agencies that are key to providing access to their constituency are identified as community anchor institutions (CAIs). Through the Connect America Fund, the Federal Communications Commission (2011) coined the CAI label and describe these entities as schools, libraries, hospitals and other medical providers, public safety entities, institutions of higher education, and community support organizations that facilitate greater use of broadband by vulnerable populations, including low-income, the unemployed, and the aged.

Relevant to the scope of this study, CAIs with missions of education and scientific research will serve as the key target population providing information about adoption rates of applications and services made available through connectivity to R&E networks. Looking at the list that describes entities considered to be CAIs it is easy to understand the strong relationship that exists between connectivity and the vitality of the rural community served. Examples abound across the rural areas of the United States and are similarly found worldwide. Additionally, the role of CAIs is critical to populations residing on tribal lands. Analysis of information provided by the American Indian Higher Education Consortium (2018) confirms that more than 75% of accredited North American tribal colleges and universities are located in the upper Midwest and Pacific northwest, adding to the list of CAIs in this region that should expect access and use of the resources provided by R&E networks.

The data collection and analysis activities for this study will focus on a large section of the United States just described that falls within the NTNC footprint. The researcher collaborated with the NTNC membership to identify study participants and implement research activities. The population sample was selected by identifying and inviting no more than five representatives per member state within the NTNC with a goal of confirming participation by no less than two representatives per state. Participants represented groups that included primarily institution level IT administration and management. Care was taken to select study participants representing institutions of different sizes and types, and from communities broadly representative of NTNC states.

Finally, efforts to identify challenges to adoption rates were approached from the perspective of the CAIs who serve in the role of change agents relative to the context of this study. As defined by Rogers (2003) in his diffusion of innovations theory, a change agent is an individual who influences clients' innovation decisions in a direction deemed desirable by the change agent. For this study, the change agent or agency is the R&E network provider or their representative who, at the local level is likely to be located at the higher education institution that is a member of the R&E network community and already connected to the larger global R&E network. Here, as expected, the change agency promotes the benefits of access to the network and its resources and may not always be cognizant of the local system culture or social structure in place that could be serving as a barrier to adoption of these resources. In many cases, the costs to enable local systems to connect to the larger network are borne by sponsoring institutions, through non-profit membership models, and frequently through state-funded appropriations. In this context, it is easy to understand the perspective of a change agency that operates from a

vision that emphasizes obligation to ensure that these valuable resources are consumed (DiMaria, 2016).

Organization of the Literature Review

Several existing models have been reviewed and an overview of their history and relationships are highlighted within this review. Research has included journals and other published resources based in relevant fields that include Management Information Systems, anthropology, sociology, education, and technology adoption. As a result of the review, three models have emerged as the most appropriate and fitting for the described research, and they are described and explored in more detail. This review now continues forward with an initial overview of the history of theories and models that have been developed in this field, followed by detailed descriptions of the models identified as the most appropriate. Criticisms against the models are discussed. The review closes with a summary of the findings.

Background Research

Development of this study required a thorough review and comparison of established and well-known models on technology adoption in order to determine the most appropriate theory and model for the research topic. Criteria for alignment included appropriateness to higher education and the R&E network communities described previously. Many studies have been conducted going back to the 1940s that focus on related topics including adoption and change models, and the use of professional development practices best suited for supporting change in individuals and systems. With the ultimate goal of conducting a study that sheds light on challenges to adoption of R&E network resources by the higher education community within a regional U.S. network, it is important to understand the historical path the field of technology

adoption has taken in order to compare theoretical frameworks and methods. The result is a select list of those models most appropriate and with a good fit to the research study focus.

Two key differentiating factors between the goals of this study and those existing in this field are notable. First, the specific technological innovation at the center of the adoption process in this study is the R&E network along with the services it supports and enables. Second, the identified system to be studied refers to any of the various CAIs defined earlier, with primary focus on higher education institutions. While similarities exist in efforts to identify challenges of adoption, no existing published research was found at the time this review that focused on systems representing R&E networks and their resources as the primary technology innovation.

Several models related to innovation adoption and acceptance have been developed since the early to mid-twentieth century. The origin of contemporary innovation diffusion research is credited to a notable study on adoption of farming innovations begun in the 1940s. Efforts through the decades have been made to refine and extend the various models to fit specific disciplines and fields, the results of which have generated concerns within the field about the level of chaos this has caused due to lack of extensive use of any of the model extensions (Bagozzi, 2007). The focus of this literature review has been to identify theories and methodologies that appear to be the best fit for the research topic. Along with a brief overview of foundational theories, three models serve as the basis to this discussion and are compared for their perceived fit to the field at the heart of the current study. They include Rogers Diffusion of Innovations (2003), the Technology Acceptance Model (TAM; Davis, 1986), and the Unified Theory of Acceptance and Use of Technology (UTAUT; Venkatesh, Morris, G. Davis, F. Davis, 2003).

With clear ties to previous social science theories, Ajzen (1996) indicates that the theory of reasoned behavior, and its predecessor, the theory of reasoned action, are popular theories that assist in understanding the relationship concerning intention as a mediator between action and attitudes (as cited by Straub, 2009). Further, a theory by Ajzen & Fishbein (1977) suggests that an individual's behavior is a result of their attitudes about the expectation of a behavior and social norms about a particular behavior (as cited by Bagozzi, 1985). Attitudes are constructed based on an individual's perceptions about an innovation, specifically, the perceived ease of use and perceived usefulness (Agarwal & Prasad, 1998b).

A key model that serves as the foundation for this research is the diffusion of innovations as developed by Rogers (2003). Rooted in the anthropology research tradition, Rogers' theory is one of the most popular models for exploring diffusion and adoption of new technology innovations (Sahin, 2006). Cultural anthropology is a large discipline within the scientific study of anthropology that focuses on the study of human cultures, beliefs, practices, values, ideas, technologies, economies, and other domains of social and cognitive organization. This field is based primarily on cultural understanding of populations of living humans gained through first-hand experience or participant observation (Bernard, 1998). Related fields extend to include sociocultural anthropology, social anthropology, and ethnology.

Anthropologists frequently reference instances when the planners and officials in charge of diffusion programs fail to account fully for the cultural values of the expected adopters of an innovation. As a result, the diffusion program often fails or at least leads to unanticipated consequences (Rogers, 2003). The capacity of anthropologists to understand the context and culture of their individuals of study, coupled with their data gathering over time, provides

anthropological diffusion scholars with a unique means of understanding the consequences of innovation (Bernard, 1998).

A well-known cultural representation framework in cultural anthropology is the grid-group framework. It is a typology of social environments created by anthropologist Mary Douglas (1997) that has been adapted, modified, and applied over the subsequent years to develop into a major body of literature not only in anthropology but also in political science, public policy, and related social science disciplines (Chai, Liu & Kim, 2009).

Rogers' introduction to this research began in 1962 in the field of agriculture, and his initial model was subsequently modified through other studies to fit research needs across a variety of disciplines, including marketing, public health, and communication. Previous research has supported the use of Rogers' theory as an appropriate framework for investigating the adoption of technology in higher education and educational environments (Medlin, 2001; Parisot, 1995).

Several aspects of this model also lend themselves as a good fit for this study. One such element is the articulated description of the change agent and their role in the success and failure of innovation adoptions. The frequent inability of a change agent to see beyond their own perspective of an adoption they perceive as one that holds just as much value for everyone else all too often serves as a barrier to the communication element of the diffusion process, potentially threatening successful adoption.

Another element in this model is the recognition that the innovation process includes both the element of the technology tool as well as the way it is applied or used to the user's benefit. Rogers (2003) indicates that many technologists believe that advantageous innovations will sell themselves, that the obvious benefits of a new idea will be widely realized by potential adopters,

and that the innovation will diffuse rapidly. Instead for most innovations, diffusion occurs at a much slower rate, at least in the eyes of the inventors and technologists who create the innovation and are anxious to promote them to others.

Rogers identified his work as the contemporary model of the classical diffusion paradigm first developed by Ryan and Gross in their study on the Diffusion of Hybrid Corn in Iowa (Ryan & Gross, 1950). The research method employed by this notable study included retrospective survey interviews which were subsequently coded into numbers with the study participants assigned to adopter categories based on the timing of their adoption of the new seed variety. The results of the study, and the many that followed using the same methodology, focused on the important roles that communication channels and interpersonal networks play in the successful adoption or rejection of an innovation.

To further explain the processes surrounding adoption of innovations, Rogers (2003) asserts that diffusion is a kind of social change, defined as the process by which alteration occurs in the structure and function of a social system. When new ideas are invented, diffused, and adopted or rejected, this leads to certain consequences and social change occurs. Dissemination is yet another term relevant to this discussion, where Rogers clarifies that adoption can occur as a result of diffusion versus dissemination, which is perceived as a planned process for diffusion. For Rogers, either word is used for both the planned and the spontaneous spread of new ideas.

The diffusion model is built on a conceptual process that is distinguishable in all diffusion research studies. Occurring in order, Rogers defines them as the basis of the diffusion process where 1) an *innovation* 2) is *communicated* through certain *channels* 3) over *time* 4) among the members of a *social system* (Rogers, 2003). Not all innovations are equal, however,

and the perception of the attributes of an innovation by the potential adopter, whether an individual or a system, also plays a key role in the rate of adoption.

The diffusion process begins with the innovation in question. Rogers (2003) identifies qualities that are the most important characteristics of innovations in explaining their rate of adoption. These include relative advantage, compatibility, trialability, and observability. Of these, the first two attributes of relative advantage and compatibility serve as especially key indicators for an innovation's rate of adoption (Rogers, 2003).

Next in the process is communication. Communication channels are key to innovation adoption since diffusion itself is its own type of communication where messages are focused specifically on a new idea (innovation). While the process of communication can take several forms, from the interpersonal channel that is frequently characterized by face-to-face exchanges, to contemporary mass media and social media, repeated investigation on diffusion indicates that most people depend primarily on subjective evaluations provided by those closest to them. Described by Rogers (2003) as near peers, the experiences relayed by these individuals to potential adopters serve as a source for modeling and imitation that can be used to convince an individual of the value of a new idea or innovation (Rogers, 2003). Critical also to successful adoption is the similarity or differences between individuals or groups involved. Simply due to the nature of the interaction, the change agent and the potential adopter are going to have at least somewhat different attributes. If they were the same, there would be no innovation information to exchange or adopt. The degree to which individuals with very similar attributes interact is described as homophily. Likewise, when the opposite is true, the term is heterophily. This describes a scenario where individuals in an exchange have very different attributes and problems arise because the potential adopter cannot see the advantage or value of an innovation

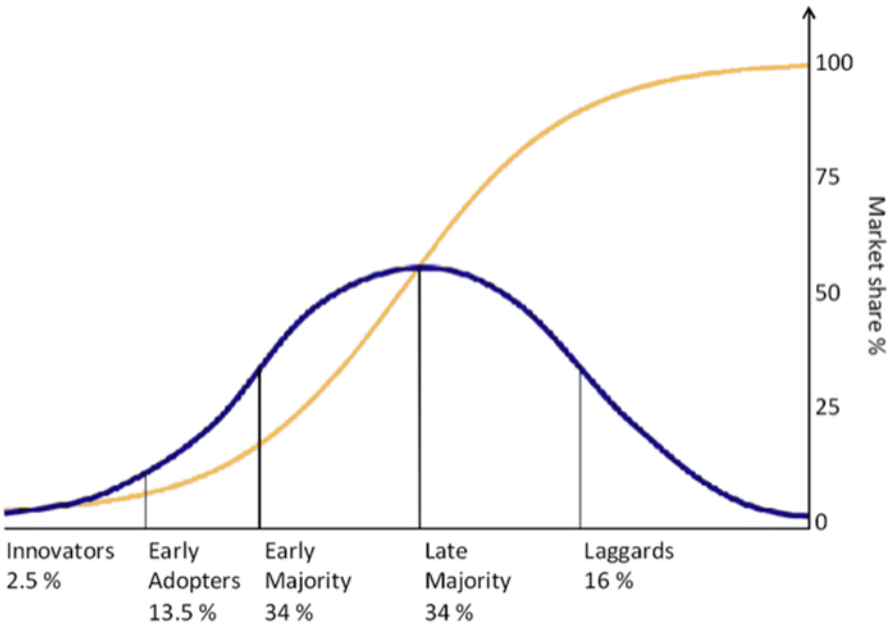
that is being promoted by someone who is so different from themselves. The right blend of heterophily and homophily has a much higher chance of success in the potential adoption of an innovation. Rogers is cautionary, though, in reminding researchers that while some level of heterophily among individuals and groups is needed, it is difficult to achieve. Again, by nature of this type of interaction, individuals who have already adapted an innovation serve as the change agents themselves, heterophilous to the potential adopter because they already have previous knowledge and experience with an innovation. This previous experience held by change agents is often highly related to socioeconomic status, education, and other elements (Rogers, 2003). The difference between the two individuals or groups, in this case, can be strong enough to jeopardize the trust between change agent and potential adopter that is needed to explore and learn about a new idea or innovation.

Third in the diffusion process is the element of time. Here, Rogers draws a distinction between his model and others typical to behavioral science research where time is not used as a variable and is often completely ignored. Rogers (2003) defends the inclusion of the time element across three dimensions: 1) the decision process through which an individual or group passes from initial knowledge and introduction to an innovation, toward either adoption or rejection; 2) the innovativeness of an individual or unit, aligned to the classifications of adopter categories ranging from innovators, early adopters, early majority, late majority and laggards, and 3) the rate of adoption of an innovation by a system or larger group over a given period of time. In this last dimension the research conducted by Rogers has demonstrated consistent results by plotting adoption rates by frequency over time. The results have shown a consistent distribution in the form of an S-shaped curve, where at first, only a few individuals adopt an innovation during a given time period, followed by a steep increase in adoption by the largest

group of individuals or units, and finally leveling off to indicate a remaining small group who are yet to complete the adoption. Rogers (2003) indicates that while most innovations show an S-shaped curve of adoption, there are those that lean more strongly toward either end of the curve. A steep curve early on indicates a fast adoption rate soon after introduction, while a lazy slope to the curve indicates a slower rate of adoption. These distinctions are also studied in depth within diffusion research.

Figure 2.1

S-curve representing the distribution of adoption over time (Rogers, 2003)



Mentioned earlier, Rogers is also credited with developing an efficient vernacular for describing levels of innovativeness. His five adopter categories are widely recognized and familiar, especially relevant to the field of technology (Rogers, 2003). They include innovators, early adopters, early majority, late majority, and laggards. According to Rogers (2003), diffusion research shows consistent commonalities across those in the various categories. For example, innovators actively seek out new ideas and learn about them. They tend to have a network of peers that extends more broadly and beyond their own local support system. Because they adopt

ideas early on, they have less ability to rely on experiences or opinions of others when forming their own opinions because the idea or innovation is still too new to have much of a precedent or basis of information. At the other end of the spectrum, those whose tendency is to adopt ideas and innovations after a lengthier time period tend to have smaller social and peer networks resulting in lower levels of exposure to a variety of ideas, and later exposure to new ideas and innovations. Those in this category tend to have a lower socioeconomic status and make less use of mass media, relying primarily on interpersonal communication channels within their close social system (Rogers, 2003). Consistently demonstrated by diffusion research, time is a critical factor in measuring the rate of adoption for an innovation in a system, and not just for the rate of adoption by an individual. Rogers emphasizes that aspects of diffusion cannot just be explained by individual behavior, but by the system as a whole which has a direct effect on diffusion, and an indirect influence through the behavior of its individual members. (Rogers, 2003). The discussion on time as it relates to the rate of adoption is significant within the context of this research, where the focus is not just on adoption rates of individuals, but also on adoption rates of individuals as members of a larger unit or system.

The social system is the fourth element of the diffusion process, clarifying the specific units that serve as the sample population of a study. A social system or unit can consist of individual members of the system, and informal or formal subgroups or organizations within a larger system. Typically, units or systems are identified by their common and cooperative effort to seek to solve a problem or issue. The pursuit of a common goal not only serves to bind a system or unit together, it also has implications for the rate of adoption and the diffusion process, where it can serve to facilitate or impede the process (Rogers, 2003).

Within the makeup of the social system is the structure that exists to give regularity and stability to the behaviors of the individuals and larger units within a system. The structure can reference the more formalized social and bureaucratic hierarchies that exist within a system, and also the less formal interpersonal networks that exist between individuals and subgroups of a system. This framework can serve as a valuable tool for predicting behavior of the individual or unit.

The predictability described here is achieved by a thorough understanding of the social and cultural norms that are in place for a given system or unit. Rogers (2003) describes norms as the established behavior patterns for the members of a social system, defining a range of tolerable and acceptable standardized behavior of members within a system. It is these norms that must be addressed by change agents and opinion leaders of an innovation in order to approach the diffusion process. For purposes of this study, attention to the role of change agents and opinion leaders is a critical element in successful adoption of the innovation in question. While it is relevant to focus on diffusion efforts within the system, including the important impacts of change agents and opinion leaders within the system as relevant, the study cannot neglect the impacts of change agents and opinion leaders external to the system. These include stakeholders with roles involving policy and funding decisions especially relevant to publicly supported resources. It is understandable that addressing this broad perspective threatens to make the study unwieldy and too broad in scope. Nevertheless, research with a focus on an innovation that encompasses a concept such as equitable access to resources in support of education should be cognizant of the numerous facets both social and political, both contemporary and historical, that play a significant role in adoption challenges.

Further detailed discussion on the differences between change agents and opinion leaders is provided by Rogers (2003) in order to draw distinction between the roles of these two important characters of the diffusion and adoption process.

As stated previously, especially relevant to this research, these roles exist both within the system and also external to the system. Opinion leaders are influential and play a pivotal role within a system by influencing either for or against the adoption of an idea or innovation. Opinion leaders are frequently early adopters who hold strong communication and social structures within the system and local culture. These characteristics are a few of several that support opinion leaders in their roles as models for the innovation behavior. Alternatively, there exist opinion leaders who enjoy equally as much influence in their ability to reject an innovation. In either case, as long as the opinion leader aligns to the norms of the system, their influence to advance or stymie the progress of adoption is a force not to be taken lightly or dismissed in adoption and diffusion efforts led by change agents.

Change agents can also exist within a system or originate and work to exert their efforts from outside of the system. Most familiar to this scenario is the change agent and their related change agency who attempt to implement innovations in a system that they consider to be in the best interest of the potential adopter. The opposite can also be the goal, where the change agency works to stop or mitigate the adoption of ideas or innovations that the change agency deems as undesirable for the system in question. Regardless, change agents are most frequently perceived by individuals or units within a system as heterophilous to their system and thus are likely to be challenged, or mistrusted and dismissed by individuals or units in the system. In order to mitigate the challenges to adoption that can be caused by this perceived disconnection between the parties, change agents will frequently search out and work to partner with identified opinion

leaders in a system in order to ensure higher success rates. Using the cover of an opinion leader internal and thus more homophilous to the system allows the change agent to send communications about an idea or innovation via channels that are acceptable to the individuals or units within a system (Rogers, 2003).

The innovation diffusion work by Rogers (2003), the classical diffusion paradigm from Ryan and Gross (1950), and the many subsequent theories and models that use the same methodology provide insights into the efforts required for successful adoption of R&E resources and tools by potential adopters both individual and at the system level.

Criticisms to diffusion theory exist. Because of the impacts on diffusion originating at both the system and individual level, researchers are cautioned in their vision of research that will clearly identify exact causes of diffusion and accurately quantify those causes. Humans and human networks are complex and the forces acting to persuade individuals or the organizations and systems they are part of make it difficult to account for all possible variables. Straub (2009) voices concerns regarding lack of enough thorough application of the methods, which, along with inconsistent results can serve to reduce heuristic value of diffusion research.

The Technology Acceptance Model (Davis, 1986) is a second theory on technology adoption reviewed in detail in preparation for this study. While the diffusion research studied by Rogers (2003) was initially developed to describe adoption of ideas and innovations in a broad sense, including technology, the Technology Acceptance Model (TAM) developed later had the specific adoption of technology tools and resources as its primary context. As stated by Davis (1986), the goal of his research was to develop and test a theoretical model on the effect of system characteristics on user acceptance of computer-based information systems. The outcomes from use of the TAM was to improve understanding of user acceptance processes, providing new

theoretical insights into the successful design and implementation of information systems. In addition, the TAM would provide the theoretical basis for a practical user acceptance testing process. This methodology would enable system developers and implementors to evaluate proposed new systems prior to their implementation, maximizing an efficient product development process by allowing providers the ability to focus their efforts on the tools and resources deemed to be most valuable to the end user community (Davis, 1986).

Using as a foundation the theory of reasoned action by Fishbein (1967), and further refined by Fishbein & Ajzen (1975), TAM has been influential and is the most widely applied model of users' acceptance and usage of technology (Venkatesh, 2000). The Fishbein model was attractive to Davis in part due to the intent of the framework to model the determinants of a person's behavior with respect to a target object, measuring the person's attitude toward performing the behavior with respect to the object. This contrasts with other frameworks wherein the measurement is focused on a person's attitude toward the object itself. Original research of the TAM was to develop and test a theoretical model of the effect of system characteristics on user acceptance of computer-based information systems (Davis, 1986). In particular, Davis (1986) directed his research on the class of systems referred to as end-user systems, where the tool or resource is directly used by individual members within an organization, at their own discretion to support their work activities. Later applications of the model included those in educational settings highlighting adoption by student teachers (Ma, Andersson, & Streith, 2005), implementation of laptop-based testing (Baker-Eveleth, Eveleth, O'Neill, & Stone, 2007), and adoption of online learning (Ndubisi 2006), all summarized by Straub (2009).

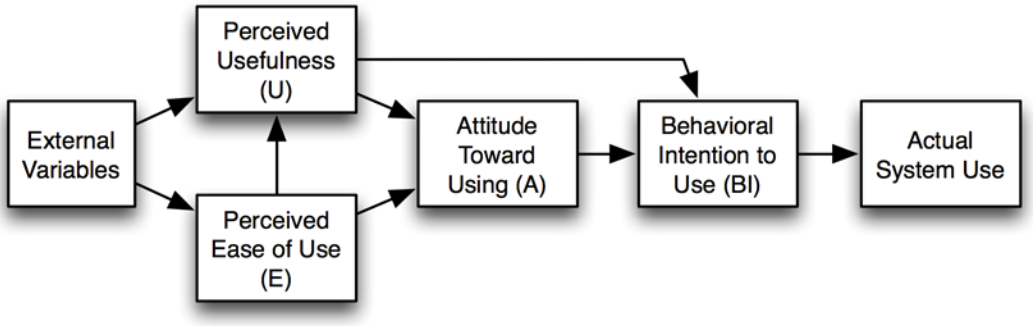
Developed in the field of Management Information Systems in an era where development of end-user technology-based tools were experiencing substantial growth, the research conducted

by Davis focused on the potential of an intervening motivational response by the user to speed product acceptance, as opposed to the typical evaluation methods of the day that primarily used objective performance criteria of the tool or resource, taking into account little of the human aspect of the adoption (Davis, 1986).

Aligned to long-standing criteria for how success is measured in Management Information Systems (MIS), Davis used three key variables as a foundation for his research. These include actual system usage, user attitudes, and performance metrics (Davis, 1986). Credited with much of the foundational development of this model, Davis (1986) aligned the concept of self-efficacy, an element of social cognitive theory as described by Bandura (1986) with one characteristic of TAM, the perceived ease of use. Another characteristic of TAM, perceived usefulness, was also incorporated into the theory as a result of previous research that found it to be a consistent influence of future individual use of technology (Adams, Nelson, & Todd, 1992; Agarwal & Prasad, 1998a; Lippert & Forman, 2005; as reported by Straub, 2009). Davis' work is also credited for launching a renewed interest in spotlighting the importance of individual perceptions of a technology. Both Davis (1986) and subsequent studies on mandatory information technology implementation (Massey, Montoya-Weiss, and Brown, 2001) report findings that highlight the value of addressing how subgroups within a system may hold different attitudes on perceived ease of use and perceived usefulness, echoing the message by Rogers (2003) and others who note that a frequent misstep by change agents and the researchers in this field, is to completely ignore the impact of culture and social connections on both individual and organizational rates of adoption.

Figure 2.2

Conceptual framework for the Technology Acceptance Model (Davis, 1986)



Criticisms of TAM focus on one critical flawed concept, that of directly mapping perceived ease of use with the concept of self-efficacy. Pointing to the original definition of perceived ease of use pertaining to a judgement about the qualities of a technology, Straub (2009) argues that self-efficacy is a judgement about the abilities of an individual. While stronger perceptions of self-efficacy may affect perceptions of ease of use, using either as a predictor for the other is presumptuous at best. Also raised by Straub (2009), TAM is not appropriate for education settings since it does not catch the intricacies and influences relevant to that environment.

The third model researched in detail for this review is a successor of TAM. The United Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh, Morris, Davis & Davis, 2003) is one of the more recent extensions of TAM. Because explaining user acceptance of new technology is considered to be a mature research area in the field of information systems, a wealth of research in this area has been completed, resulting in the development of several models that extend and refine the original theories and models. Much of the research is based not only within the field of information systems for business and commerce, but also psychology and sociology. This has all led to a diverse selection of research models from which to choose and often leads to the criticism of chaos characteristic of this field (Bagozzi, 2007). As Bagozzi

noted, the chaos is a result of too much effort spent on developing extensions of the model and not enough effort dedicated to replicating and refining the original model. Developed and tested by several researchers who authored both the original and modified versions of TAM, primary goals of UTAUT research were to empirically compare eight of the most widely used existing models of adoption and acceptance in order to arrive at a baseline assessment of the explanatory power of the individual models against which a new unified model could be compared, and then to develop and empirically validate the new model, UTAUT. These objectives operate under a larger vision, identifying a model that is more unified, more parsimonious, and yet accurately assesses the likelihood of success for new technology innovations and supports understanding of the drivers of acceptance in order to proactively design interventions targeted at populations of users that may be less inclined to adopt and use new systems. In addition, after the initial comparison of existing adoption models was completed and prior to moving forward with development of a new model, the developers of UTAUT reported that their findings had confirmed that the extensions of the various models mostly enhance the predictive ability beyond original specifications (Venkatesh et al., 2003).

The eight models reviewed and compared in preparation of UTAUT development include the theory of reasoned action (Fishbein & Ajzen, 1967), the technology acceptance model (TAM) (Davis, 1986), the motivational model (Vallerand, 1997), the theory of planned behavior (Ajzen, 1991), a model combining TAM and the theory of planned behavior (Taylor & Todd, 1995), the model for PC utilization (Triandis, 1977; Thompson et al., 1991), the innovation diffusion theory (Rogers, 2003), and social cognitive theory (Bandura, 1986). By applying the eight models using data from four organizations over a six-month period with three points of measurement, the models explained between 17 percent and 53 percent of the variance in user

intentions to use information technology (Venkatesh et al., 2003). Once developed, UTAUT was tested on the same data and outperformed all of the eight original models. Further testing on data from two new organizations indicated similar results. The findings proved that UTAUT can serve as a useful tool for managers who need to assess the likelihood of success for new technology innovations.

In comparing the eight models, Venkatesh et al. (2003) identified two primary themes of research, one where the focus is on individual adoption of technology, and the other on adoption success at the organizational level. In the UTAUT comparative study, usage was the key dependent variable, used to understand and perceive that the role of intention is as a predictor of behavior (Venkatesh et al., 2003). The comparative study completed an extensive review of tests on the eight identified models, determining that of those numerous tests, only four had reported empirically based comparisons of two or more of the models, resulting in publication of the findings (Venkatesh et al., 2003).

The comparative study identified five limitations of existing models that have implications for this research. The first limitation is the technology studied. Where existing research had focused on relatively straight-forward, individual-oriented applications, Venkatesh et al. (2003) were interested in identifying and predicting acceptance of technologies more appropriate for organizations.

The second limitation focused on the study participants. In the existing models it was found that the primary participants were students in an academic setting. For purposes of this study, while the institutional academic setting was one of the chosen environments, the scope of the study expanded to encompass perspectives of faculty, researchers, and information technology management staff in order to ensure relevance to the subject.

Timing of measurement is the third limitation. Indicated as a key element of initial innovation diffusion research by Rogers (2003), the research also expanded its description to include timing of the measurement that typically occurs post-implementation, resulting in perspectives of the participants that have evolved over time. Especially when an innovation has been in place long enough for it to become part of routine use, participants' recall of the adoption process may be less precise than it might have been when the innovation was still new and challenging to the status quo.

The fourth limitation is the nature of the measurement. Several existing models employed cross-sectional or between-subjects comparisons. In contrast to those studies, Venkatesh et al. (2003) were interested in tracing participants through various stages of experience, comparing all models on all participants.

The fifth limitation is the environment within which the technology innovation is deployed. Most existing research has targeted adoption within a voluntary environment, as opposed to a setting where adoption is considered to be mandatory. The study conducted by Venkatesh et al. (2003) emphasizes the need to distinguish between the implications of the two environments and aimed to conduct the study focusing on both (Venkatesh et al., 2003). This study concentrated on participation in a voluntary setting, both for the individual and for the larger system itself.

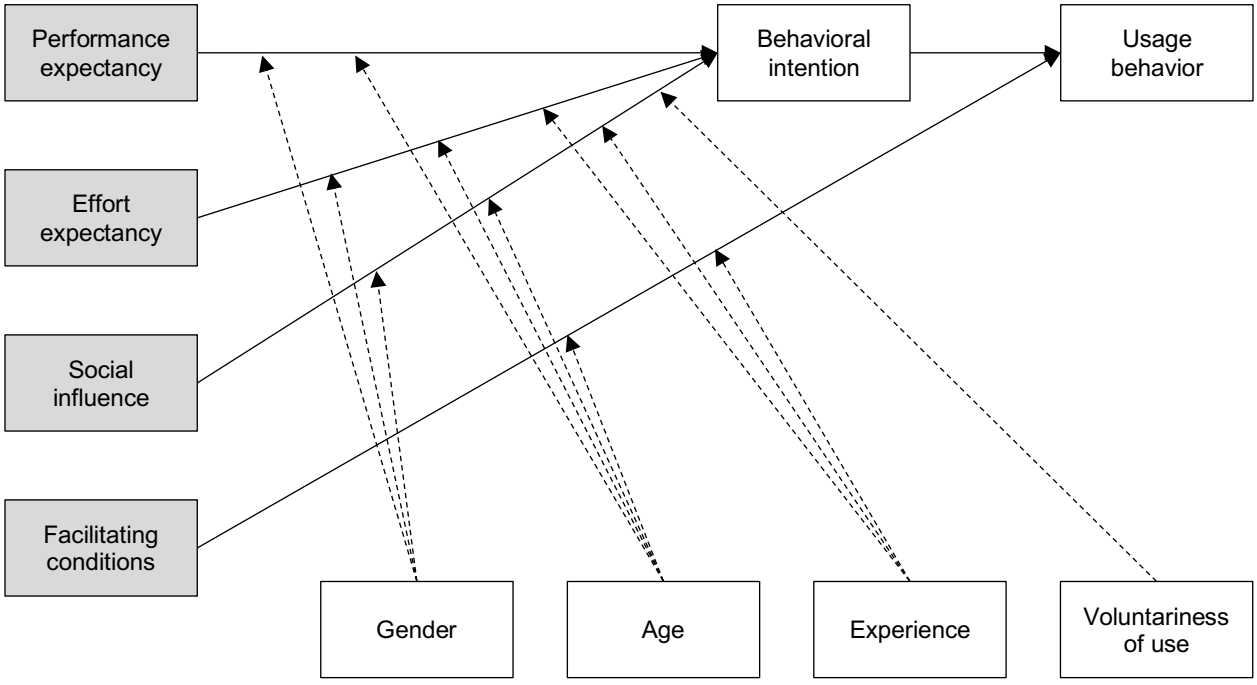
Additional elements essential to the comparison study included the deliberate choice of setting characteristics across the population samples, all selected to ensure heterogeneity. Timing of measurement was placed at three different post-implementation times in order to collect longitudinal data. The questionnaire itself was a blend of items developed and validated across

all of the existing research models. Finally, actual usage behavior was measured by tracking duration of use via the technology system's network traffic logs.

Extensive efforts were implemented to test for reliability and validity. Overall results of the new UTAUT model indicated that the patterns of results found were consistent with results of all previously developed research models (Venkatesh et al., 2003). Notable in the results was the subsequent examination of moderating influences (variables), many of which were suggested in existing models. These include influences such as experience, voluntariness, gender and age. Testing on these influences required that data be pooled across studies and time periods and resulted in an increase in predictive validity of the model (Venkatesh et al., 2003).

Figure 2.3

Research model for the Unified Theory of Acceptance and Use of Technology (Venkatesh et al., 2003)



Note: The four main UTAUT constructs (shaded) are posited to be direct determinants of user acceptance and usage behavior. The dashed lines denote moderating (interaction) effects.

As a result of this work, Venkatesh et al. (2003) were able to defend the numerous extensions of the original models by providing evidence of enhanced predictive validity beyond the original studies (Venkatesh et al., 2003).

Successful in demonstrating a more parsimonious model, UTAUT reduces the number of constructs from seven identified in the numerous original studies, down to four that the researchers believe play a significant role as direct determinants of user acceptance and usage behavior. These consist of performance expectancy, effort expectancy, social influence, and facilitating conditions. The researchers note that the labels applied to these constructs are independent of any theoretical perspectives.

Table 2.1

Major Constructs from the UTAUT Model that Serve as Direct Determinants of User Acceptance and Usage Behavior

Construct	Definition	Relevant Findings from Venkatesh et al. (2003)
Performance expectancy	The degree to which an individual believes that using the system will help him or her to attain gains in job performance.	In their study, this construct proved to be the strongest predictor of intention and was significant across all times of measurement for both voluntary and mandatory environments.
Effort expectancy	The degree of ease associated with the use of the system.	This construct was shown to be significant in both voluntary and mandatory settings, however it was only shown to be significant in the first of three longitudinal measurements. This indicates that effort expectancy is likely to be more salient in the earlier period of an adoption, as opposed to later when degree of ease is no longer an issue due to increased knowledge and skill of use over time.
Social influence	The degree to which an individual perceives that important others believe he or she should use the new system.	Uses the term *social norms* to define this construct, including subjective norm, social factors, and image, and shows significance primarily in mandatory settings. Social influence has an impact on individual behavior through three mechanisms: compliance, internalization, and identification. This view of compliance is consistent with results in the technology acceptance literature indicating that reliance on others' opinions is significant only in mandatory settings (e.g., Venkatesh & Davis, 2000; Warshaw 1980).
Facilitating Conditions	The degree to which an individual believes that an organizational and technical infrastructure exists to support use of the innovation.	Identifies elements of the technological and/or organizational environment that are designed to remove barriers to use. Facilitating conditions are a direct antecedent of usage. The effect is expected to increase with experience as users of technology find multiple avenues for help and support through the organization, thereby removing impediments to sustained usage (Bergeron, Rivard, & DeSerre, 1990).

The results of the research conducted by Venkatesh et al. (2003) and the resulting unified model, UTAUT, confirmed its ability to account for 70 percent of the variance in usage intention. This was a substantial improvement over any of the original eight models and their extensions. UTAUT provides perspective on how determinants of intention and behavior change over time. The UTAUT research also considered moderators such as gender and age, both of which have received little attention in existing research.

An admitted limitation of the UTAUT study and a promotion for further research is to focus on underlying influential mechanisms that are significant in their influence on adoption of

an innovation. These include computer literacy, social and cultural backgrounds. Given the nature of this research, consideration of the influence of social and cultural backgrounds is relevant. These mechanisms are also important to the discussion on opinion leaders within a social structure or system. In addition, clarifying definitions for voluntary and mandatory environments is needed to ensure consistent focus.

Recommended by the authors of the UTAUT comparative study for consideration of further research is the addition of extended research on UTAUT to include technology adoption of different technologies and the resources and tools made available by them, believing that this can further strengthen the overall generalizability of UTAUT (Venkatesh et al., 2003). Other areas of future research can include a tie of this mature research stream into other established areas, including user acceptance and individual or organizational usage outcomes. Future research could also take a closer look at the systems that are perceived as successful by IT standards to determine if they are perceived by the system or organization in the same way.

Criticisms of UTAUT by Straub (2009) indicate that it is a model that measures mandatory only adoption as opposed to voluntary adoption. UTAUT is still new and relatively untested and so has seen little use in subsequent studies since its development, with few resulting study publications. Because of this, there is concern about its appropriateness to environments such as educational institutions and informal learning situations. It is believed that this research can provide significance and value to this field as a way to expand the UTAUT method to other environments.

Although it was found not to cover the context for this study, the Concerns Based Adoption Model (Hord, S.M., Rutherford, W.L., Huling-Austin, L., & Hall, G.E. 1987) is also included in this review of existing adoption models since its development and use occurred in

parallel with many of the theoretical models previously mentioned. The research conducted for this literature review found very little cross-references between CBAM and the other models. Yet those practitioners with a lengthy career in this field will quickly identify key themes shared by many if not all of the assessment models in development at that time, including those of CBAM.

The Concerns Based Adoption Model (CBAM) was developed at the University of Texas-Austin in the 1970s and 1980s by Teacher Education researchers (Southwest Educational Development Laboratory, 2018) as a way to deal with specific types of adoption environments. According to Hall & Loucks (1978) the goal of CBAM was to ease the problems encountered when diagnosing group and individual needs during the innovation adoption process (as cited by Straub, 2009). The focus is on change in schools, the school improvement process and professional development practices. Again, although its theoretical underpinnings appear to parallel those of other adoption theories developed in the same time period and are recognizable by anyone with background in this field, no evidence was found that referenced those theories or any impact they might have had on the CBAM model. Findings from research conducted by CBAM also mirror trends in adoption of education technology into the curriculum that were widely discussed at the time of its development. Similar findings surfaced as a result of a case study conducted on the use of this type of model on K-12 school districts in North Dakota. Coaching and mentoring were found to be a critical element shared by districts achieving improved results from technology adoption, while those with weaker and slower adoption results were shown to have weaker models for support of educators in their attempts to adopt new technologies and the instructional models that accompanied them (Owen, 2004).

Like the others, CBAM also is subject to criticism. While the CBAM model was readily accepted and acknowledged as one of the most robust and empirically theoretical models for the implementation of education innovations from the 1970s and 1980s, it also drew attention for some of its shortcomings. One argument proffered by Anderson (1997) was that the original model was based primarily on applied research, and benefits could be realized by expanding the model through research with stronger theoretical motivations. Additional limitations of the model, as described by the model developers themselves, admit to a top-down context for the research focus, where the model is centered primarily on efforts by the change agent to move things along (Hord et al., 1987).

As explained earlier, due to the more limited scope of the CBAM model it was determined that this would not fit well with the objectives of this research.

Summary from the Literature

The research conducted in this literature review aimed at identifying a model for exploring the challenges to adoption of R&E network resources results in relatively few existing tools to use as a model. The objective of this literature review was two-fold in its role as preparations were made to implement this study. First, it addressed the need to conduct a comparative review of the existing theories and research models of technology adoption for the purpose of understanding the theoretical roots of this field, and to determine which of the models provide a better fit for this research study. Second, using those models best aligned to the intent and scope of this study, one or more existing methodologies were identified that could potentially be modified or extended for use in this research in order to adequately address the specific context of the study.

In the field of advanced network technology, higher education plays a significant role in development and deployment of a national and global technology infrastructure that is intended for access by all institutions regardless of their location, size or populations served. Analysis of the information found for this literature review narrowed the choices of theories and methodologies from existing studies down to three key models that appear to align well with the focus of this research. The existing studies on technology adoption identified in this review focused on a variety of settings including business and organizations, K-12 teacher professional development and eCommerce. One concern regarding the various studies criticized existing research for too frequently depending on a target population of undergraduate college students (Venkatesh et al., 2003). Of the sources reviewed by the researcher, none were found to use the population of an R&E networking community as their target population. In addition, use of Q methodology was not employed for any of the studies reviewed. This resulted in the need to modify existing framework and methodology to more accurately represent the study's theme and population. In the early stages of research design, it was anticipated that a combination of innovation diffusion (Rogers, 2003) and UTAUT (Venkatesh et al., 2003) would be used to construct the design of the Q methodology model proposed for this study. The intent of the UTAUT model was to develop a unified and clean model that combined the key concepts and empirically derived similarities of several existing models into one useful and parsimonious model on technology acceptance and use. It was anticipated that employing the use of established and validated models could serve as a foundation for a modified model useful for this study.

Implications

UTAUT's theoretical perspective on how the determinants of intention and behavior evolve over time holds several characteristics that were appropriate to include in the framework for this research. Merged with elements related to socio-cultural aspects addressed in Rogers (2003) diffusion of innovations sharpens the focus on the social constructs for the context of this study. UTAUT also emphasizes the role that social influence plays in driving behavior among sub-groups and individuals of a community, providing guidance for development and implementation of diffusion efforts across a community or organization (Venkatesh et al., 2003). UTAUT researchers are clear in emphasizing that despite the ability of the existing models to predict intention and usage, current theoretical perspectives on individual acceptance are still weak in providing prescriptive guidance to developers (Venkatesh et al., 2003). Venkatesh & Davis (2000) suggest that future studies should focus on integrating UTAUT with research that has identified causal antecedents of the constructs used within the model in order to provide a greater understanding of how the unique cognitive elements that were the focus of this research were formed. Examples of previously examined determinants of the core predictors include system characteristics (Davis, 1986), and self-efficacy (Venkatesh, 2000). Additional determinants that have not been explicitly tied into this stream but merit consideration in future work include task-technology fit (Goodhue & Thompson 1995) and individual ability constructs such as general cognitive ability/intelligence (Colquitt et al., 2000; Venkatesh et al., 2003).

Also recommended by Venkatesh et al. (2003) is consideration of further research that attempts to identify and test additional boundary conditions of the model with the aim of providing an even richer understanding of technology adoption and usage behavior. This type of research might expand to include additional theoretically motivated moderating influences,

different technologies, different user groups, and other organization contexts. Results from such studies would have the important benefit of enhancing the overall generalizability of UTAUT and extending the existing work to account for additional variance in behavior (Venkatesh et al., 2003). It is believed that this study aligns to this sentiment and will result in useful findings relevant to both the continued generalizability of the UTAUT model, while also providing insights into the study objectives, where technology adoption and use of innovations are explored in settings not previously studied. These efforts have the potential to extend knowledge and value to the research community in this field.

Further, it was the intent of this study that results would hold valuable insights relevant for members across the R&E network community. For those wishing to promote the innovation availability, study results can serve as a resource to provide an understanding of where current end users are in their beliefs about the expectations and value of these innovations, helping the R&E community make decisions on expansion and upgrades that best justify the level of ongoing investment in terms of technical and human resources. Understanding the specific resources or resource characteristics that are the most attractive to potential end users further ensures effective and strategic planning. For the academic community this understanding can be useful as they work to strengthen elements of degree programs, research experiences, curriculum, training and workforce development intended to increase interest in research areas and increase the number of students going into research across disciplines and across institutions. The user acceptance testing of UTAUT may provide useful information about the relative likelihood of success of proposed systems early in their development, where such information has greatest value.

From a broader perspective, the value of the outcomes of this study can help to identify an expanded perspective on the challenges to adoption of R&E network technology innovations and ultimately assist in clarifying the value proposition of access to R&E network resources.

CHAPTER 3. METHODS

The study employed Q methodology using a modified form of the UTAUT technology adoption model as the underlying theoretical framework in order to identify opinions of end users regarding challenges to the adoption of R&E network resources for teaching and research at their local institutions. For purposes of this study, challenges identified by the R&E network user community were aligned with those found in the UTAUT study to play significant roles as direct determinants of user acceptance and usage behavior. These were used to develop a framework that served as the basis for a broadly representative Q-set reflecting contemporary challenges specific to R&E network resource adoption. The framework guided the study's focus on the two following research questions:

- What are salient challenges to adoption of Research & Education (R&E) network resources experienced by higher education institutions across the Northern Tier Network Consortium?
- How can knowledge of these challenges serve to inform those who advocate for and champion the use and expansion of these resources, both in the NTNC and peer networks across the U.S.?

Research Design

The research design for this study applied Q methodology to the established theoretical framework of the UTAUT technology adoption model, which was augmented to incorporate specific elements relative to R&E network resources and technologies. The design of the instrument referenced this modified UTAUT model to develop Q-sample statements (i.e., the Q-set) reflective of the research themes. The concourse encompassed both the behavior determinants identified by the UTAUT model, as well as those identified by the researcher based

on experience and knowledge within the R&E community. The Q-set included a balanced representation of statements on the UTAUT determinants and the researcher-identified themes.

Originally developed through an adaptation of the quantitative technique known as factor analysis, the history of Q methodology dates back to 1935 when it was first introduced by William Stephenson and then described by his widely referenced book, *The study of behavior: Q technique and its methodology* (1936). The intriguing and unique element of Q methodology is the practice of "inverting" the typical factor analytic procedure, allowing the research elements, rather than the participants, to become the study sample. In this method, the variables were the different persons who participated in the study. This allowed the study to identify correlations between persons or whole aspects of persons. Stephenson (1936b, as cited in Watts & Stenner, 2012) indicated that this process results in the persons, traits, or other type of variables, to load onto the emergent factors of an inverted factor analytic study.

Q methodology looks for correlations between subjects (participants) across a sample of variables. Q factor analysis reduces the many individual viewpoints of the subjects down to a few factors, which are claimed to represent shared ways of thinking. It is important to note that Q methodology does not claim to identify perspectives of individuals that are consistent across a period of time, but rather that the participants did identify these viewpoints at a particular point in time (Watts & Stenner, 2012).

The decision to apply Q methodology to this study was justified in two primary areas. First, applying the Q technique to an investigation targeted at revealing the most salient themes surrounding the challenges to adoption of R&E network resources supported by higher education institutions in rural America will serve to inform those tasked with ensuring the deployment of equitable access to R&E resources. This concept is important to both sides of the discussion,

whether it is for education and work force training, such as is relevant to the higher education community described in this study, or to those working to accomplish the larger overarching goal of achieving ubiquitous access to network resources by populations located in rural and remote areas of the U.S. This process applied inductive reasoning, moving from conclusions gathered from a specific population and generalizing to the larger R&E community through the process of gathering the evidence, seeking patterns in the responses, and forming hypotheses based on what is uncovered through the analysis process.

Second, applying Q methodology to an established technology adoption model that has been expanded/modified to include themes relevant to R&E resource technologies describes one of several ways in which this research adds to the existing body of literature on this type of research design and methodology. The literature review conducted as a foundation to the development of this study did not find existing research using a similar methodology or context.

Elements of Q Methodology

Individual elements that comprise the foundation of Q methodology along with the sequential steps in the research process are discussed below.

Defining the Concourse

In order to develop the themes around which to base statements for this study, the researcher referenced the framework provided by UTAUT as a basis for building the initial concourse. This process consisted of modifying the context of the behavior determinants identified in the UTAUT model to include elements germane to the adoption of R&E network resources. The results served to elevate this theme as the primary focus of the study.

The source of the expanded content specific to R&E network resources was derived from the researchers' experiences in this field. The items were identified based on emergent common

themes identified by R&Es in the U.S. at the time of this study. They were further confirmed through findings identified as limitations to the current configuration of advanced cyberinfrastructure resources (Monaco et al. 2016).

Condition of Instruction

The guiding question that served as the condition of instruction for the sorting task closely followed the intent of the study: "*How closely does this statement reflect your personal views and opinions regarding your institution's adoption rates of R&E network technologies?*"

Development of the Q-Set

True to the nature of Q methodology, development of the Q-set is critical in order to reveal operant subjectivity on the identified study themes. Construction of the Q-set for this study was achieved by developing statements aligned to each of the determinants included in the UTAUT framework, and then modifying and expanding them to encompass the context of adoption and use of R&E network resources. See Table 3.1 for a brief overview of the theoretical framework. Refer to Appendix A for the detailed description and alignment of the Q statements with the theoretical framework.

Table 3.1

Framework for Q-Set Development

Construct	Description	Root constructs	R&E adoption challenges
Performance expectancy	The degree to which an individual believes that using the system will help him or her to attain gains in job performance.	Perceived usefulness Extrinsic motivation Job-fit Re-invention Relative advantage Outcome expectations	Performance expectancy relevant to the benefits for work/research is often at low levels for both researchers and IT personnel.
Effort expectancy	The degree of ease associated with the use of the system.	Perceived ease of use Complexity Ease of use	Users (of R&E resources) frequently believe the level of effort required to access and obtain the service will be higher if they are located at smaller, more rural institutions.
Social influence	The degree to which an individual perceives that important others believe he or she should use the new system.	Subjective norm Social factors Image	Institutional/discipline/collegial influences impact motivation of individual researchers to seek out these resources at their home institution.
Facilitating conditions	The degree to which an individual believes that an organizational and technical infrastructure exists to support use of the system.	Perceived behavioral control Facilitating conditions Compatibility	Adequacy of IT resources to support advanced scientific research.

This method of Q-set development is referred to as a structured sample, since the statements are systematically composed based on an established theoretical framework while at the same time providing the opportunity to test existing theories on a theme previously unresearched (McKeown & Thomas, 2013). The patterns and themes that emerge through analysis of Q-sort results support an inductive approach toward analysis and results of the study.

Vetting of the Q-Set

Prior to commencement of the research study, the Q-set was vetted by experts in the community of R&E networks. Each reviewer was provided with copies of the study proposal, the Q statements, and condition of instruction. Reviewers invited to vet the Q-sort included representatives within the following roles:

- Faculty/Researchers from the Education Doctoral Program at North Dakota State University
- IT Leadership from a public land grant institution within the NTNC region
- IT Leadership from a national R&E network organization

Feedback provided to the researcher as a result of this review was used to further edit and refine the methodology, design, and research instrument prior to commencing with the full study.

Sampling Procedures: P-Set

Participant selection for the study was directed by theoretical considerations and is therefore considered nonrandom; specifically, this used purposive sampling where participants are specifically chosen based on their relevance and relationship to the goals of the study (McKeown & Thomas, 2013).

The participants (referred to as the *P-set* in Q methodology jargon) for this study included IT leadership at public higher education institutions and Tribal Colleges and Universities of the Northern Tier Network Consortium, which is located in 13-member states spanning the upper

great plains, Pacific northwest and Alaska. The sampling scheme is shown in Table 3.2. In reference to the impact on adoption held by both change agents and opinion leaders described by Rogers (2003), the sampling for this P-set allows representation by those who would be perceived as change agents more external to the system (IT leadership). The TCU participants were representative of institutions in the ten of the NTNC states where TCUs are located. Public institutions were represented by one member of IT Leadership. The target of 55 participants represented current organizational structures where use of R&E resources was emergent or already in place. The selection of this population ensured that opinions were collected from a deliberate representation of the population, although it cannot confirm that the viewpoints exhausted the full range of attitudes on this topic (McKeown & Thomas, 2013).

Table 3.2

Participant Sampling Scheme

Type of institution	Number of targeted participants/institutions
Tribal college	29
Public institutions	26

Demographics of Participant Institutions

Demographic information of the identified study participants is shown in Table 3.3. Participants represented nine of the thirteen members states in the NTNC. Of the 55 participants originally invited to participate, 23 responded and completed a Q-sort representing their institution. The institutions are listed in order of Q-sort completion. Information provided for each participant included the size based on the number of institutional IT staff, identification of those that are land grant institutions and Tribal College and Universities, and the population of the town or community in which the institution is located.

Table 3.3

Demographics of the P-Set

Q-sort	Type of institution[a]	IT staff size[b]	Local town/community population
01	LG	L	23,938
02	LG	L	23,938
03	PR	L	10,772
04	TC	S	840
05	TC	S	1,814
06	TC	S	14,354
07	TC	S	25,847
08	TC	S	72,865
09	TC	S	13,000
10	TC	S	199
11	LG	L	255,214
12	TC	S	89,045
13	LG	L	122,359
14	PR	L	168,916
15	PR	L	73,340
16	PR	L	57,056
17	N/A	M	N/A
18	PR	L	73,340
19	PR	M	13,029
20	LG	L	294,356
21	PR	L	25,847
22	LG	L	48,844
23	PR	L	21,076

[a] TC = tribal college, LG = land grant, PR = public research.

[b] S = small (20 or fewer), M = medium (21 to 50), L = large (51 or more).

Data Collection: Q-Sorting

Q methodology employs the Q-sort, a prearranged frequency distribution, also referred to as forced or forced-choice. The results provide operant subjectivity, where study participants provide their unique perspectives and opinions on an issue. Each participant was asked to rank-order a set of statements on a continuum ranging from agree to disagree. All statements must be ranked, relative to the others.

When a person was invited to participate in the study, their access to the research instrument was provided via an internet web link for the web site where the electronic instrument

was located. Instructions for accessing and completing the online Q-sort process were provided on the site.

It was recommended that the participant start the process by reading through the Q-set statements and then proceed to complete an initial sort of the statements by categorizing statements into essentially three areas. One area represents statements with which the participant strongly agrees. Another represents statements with which the participant strongly disagrees. A third area holds those statements toward which the participant is the most neutral or ambivalent.

The participant then moves on to complete a forced choice distribution of all of the statements, where those to the far right of the grid represent the statements which are most characteristic of their attitude (+5). Those to the far left of middle are those which are most uncharacteristic of their attitude (-5). The rest of the statements must be placed somewhere in the middle section of the grid, matching the participants' strength of attitude toward the particular topic. It is recommended that participants follow this order of sorting since it is typically easier for participants to readily identify those statements that elicit strong feelings. Once those statements have been placed on the grid, attention can be turned toward those remaining and how to categorize them in a position that best matches the participant's opinion on each topic.

In addition to the Q-sort, data was also collected through a demographic survey, and from responses to follow-up questions asked during a phone interview. Results of follow up instruments served to further enlighten the instrument development and interpretation of results.

Q-Sort Response Distribution Table

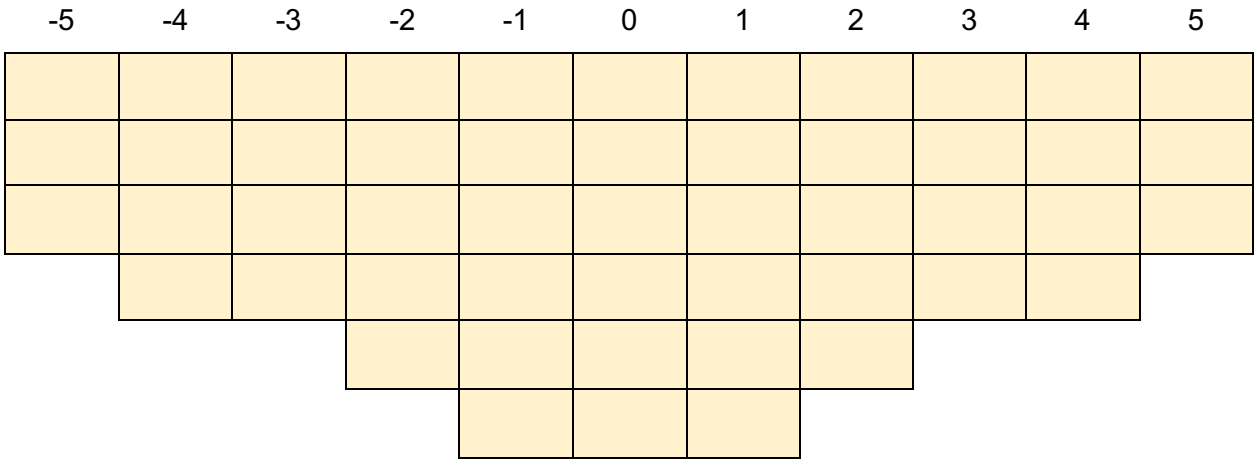
The nature of the study dictates the range of a distribution (i.e., the width of the Q-sort response scale) and the total number of Q statements. In his discussion on technical procedures for applications of this methodology in political science, Brown (1980) suggests that when most

participants in a study are expected to be relatively uniformed or uninterested in the topic of discussion, a more normalized distribution table is appropriate. However, when the opposite is true, and the topic is likely well known and controversial, there is likely to be less ambivalence toward the topic, thus a more flattened (platykurtic) distribution is used so participants are able to categorize more of the statements at either extreme of the continuum. Guidance by Brown (1980) also indicates that Q-sets with 40 to 60 items should use a distribution range of +5 to -5 with a relatively average flattened distribution.

For purposes of this study, the topic was perceived to be held in general awareness by most of the participants, with a portion having more or less awareness, depending on their role. Likewise, the topic was not likely to be perceived as overly controversial. With an anticipated P-set consisting of approximately 55 participants, and a Q statement list anticipated to be at 50, the response distribution table for this study would consist of a distribution range of +5 to -5 with an average or normal distribution curve, as indicated in Figure 3.1.

Figure 3.1

Q-sort forced response distribution table developed to accommodate a Q-set of n = 50 statements



Note: Statements are scored according to the values shown at the top of each table column.

Data Analysis

Collected Q-sort data was analyzed using a three-step process: correlation, Q-factor analysis, and the computation of factor scores (McKeown & Thomas, 2013). To begin, completed participant Q-sort data was coded with score values ranging from -5 (most uncharacteristic) to +5 (most characteristic) according to the placement in the response table (Figure 3.1). The statement scores were logged to preserve a record for responses of each study participant. Analysis at this phase consisted of computation of the Pearson product-moment correlation for each pair of Q-sorts, which produces the initial correlation matrix. The most appropriate number of factors to retain was then determined, and those factors were extracted from the correlation matrix using the principal components method and rotated to a final solution using the varimax procedure.

Q-factor analysis is the critical element in the statistical analysis of Q-sort data. This is the process through which participants can begin to be grouped based on their unique responses to the Q-sort. It is important to note that analysis is not an attempt to identify participants with similar perspectives or opinions, but rather, to identify the particular perspectives and opinions that become most salient, and identified as factors to be further analyzed. Review of the results focused initially and primarily on the theoretical significance of the emergent factors, in consideration of the context of the study theme.

The computation of factor scores is further evidenced in the theoretical arrays based on the empirical generalizations of specific viewpoints held by individuals whose Q-sorts significantly loaded on the same factor. It is this information that allows the researcher to understand the operant subjectivity that emerges as a result of the analysis (McKeown & Thomas, 2013).

CHAPTER 4. RESULTS

This chapter includes a brief overview of the specialized methods used to complete data collection, statistical and qualitative analysis. Results are provided, followed by an in-depth interpretation of the findings in the context of the theoretical framework and the research questions.

Study Overview

This research study employed Q methodology using a modified form of the Unified Theory of Acceptance and Use of Technology (UTAUT) model as the underlying theoretical framework. The framework guided the process to identify common perspectives of IT leadership regarding challenges to the adoption of R&E network resources used for teaching and research at their respective institutions. Issues identified by the researcher as potential challenges to adoption of R&E network technologies were aligned with the constructs found in UTAUT research to play significant roles as direct determinants of user acceptance and usage behavior. The key concepts and themes formulated in the UTAUT were used to develop a framework that provided a basis for a broadly representative set of descriptive statements (collectively known as the *Q-set*) reflecting contemporary challenges specific to R&E network resource adoption. A sample of purposively selected IT administrators from member institutions of the Northern Tier Network Consortium served as the participants (known as the *P-set*) in this study. Members of the P-set individually ranked each statement in the Q-set across a fixed response continuum according to how closely they felt a statement, also referred to as an *item*, characterized the end users at their respective institutions. The ranking data from participants (known as the *Q-sorts*) were correlated and factor analysis was completed. The emergent factors represent archetypal perspectives regarding the relevant issues.

Data Collection

Data collection ran from March through May of 2019 via an interactive online tool developed specifically for collecting Q-sort data. Complete records were collected from a final P-set of $p = 23$ participants.

The first and most important phase of data collection is the sorting task, which is a carefully structured process where each participant ranks the items of the Q-set that consisted of $n = 50$ statements in this study. The sorting task is framed by a guiding question, known as the *condition of instruction*, to ensure that the ranking process is based on each participants' unique perspectives in the appropriate setting and context. The following question was the condition of instruction used in this study: "How closely does this statement reflect your personal views and opinions regarding your institution's adoption rates of R&E network technologies?" Participants ranked each statement relative to all other statements in a forced-choice process using a graphical representation of a fixed response distribution table (see Figure 3.1). Participants sorted the statements in the Q-set by placing the statements into the response table. The placement of a statement to the left or right of other statements in the table is a relative indicater of how closely the statement reflects a participant's attitude, less or more, respectively. Responses for each statement are scored according to its horizontal position in the table. As shown in Figure 3.1, there are 11 columns in the response table used in this study scored from -5 to +5 from left to right (i.e., from less to more characteristic).

Upon completion of the sorting task, participants were asked to provide narrative feedback with any insights regarding their three highest and three lowest ranked statements. This was followed by two basic institutional demographic questions. First, participants were asked for the names of their institutions. This information was needed only to establish general profiles of

the institutions. While this piece of information could potentially compromise anonymity, participants were assured of confidentiality. Second, participants were asked to estimate the number of IT staff at their respective institutions (up to 20, 21 to 50, 51 or more). The data collection process for each participant concluded by asking for volunteers for a brief follow-up interview at a later date to further discuss and clarify their responses.

Q-Factor Analysis

The statistical technique used in Q methodology is a specific form of exploratory factor analysis known as Q-factor analysis. The forced ranking of statements provided by participants results in a data set representing their subjective perspectives. This serves to highlight the psychological significance of items in a Q-sort relative to each participant and further defines and standardizes the nature of this significance within the study (Watts & Stenner, 2012).

Statistical analysis of the Q-sort data collected for this study was conducted with KADE (version 1.1.0), a desktop application developed by Shawn Banasick (2019) specifically for Q-factor analysis. Analysis proceeds through a series of statistical and qualitative steps, the layers of which ultimately provided the researcher with insights into challenges to adoption of R&E network resources at the participants' local institutions. Analysis began with the computation of a correlation matrix for the Q-sorts, on which Q-factor analysis was completed. This process is intended to extract a set of factors from the correlation matrix. The results of the model serve to facilitate the qualitative methods applied next, where factor arrays are constructed in order to provide a visual representation of archetypal Q-sorts that exemplify the perspectives that characterize each factor. Completion of the analysis is achieved from reviewing insights revealed by consensus and distinguishing statements for the group of extracted factors, along with information revealed from demographic and anecdotal information provided by post Q-sort

survey questions and participant interviews. This additional data serves to fill the gaps left unexplained from quantitative data, fleshing out a more complete description of participant views. A detailed discussion of the analysis process is provided in the following sections.

Correlation Matrix for the Q-Sorts

Analysis begins with the computation of a correlation matrix containing the Pearson product-moment correlations of each pair of Q-sorts—i.e., bivariate correlations are computed between pairs of participants, or more specifically, their Q-sorts. The complete 23 × 23 correlation matrix for the Q-sorts collected in this study is provided in Appendix B. Analysis of the correlation matrix enables the researcher to identify those Q-sort groups that are highly intercorrelated and as well as those that have very low correlations (Watts & Stenner, 2012). Q-factor analysis ultimately results in a description of the most prominent groups of common viewpoints (Watts & Stenner, 2012).

Selecting Methods for Factor Extraction and Rotation

Two critical decisions are required by the researcher once the correlation matrix has been computed. Several methods for factor extraction and rotation are available and should be considered carefully in light of the scope and intent of the study. Much of the debate on the most appropriate methods for factor extraction and rotation have their foundations in the comparison between the data reduction techniques demonstrated in R factor analysis and Q methodology. While the intent of the data reduction method commonly applied in R is to maximize the separation of factors and arrive at the simplest factor structure, it must be emphasized that this outcome is the product of a mathematical process, accounting for little if any of the theoretical underpinnings of a study. The intent for the value of Q methodology as envisioned by its originator, William Stephenson (1936), was to develop a model that would turn the spotlight on

the qualitative and theoretical considerations of the research study in question, thereby further illuminating findings suggested in the statistical results through the use of observation and interpretation, along with consideration of alternative explanations not evident in analysis of mathematical results only, thus his preference toward centroid and theoretical rotation methods (Ramlo, 2016).

The debate continues and practical rationale on both sides of the argument are easily sourced. In selecting the methods for extraction and rotation of factors in this study, a determination was made by the researcher to use principal components extraction and varimax rotation, thus ensuring the study would focus more on statistical and mathematically derived findings, as opposed to allowing the theoretical underpinnings of the study to take center stage. Closely associated to factor extraction is the rotation of factors to further improve interpretability. According to Akhtar-Danesh (2016) theoretical rotation, also referred to as manual or judgmental rotation, is a method that is known to generally lead to subjective rather than objective results since it allows researchers to manipulate factor rotation around some predetermined theoretical context. This can further influence analysis, since it allows rotation to continue until some convincing solution is found, leading to a subjective, data-driven solution. Again for this reason, varimax was chosen for factor rotation where the focus is on a technique that maximizes the variance of each factor loading.

Other considerations were also taken into account in selecting principal components analysis (PCA) for factor extraction and varimax as the method for factor rotation. Central to the debate between the various methods is that a distinctive difference between PCA and other methods including the traditionally used centroid method is that PCA consistently provides results that are more orthogonal rather than not. While the argument against PCA for its more

purely statistical outcomes is understandable within the discussion regarding theoretical criteria, further critical consideration is necessary when compared within the context of the specific research at hand (Akhtar-Danesh, 2016; Ramlo, 2016).

Exploratory factor analysis methods like Q are typically applied to the early stages of research where efforts to determine data classification and hypothesis generation are a primary focus (Akhtar-Danesh, 2016). Since the literature review conducted in preparation for this study did not reveal any existing studies on this topic combined with this specific user group it was determined that this research could provide initial foundational results to the benefit of the user community. While researcher bias was also a concern, as discussed next, it was believed there would be value in the study's ability to definitively articulate a spectrum of existing unique perspectives on this topic.

Also supporting the decision to use these methods of factor extraction and rotation is that of the researcher's own pro-innovation bias which could interfere in the process of data analysis. Discussed in length in other sections of this paper, the researcher's positionality within this field could impose the threat of pro-innovation bias and was considered to be a relevant challenge to this study. Both the development of the research focus and subsequent methodology were heavily dependent on the researcher's long-term experience and knowledge of the study topic. Development of the Q concourse and the choices of statements included in the Q set were firmly based in the researcher's knowledge base and as a consequence, were also likely to encompass a strong subjective viewpoint of the researcher. Given these considerations, concern that the Q statements and Q sort analysis could easily be influenced by the perspective of the researcher is relevant to the decision to choose PCA. It was important that any subjective views of the

researcher did not inadvertently influence results. Orthogonality of the factors appeared to provide a more clear and decisive vision of the results from which interpretation follows.

Factor Extraction

The step in Q-factor analysis of factor extraction essentially serves as a process to decompose the correlation matrix into constituent parts that ultimately present the factors. The factor extraction process is a data-reduction process that condenses the Q-sorts into factors—that is, it reduces the original number of Q-sorts (participants) into a concise yet representative set of factors that best capture the major common themes and similar perspectives among the participants.

Each participant has varying levels of affinity or similarity to the factors. This relationship of a Q-sort to a factor is expressed as a bivariate correlation, otherwise known as a *pattern coefficient* or *loading* in factor analysis jargon. Ultimately, the factors provide a way to classify participants into groups of similar subjective viewpoints (Watts & Stenner, 2012).

Principal component analysis (PCA) was used as the specific method of factor extraction in this study. As previously described, there are other extraction methods, but they typically return very similar results (Watts & Stenner, 2012). Further, PCA is the current extraction technique of choice within the research community. Although technically PCA produces a new set of variables known as *components*, the general term *factor* is used in this manuscript (and in the research literature in general).

Initial Factor Extraction

The factor extraction process begins with the eigenanalysis of the correlation matrix. The primary purpose of this step is to determine the most appropriate number of factors to retain for full analysis; thus, more factors than are reasonably needed are initially extracted, usually seven

or eight candidate factors (Brown, 1980). The analytical software used in this study (KADE) defaults to eight as the initial number of factors to extract.

These first eight candidate factors were extracted as a matrix of factor loadings, which are measures of the initial association (correlation) of each Q-sort with each factor (Watts & Stenner, 2012). This initial loading matrix is said to be unrotated in order to distinguish it from the final version of the loading matrix which retains only a subset of the eight candidate factors and undergoes subsequent analytical rotation. The complete initial loading matrix is given in Appendix C.

The initial extraction also provides the first eight eigenvalues (characteristic roots) of the correlation matrix. In factor analysis, the eigenvalues are computed as the sums of squared loadings for each column in the loading matrix; in other words, it is the sum of the r^2 values for a factor and all Q-sorts. Thus, an eigenvalue represents the total proportion of variance in the observed variables (Q-sorts) that can be linked to a factor. The eigenvalues from the correlation matrix are important in determining the number of factors to retain. The first eight eigenvalues for this study are given in Table 4.1.

Table 4.1

First Eight Eigenvalues from the Correlation Matrix

Factor	Eigenvalue	Proportion of variance extracted	Cumulative proportion of variance
1	6.39243	.2779	.2779
2	2.98791	.1299	.4078
3	1.69338	.0736	.4815
4	1.65819	.0721	.5536
5	1.29722	.0564	.6100
6	1.23538	.0537	.6637
7	0.99951	.0435	.7071
8	0.95522	.0415	.7487

Note. Principal-components extraction.

Determining the Number of Factors to Retain

There are numerous approaches that are helpful in determining the appropriate number of factors to retain. The following methods were applied to the data from this study: (a) Kaiser-Guttman criterion, (b) proportion of variance extracted, (c) scree test, (d) parallel analysis, and (e) interpretability. The results from each of these techniques are described below.

Kaiser-Guttman Criterion. Also known as Kaiser's rule and K1, this basic guideline for the number of factors to retain operates on the eigenvalues from the correlation matrix. Factors corresponding to eigenvalues greater than 1.0 are considered to be substantial and meaningful; those with eigenvalues of lesser magnitude are considered too weak to merit serious attention (Guttman, 1954; Kaiser, 1960, as cited by Watts & Stenner, 2012). However, Kaiser's rule is known to overextract (i.e., produce too many factors; McKeown & Thomas, 2013). As can be seen from the eigenvalues given in Table 4.1, the Kaiser rule indicates six factors for the present data set.

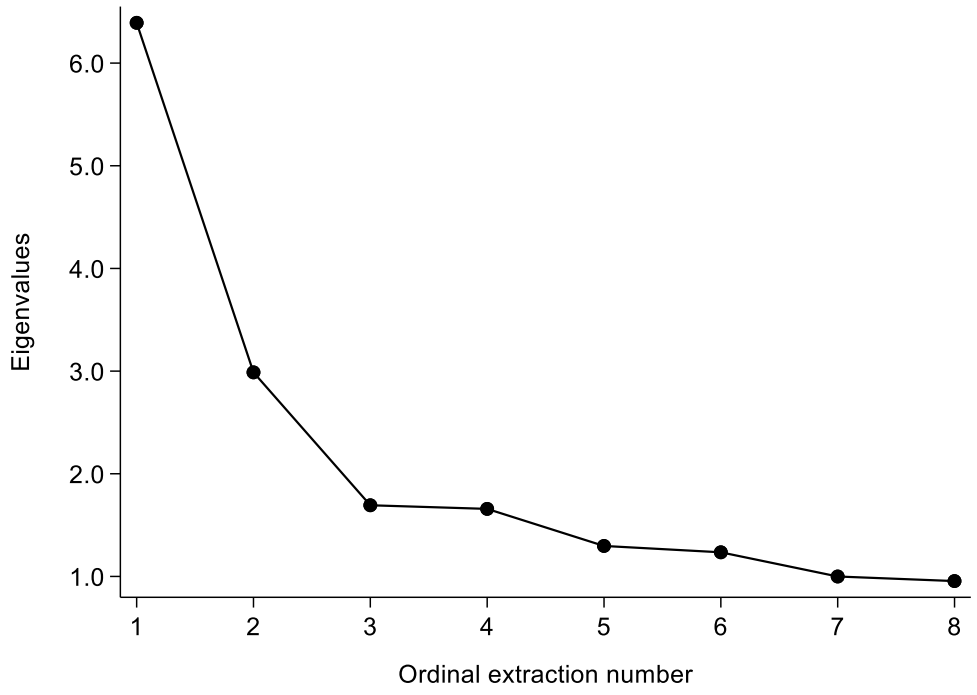
Proportion of Variance Extracted. The eigenvalue for a factor is essentially the sum of the proportion of variance accounted for by that factor in all the Q-sorts. Ideally, a set of factors should account for as much of the variability in the original Q-sorts as possible (Brown, 1980). This provides a clear indication of the stability and potential explanatory power of a set of extracted factors (Watts & Stenner, 2012). So, it follows that greater eigenvalues are generally considered a good sign. Although there is not an absolute criterion, a set of factors accounting for at least 40% of the variability observed in the Q-sorts is typically considered a sound and stable factor solution (Kline, 1994). The cumulative proportion of variance extracted shown in Table

4.1 indicates that two factors should be extracted to meet this basic criterion (41%). It is worth noting that three factors account for nearly 50% of the total observed variance in the Q-sorts.

Scree Test. This classical approach (Cattell, 1966) provides guidance on choosing an appropriate number of factors to retain by using a simple ordinal plot of eigenvalues (more commonly known as a scree plot). The basic idea is to find the point that best separates the "mountain" from the "scree" (residual rock fragments and debris) in the graph; in other words, retain the factors whose eigenvalues appear to make a distinctive upward break away from the relatively flat scree pattern when inspecting the graph of eigenvalues from right to left. The scree plot for the first eight eigenvalues from this study is shown in Figure 4.1. A clear break occurs between Factors 2 and 3, indicating a two-factor solution.

Figure 4.1

Scree plot of the first eight eigenvalues from the correlation matrix

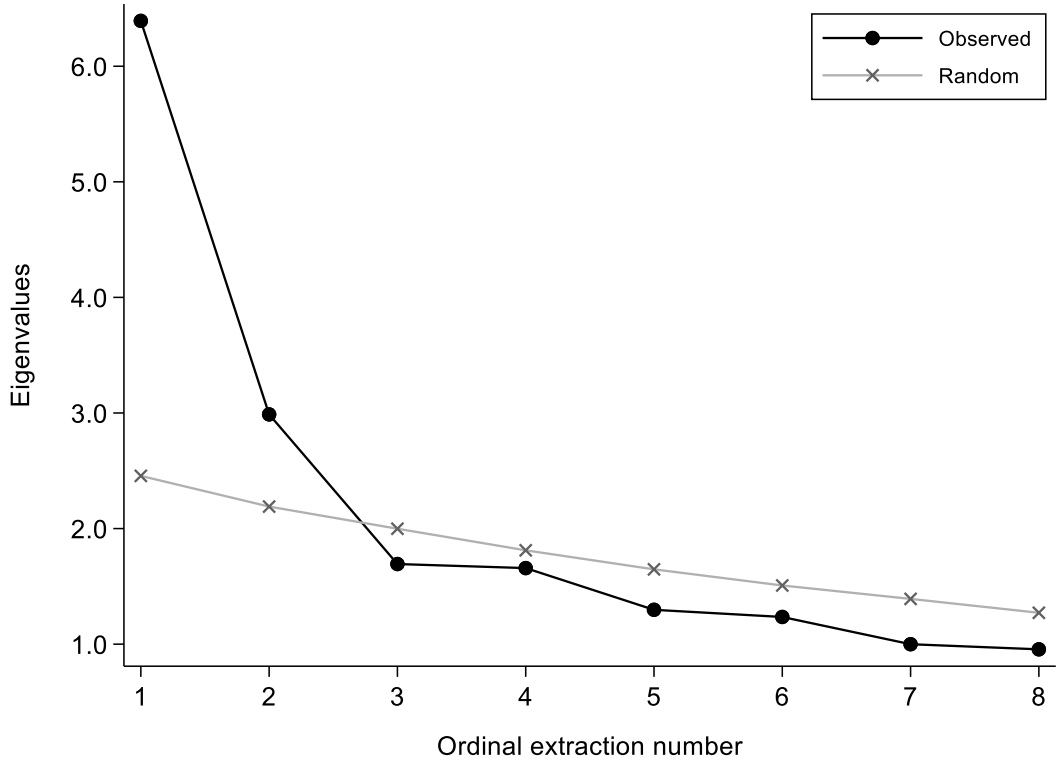


Note: The ordinal extraction number is on the horizontal axis, and the magnitude of the eigenvalues is on the vertical axis.

Parallel Analysis. This approach is essentially a more sophisticated version of the Kaiser-Guttman criterion where the observed eigenvalues from the correlation matrix are compared to a set of mean eigenvalues derived from randomly generated data based on the same numbers of participants and statements (i.e., parallel null data sets). The number of factors to retain is indicated by the number of observed eigenvalues from the real data that exceed their random counterparts. The results of the parallel analysis for this study (Figure 4.2) suggest that two factors should be retained.

Figure 4.2

Graph of the first eight eigenvalues from the observed data set and the mean eigenvalues from the random parallel data sets (100 replications)



Note: This plot indicates that two factors should be retained.

Interpretability. Although it is fairly subjective, the interpretability and substantive meaningfulness of the results is perhaps the most important criterion for determining the number

of factors to retain. This requires a preliminary "peek" ahead at the next step in the process known as *factor rotation* in order to examine each of the rotated loading matrices for the various potential solutions. In this study, the two-, three-, and four-factor solutions were determined to be the most reasonable in terms of interpretability. Of these, the three-factor solution proved to be the most meaningful. This solution addresses several distinct characteristics across the three groups of Q-sorts loading on each factor. Adding a fourth factor resulted in repositioning only a few Q-sorts and served to diminish defining characteristics for each factor. Three factors are therefore the most parsimonious yet meaningful solution.

Final Factor Extraction

A summary of the results from each of the number-of-factor tests is provided in Table 4.2. Overall, these tests suggest that at least two factors should be retained.

Table 4.2

Summary of the Number-of-Factor Tests

Test	Number of factors indicated
Kaiser-Guttman criterion	6
CPVE $\geq$ 40%	At least 2
Scree test	2
Parallel analysis	2
Interpretability	2, 3*, and 4

* The three-factor solution was deemed the most meaningful.

A summary of the key features of the three most reasonable factor solutions (namely, two, three, and four factors) is given in Table 4.3.

Table 4.3

Comparison of Various Factor Extraction Solutions

Solution property	Number of factors		
	2	3	4
Cumulative proportion of variance extracted	40.8%	48.2%	55.4%
Number of defining sorts per factor	13, 10	12, 7, 3	10, 4, 4, 5
Number sorts not flagged	0	1	0
Greatest correlation among factors	.288	.273	.433

Note. All factor extractions were completed using the principal components method followed by varimax rotation.

While the two-, three-, and four-factor models were all viable solutions, the three-factor solution was chosen as the best model for analysis in this study. This decision was based on a review of results from the five number-of-factor criteria discussed previously. Although many of the tests indicated the two-factor solution, that model barely met the recommended minimum 40% criterion for the cumulative proportion of variance extracted (40.8%), while the three-factor solution explains nearly half of the observed variance (48.2%). Further, the three-factor model shows low correlations among the three factors (max $r = .273$), indicating the unique perspectives of each factor group; the four-factor solution has factors that correlate as much as $r = .433$. Finally, and perhaps most importantly, the three-factor solution was judged to be the most meaningful and interpretable. Adding a fourth factor resulted in repositioning only a few Q-sorts and served to diminish defining characteristics for each factor. Thus, the three-factor model is both parsimonious and meaningful.

Factor Rotation and Flagging the Defining Sorts

The goal of factor rotation is to simplify and clarify the relationships among the factors and the Q-sorts. Ideally, this will result in what is known as simple structure of the loading matrix where each Q-sort will have only one large (salient) loading on a factor and very small

(ideally near zero) loadings on the remaining factors—i.e., each participant would be strongly associated with only one factor. Of course, the data do not always allow for simple structure to occur. Varimax, a popular analytical rotation algorithm, was used in this study and described previously in more detail. Varimax is typically the preferred method used in Q-factor analysis (Watts & Stenner, 2012).

Following rotation, the next step is to identify those participants whose Q-sorts exemplify each of the given factors. Such individuals (and their Q-sorts) are more commonly known as *defining sorts*. This process is known as *flagging*, and Q-sorts that have been identified as a defining sort for a factor are said to be *flagged*. A Q-sort *i* is initially identified as belonging to factor *j* if the squared loading of the Q-sort on that factor (a_{ij}^2) accounts for at least 50% of the communality of the sort (communality, h_i^2, is the sum of squared loading for a given Q-sort across all factors in the solution). So, if the criterion

$$\frac{a_{ij}^2}{h_i^2} > .50$$

is met, then sort *i* is deemed a defining sort for factor *j*. Note that this criterion prevents a Q-sort from being a defining sort for more than one factor (which are not useful as defining sorts). Additionally, a nominal level of salience was set at .45 for the loadings; all loadings for defining sorts met this criterion. Three factors account for 22 of the 23 completed Q-sorts (see Table 4.4); only one Q-sort (participant #4) was not flagged as a defining sort for any of the factors. True to the intent and design of Q methodology, what began as a group of p = 23 participant Q-sorts providing individual perspectives has now been reduced to three general viewpoints (factors) that can be further analyzed to provide more specific insights and details on the actual meaning of the three factors.

Table 4.4

Factor Loading Matrix (Rotated) with Defining Sorts Flagged

Q-sort	Inst. type[a]	IT staff size[b]	Factors[c]		
			1	2	3
01	LG	L	0.2624	0.1730	0.3377 X
02	LG	L	0.1100	0.0507	0.7408 X
03	PR	L	0.3456	0.5800 X	0.2636
04	TC	S	-0.3410	-0.3496	0.4584
05	TC	S	0.7154 X	-0.1257	-0.1049
06	TC	S	0.6911 X	0.1451	-0.2511
07	TC	S	0.1297	0.5360 X	-0.0025
08	TC	S	0.0480	0.2031	0.6550 X
09	TC	S	0.5754 X	0.2813	0.2755
10	TC	S	0.7901 X	0.1020	-0.0046
11	LG	L	0.4005	0.6613 X	0.1683
12	TC	S	-0.0164	0.7631 X	-0.3253
13	LG	L	0.4884 X	0.1339	0.2481
14	PR	L	0.4832 X	0.1831	0.2503
15	PR	L	-0.1446	0.5815 X	0.3987
16	PR	L	0.6899 X	0.1486	0.0092
17	N/A	M	0.5522 X	0.1325	0.1577
18	PR	L	0.1591	0.5010 X	0.1668
19	PR	M	0.6391 X	-0.2595	-0.0322
20	LG	L	-0.3708	0.6277 X	0.2593
21	PR	L	0.6119 X	0.4869	0.1200
22	LG	L	0.6198 X	0.3631	0.1854
23	PR	L	0.6649 X	0.0222	0.0367
Proportion of variance extracted:			27.8%	13.0%	7.4%
Cumulative proportion of variance extracted:			27.8%	40.8%	48.2%

Note. Varimax rotation. Participant #04 is the only non-flagged Q-sort.

[a] TC = tribal college, LG = land grant, PR = public research.

[b] S = Small (20 or fewer), M = Medium (21 to 50), L = Large (51 or more).

[c] X denotes a defining sort for the indicated factor.

Computing the Factor Score Estimates

The purpose behind creating and defining the factor-score estimates is to identify those Q-sorts that most closely align to or share the viewpoint of the identified factors. The process to

create factor-score estimates begins with the calculation of relevant factor weights for all of the Q-sorts that load significantly on each factor.

Since factor estimates are also based on averages, reliability increases, and averages are stabilized as the number of Q-sorts increases. For this study, the number of Q-sorts for each of the three factors further ensures increased factor reliability. Reliability and error measurements for each of the factor arrays are presented in Table 4.5.

Table 4.5

Factor-Score Characteristics

Property	Factor 1	Factor 2	Factor 3
Number of Defining Sorts	12	7	3
Composite Reliability	0.98	0.966	0.923
S.E. of Factor Z-scores	0.141	0.184	0.277

Assembling the Theoretical Arrays

But what do these newly surfaced individual factors or groups of Q-sorts actually look like? What story do they tell and what insights do they provide about the respondents who completed the Q-sorts in a given study? The creation of a theoretical array for each of the identified factors is an attempt to visualize as closely as possible an example of how the Q-sorts for each factor appear on a distribution table. A theoretical array is a hypothetical Q-sort that is essentially an average of the factor's defining sorts. In this way, it is an archetype that represents the general perspectives expressed in a factor. It should go without saying that it is extremely unlikely that any single observed Q-sort in a study is going to correspond perfectly with the distribution derived for the theoretical array of its identified factor. The factor estimates provided through the steps conducted prior to this intend to provide a likely distribution of statements that matches as closely as possible to the Q-sorts identified for each factor.

An analysis of the overall perspectives or viewpoints of Q-sorts within each factor proceeds with an effort to normalize scores for each Q-sort. Calculating the z-scores for items in each factor allows for cross-factor comparisons that provide this high-level assessment. The correlations among the scores of factors identified in this three-factor solution indicate factor correlations ranging from 0.2024 to 0.2725, as seen in Table 4.6. These correlations are considered to be low to moderate and further confirm the existence of the three unique perspectives held by the groups within this study**.** Higher correlations would indicate that too many factors have been extracted and a more favorable solution would be to merge factors. Referencing a protocol set by Cohen (1988), these results also indicate slight correlations.

Table 4.6

Correlations Among the Factors

	Factor 1	Factor 2
Factor 2	0.2725	
Factor 3	0.2024	0.2572

Standardized (*z*) scores are central to the ability of the researcher to assemble an array for each identified factor. Scores for Q-sorts in each factor are assembled in rank order from highest to lowest and that list is then used to arrange the items in an array or example distribution table for each factor. Within each factor, those Q-sorts with the highest z-scores indicate those statements the factor participants placed at the highest or most positive side of the distribution table. Likewise, the Q-sorts with the lowest z-scores indicate those statements the factor participants placed at the lowest or most negative side of the distribution. The resulting distribution, or factor array, is intended to exemplify as closely as possible, how respondents in that factor might have placed the various items on the distribution table.

Post Q-sort Interviews

The statistical phase of Q methodology generates an abundance of mathematically derived output that is intended to maximize the key differences across participant sorts, thereby justifying the classification of participants into unique factors. The challenge going forward is to look beyond these black and white contrasts provided by the statistics and explore the deeper meaning behind the orthogonal positions of each identified group or factor. This additional layer of qualitative analysis provides the ability to determine which information is most relative to the research questions and conceptual framework of the study, and exactly why it is relevant, thereby improving interpretability. To achieve this level of insight and to further support the value and trustworthiness of the study, additional qualitative methods were employed.

For this study, the first step into interpretation beyond the statistical analysis of the individual Q-sorts was to collect additional information about each respondent. To facilitate this portion of data collection, upon completion of their online Q-sort each respondent was asked to continue the online survey by answering a short list of demographic questions about their institution. The final question asked each respondent to indicate if they would be interested in completing a post-sort live interview with the researcher. The resulting data provided information about the respondent's home institution which then enabled the collection of additional identifying characteristics for each site including community population, geographic location, whether the institution has access to a state or regional research and education network, and if the institution is a Tribal College or University, a land-grant institution, or neither.

An appointment for a post-sort phone interview was scheduled for those who had indicated a willingness to participate. Of the twenty-three Q-sort respondents, four indicated a willingness to participate in a post Q-sort interview. Each of the statistically identified factors

was represented in the group of interviewees, with one interviewee representing a Q-sort that loaded positively on Factor 1: Social, one loading positively on Factor 2: Facilitating, and two interviewees loading positively on Factor 3: Performance. In preparation for the interview, the researcher emailed to the respondent a copy of their full Q-sort responses along with a list identifying the three statements they ranked the highest and the three statements they ranked the lowest within their Q-sort. The interviews consisted of discussion addressing four key questions. Each interview began with an initial statement by the researcher to clarify the purpose of the interview followed by an informal discussion guided by questions provided by the researcher. Details of the interview framework are provided below.

Post-sort Interview Questions

- ***The purpose of this interview is to:***
    - Explore each participant's wider understanding of the issue
    - Discover why participants sorted the items as they have
    - Focus on the meaning and significance of particularly important and salient items.

Q1: Explore the meaning of the items you placed at the extremes of the distribution. (Prior to the interview, the researcher emailed to each respondent a copy of their full Q-sort responses along with a list identifying the three statements they ranked the highest and the three statements they ranked the lowest.)

- What does this mean to you, the participant?
- Why do you feel so strongly about them?

Q2: What other items/statements do you have comments about – is there anything striking that you perceived?

- What/why is this significant for you?

Q3: In reflection, did you rank any items in a way that is an anomaly or does not make sense? Why?

Due to the open-ended nature of the interviews, responses to each of the questions frequently crossed into comments that addressed several interview questions. All responses were recorded and compiled by the researcher into a spreadsheet.

This process allowed the researcher to further interpret the factor groupings indicated in the statistical results, cross-referencing them against the demographic information and interview responses. In addition, this analysis was critical for the information provided to the researcher on determining if and how the combination of mathematically derived factor groups and the additional insights gained by the post-sort interviews might reveal characteristics that align to any preconceived theories on adoption challenges specific to the topic of the study. A combined analysis of the post-sort interviews, as well as demographic indicators such as institutional size, community population size, institutional access to a state or regional network, and if the institution was a Tribal College or University, a land-grant institution or neither were all considered in the review of the institutions that comprised each factor.

To ensure the quality of data analyses, several techniques to establish trustworthiness of the study were used. Articulated in what is perceived to be break-through research on qualitative research guidelines, Lincoln & Guba (1985) describe four ways that trustworthiness can be achieved within qualitative research studies. These include credibility, transferability, dependability and confirmability. The techniques recommended by Lincoln & Guba (1985) and employed for this study are identified and described here in further detail.

One characteristic supporting trustworthiness in a study is credibility, described as a confidence in the 'truth' of the findings. For this study, the techniques used to confirm credibility were triangulation and member checking.

Methods triangulation was used in this study to further strengthen a comprehensive account across findings gathered from both the Q-sorts and the post-sort interviews. In addition to the data resulting from completed Q-sorts, each participant was invited to participate in a post-sort interview where further conversation could clarify the reasons behind why they ranked the Q-statements the way they did. Four of the 22 participants agreed to participate and were contacted directly by the researcher. Both the insights gained from the interviews, along with the additional data obtained as a result of the demographics questions at the end of the Q-sort process served to provide additional data sources to further support analysis.

Another technique frequently employed to establish credibility in qualitative research is member checking. Use of this technique typically implies that there exists a central fixed truth or reality and research results are to be compared to that truth (Lincoln/Guba 1985). For this study, member checking for the post-sort interviews was used to explore the reasons behind the respondent's ranking of the three highest and three lowest statements, as indicated in the interview questions listed previously. Beyond this, additional discussion focused on the respondent's statement rankings in comparison to those of theoretical array of their factor group was not conducted in an effort to maintain the unique focus of each respondent and avoid any influence that might impact their perspectives.

Transferability further supports trustworthiness by showing that study results can be applied to other contexts. Applicable to the scope of the community chosen for this study, it is the researcher's belief that further exploration of the challenges to adoption could be employed

by adapting this study for use across other regional networks in order to continue exploration of common themes described by respondents across the broader community. While Q methodology is not intended for use in predicting behavior, the rankings and resulting themes arising from the Q sorts and the respondents' intentions behind their sort results can identify useful information about perceptions of innovations and efforts to strengthen adoption.

Finally, Lincoln and Guba (1985) suggest that trustworthiness can be established through the use of confirmability. Triangulation of multiple data sources again serves this purpose as previously described. In addition, reflexivity by the researcher as the study is designed, implemented and analyzed is important in research outcomes. The preconceptions of the researcher relevant to this study are described in chapter five. The detailed discussion describes the researcher's pro-innovation bias that serves to color the lens through which this study has been designed and implicates the process used to develop all stages of the study, from literature review, on through the methodology and analysis.

Coding Methods Applied

Several coding methods were applied to results of both the quantitative and qualitative data to aid in a more thorough analysis and interpretation. All coding was completed manually and the methods were chosen to correspond to the theoretical framework and goals of the study.

An initial review of the statistical output allowed comparison of the extreme rankings of statements across all of the factors. A type of magnitude coding was completed, indicating the frequency of the appearance of statements categorized in the four UTAUT constructs at both positive and negative extremes for each factor. Magnitude coding is attributed for usefulness in extending and further explaining the intensity, frequency and presence of study data. Serving as

an asset to the trustworthiness of the data, Saldana (2013) emphasizes that analysis resulting from magnitude coding methods enhances the approximate accuracy and texture of the data. The number of statements representative of each of the four UTAUT constructs was counted, selecting only statements ranked toward the negative extreme (-3 to -5), and statements ranked toward the positive extreme (+3 to +5). This process served to improved perspective on how strongly the constructs were represented at both extremes by each of the factors. Results of the first cycle of coding applied to the study data are summarized in Table 4.7.

Table 4.7

Summary of Magnitude Coding for Each Factor, Identified by the Four UTAUT Constructs.

F1	-5	-4	-3	3	4	5	TOTAL per construct
PE	0	0	1	3	3	3	10
EE	2	0	1	0	0	0	3
SI	1	2	1	1	1	0	6
FC	0	2	1	0	0	0	3
F2	-5	-4	-3	3	4	5	
PE	0	1	1	3	3	3	11
EE	2	1	1	0	0	0	4
SI	0	2	1	0	0	0	3
FC	1	0	1	1	1	0	4
F3	-5	-4	-3	3	4	5	
PE	2	2	3	0	2	3	12
EE	1	2	0	1	0	0	4
SI	0	0	1	3	1	0	5
FC	0	0	0	0	1	0	1

Code list: PE = Performance Expectancy; EE = Effort Expectancy; SI = Social Influence; FC =Facilitating Conditions

In order to further clarify and organize the data a subsequent method of coding was completed. This phase encompassed several elements of the crib sheet model developed by Watts & Stenner (2012) which involves a systematic process to interpret each of the factors. For

this study, this process aimed to explore any potential alignment between the three factor groups and the UTAUT constructs. The procedure began with a close review of the extreme statements identified in the first cycle of coding. This process involved several steps. First, a summary of the most salient positive and negative statements from the first cycle of coding was compiled, noting if and how individual statements within a factor aligned or contradicted the other. In addition, this step also included a comparison of those statements especially polarized by one factor from the others. As this step progressed, themes for each of the factor groups emerged and were recorded. A summary of the salient characteristics and the important issues around which each factor is polarized is described later in this chapter. Summaries of factor comparisons in the context of each UTAUT construct are included in Tables 5.1, 5.2, 5.3, and 5.4.

Next, the researcher aligned the participants for each factor with their demographic information and the coding results, looking for any patterns and anomalies in the factors and their arrays. Again, any emergent themes and patterns were recorded. Finally, the resulting analysis and summation of characteristics and themes for each factor group provided a means for assigning a descriptive title to each factor.

Identified Study Factors

Based on analysis of both statistical and qualitative data, each factor was given a descriptive label which is aligned to the four UTAUT constructs used as part of the conceptual framework in this study. These factor names were chosen based on a summary of each factor's most prominent emergent characteristics with respect to the UTAUT constructs:

- Factor 1: Social
- Factor 2: Facilitating
- Factor 3: Performance

Qualitative Interpretation of the Factors

The initial statistical analysis process for this study resulted in the extraction of three unique factors which accounted for all but one of the 23 study respondents. A qualitative review of these findings was completed in alignment to the theoretical framework used for this study. Reference to UTAUT constructs and Roger's adoption categories reveal specific themes that are most outstanding for each factor.

Interpretation of the factors is a synthesis of information, much of which is provided as tabular and visual representations of the results from the Q-factor analysis. In particular, there are specific subsets of the Q-set (statements) which are definitively associated with each of the three factors. An examination of these statements serves to further illuminate the unique characteristics of the factors.

These various subsets of statements are presented for each factor in a number of ways. First, there is a table showing the major characteristics of each factor based upon the corresponding theoretical array. This table highlights four distinct classes of relevant statements: (a) statements assigned the highest rankings (in this case, the three statements at +5); (b) statements assigned the lowest rankings (in this case, the three statements at -5); (c) statements ranked higher by that factor in comparison to any of the other factors; and (d) statements ranked lower by that factor in comparison to any of the other factors. Note that there are additional columns in each of these tables that shows how the same statements were ranked by each of the other factors. Any items that are identified as either consensus statements or distinguishing statements (for the given factor) are also noted.

A second table is given for each factor which shows all of the distinguishing statements specific to the factor. The set of distinguishing statements for a factor consists primarily of the items placed at the negative and positive extremes within the theoretical array.

There is also a figure for each factor which illustrates the theoretical array for each given factor. Condensed into a single Q-sort, the theoretical array is created to represent the viewpoint of that factor, constructed in accordance with the size and rank order of the standardized (z) scores for the factor in question. Each theoretical array is formatted to highlight the relative positioning of statements, further defining the characteristics and themes portrayed by the factor participants. Statement numbers highlighted in blue indicate the distinguishing statements for the array. Statement numbers that are italicized and highlighted in grey indicate the consensus statement for the array.

A complete list of the standardized factor scores and the theoretical array rankings for each of the $n = 50$ statements is available in Appendix D.

A narrative follows each group of factor statistics, providing a summary of the findings and interpreting the results by each construct. For ease of discussion, each factor is identified by the descriptive label chosen for that group, where labels are aligned to the four UTAUT constructs used as part of the conceptual framework in this study. The three identified factor groups include Factor 1: Social, Factor 2: Facilitating and Factor 3: Performance.

Demographic Information and Open-ended Questions

A limited amount of demographic information was collected from respondents at the completion of their Q-sort and is included in Table 3.3. Data collected in this section included the institution name and the staff size for the Information Technology department of the

institution. The staff sizes (small, medium, and large) were reviewed as part of the analysis process.

Open-ended questions completed the online survey and consisted of a request to the respondent to further explain the reasoning behind the rankings of the three statements that were most characteristic of their institution, and the three statements that were least characteristic of their institution. A table containing responses to the open-ended questions is included in Appendix E.

Relative specifically to the targeted participants of this study, brief comments about the makeup of the three factor groups and the NTNC member states from which they originate is appropriate at this point. For Factor 1, six of the thirteen-member NTNC states are represented, and of those six, four states have had a statewide education network in place for a minimum of ten years or more. The remaining two states provide some linkage to school plants and higher education institutions employing a less formalized protocol for connection requirements. Both are working to launch full connectivity via a statewide network and are at varying stages of progress. Other characteristics of the states represented in this group may be relevant when it comes to statewide population sizes as an indicator or ruralness and the perceived characteristics of isolation and lower access to broadband. For Factor 2, four of the same states represented in the Factor 1 group are also represented. Three of the four are in the category of those states with a statewide network. The remaining three Q-sorts in Factor 2 come from institutions in three additional NTNC states. Of those three, one has a statewide K-20 network, while the remaining two do not. And for the states represented in the Factor 3 group, all share representation of states also listed for Factors 1 and 2.

Factor Nomenclature: UTAUT Constructs Versus Adopter Categories

A brief discussion on the reasons behind the choice of labels for each of the factors in this study is appropriate at this point. Relevant to the theme of the study are the theoretical models that are foundational to the research design. For reasons discussed here, one model was favored for the purpose of identifying the extracted factors.

Determined to be inappropriate for use in identifying the factors of this study are the adopter categories developed by Rogers (2003). With broad acceptance by diffusion researchers in the early 1960s, Rogers' model for standardizing a method to describe the level of innovativeness by an individual or a group continues to be widely recognized. The adopter categories are based on the S-shaped curve of adoption and include the identifiers labeled innovators, early adopters, early majority, late majority and laggards. These are intended to assist in the classification of the members of a social system on the basis of innovativeness, the degree to which an individual or other unit of adoption is relatively earlier in adopting new ideas than other members of a system (Rogers, 2003). Based on the themes of this study, it would appear at first glance that use of the adopter categories would be appropriate for distinguishing each of the factors extracted. However, application of the adopter categories to each of the extracted factors is less than perfect and, in this case, use of these categories is not in alignment with the purpose of the study. The goals of the study include efforts to identify salient challenges to adoption of Research & Education network resources and suggest ways to use the results to inform those who advocate for and champion the use and expansion of these resources. The adoption categories have evolved over the years to hold connotations both positive and negative. Applying these identifiers could therefore result in casting a positive or negative label to the groups within

each factor. This could compromise efforts to establish any collaborative efforts to address the challenges indicated by the study.

The category definitions also focus on the adoption of individuals or specific groups of individuals, so the category parameters are not crafted to encompass the adoption levels of more than one group. Specific to this study, two perspectives on adoption are involved. The first is the personal perspective of the respondents, all of whom can be described as the technology provider at the institution, typically serving in roles as similar to chief technology officer. The second perspective is that of the end user, typically representative of faculty researchers and technicians conducting research activities. In this study, the second perspective is provided by the respondent, so they are doing their best to consider the viewpoints of the end users on their campus and communicate that information through their Q-sort rankings. Thus, the Q-sorts represent perspectives of two distinct groups from each institution and as would be expected, those perspectives frequently differ from each other as often as they align.

The decision for descriptive factor names ultimately settled with aligning to the themes of the root constructs used in the research for UTAUT (Venkatesh et al., 2003). This study applied the UTAUT constructs to the Q model for use as a guide in developing the Q-set to be used by study participants. As analysis and interpretation of the factors proceeded, it became clear that each factor indicated stronger alignment to one or more constructs. The factor arrays supported by qualitative data describing each of the factors served to validate the application of one of the UTAUT constructs as the label for each factor.

The adoption categories developed by Rogers (2003) are not completely without value and application to the discussion for this study. A clear understanding of the many differences

and characteristics defined by each category are valuable in the development of communication channels and messages that can be targeted at the different audiences.

Interpretation for Factor 1: Social

This factor is characterized by a strong sentiment of alignment to the research community, where modeling and mentoring or fellowship among users is perceived to hold high value for end users, ranked highest (11:+5), and also higher by this factor in comparison to the other two factors (13:+4; 38:+4; 9:+3; 36:+3; 35:+2; 12:+2; 6:+1). Factor 1 has an eigenvalue of 6.39 and is associated with 28% of the study variance. Twelve participants are significantly associated with this factor.

Table 4.8

Factor 1 Theoretical Array Characteristics: Relative Ranking of Statements

S#	Statement[a]	Ranks in arrays			
		F1[b]		F2	F3
	Highest Ranked Statements				
11	[PE] Researchers are most likely to access national and international R&E resources (such as XSEDEnet, etc.) if they know that the institution already has access.	5		5	2
23	[PE] Use of R&E resources make it easier to collaborate on research with peers remotely, regardless of their location.	5		5	3
18	[PE] Researchers are most likely to consider use of an R&E resource if they can decide when and how it will be used.	5	D	1	1
	Positive Statements Ranked Higher in the Factor 1 Array than in Other Factor Arrays				
13	[PE] Researchers feel most comfortable adopting a new R&E resource for their research when they know it is already in use by others at your institution.	4	D	1	1
5	[PE] Researchers use R&E resources if they know they provide an advantage in convenience for research activities.	4		4	-5
38	[SI] Our researchers would use R&E resources more frequently if they could lean on a cohort of other users when designing their research model.	4		2	2
1	[PE] Using R&E resources to support research improves the job performance of researchers.	4	C	4	3
9	[PE] Researchers rely on the input of key individuals when they have questions about the value/benefits of R&E resources.	3	D	0	-2
24	[PE] Use of R&E resources increases researchers' access to advanced research tools.	3	C	3	2
36	[SI] Our researchers hesitate to use R&E resources because use of these resources by other faculty is low or non-existent.	3	D	-4	-2
35	[SI] Our researchers consider the attitudes of their colleagues when deciding if and how to incorporate R&E resources into research.	2	D	-1	-3
12	[PE] There are individuals at our institution who typically serve as leaders in adopting or rejecting new, innovative R&E resources.	2	D	-1	-1
3	[PE] Using R&E resources provides an advantage in economic terms (e.g., cost to conduct research; operational or overall cost to the institution).	2	C	2	0
6	[PE] Researchers consider the experiences and opinions of their department colleagues when deciding to use R&E resources.	1		0	-3
22	[PE] Use of R&E resources helps researchers design more extensive studies than they can without them.	1		0	-1
31	[EE] Our researchers feel that working with the system is so complicated, it is difficult to understand what is going on.	0		-5	-2

Table 4.8. *Factor 1 Theoretical Array Characteristics: Relative Ranking of Statements* (continued)

S#	Statement[a]	Ranks in arrays			
		F1[b]		F2	F3
	Negative Statements Ranked Higher in the Factor 1 Array than in Other Factor Arrays				
20	[PE] Use of R&E resources helps researchers complete research tasks more quickly and efficiently.	0	D	5	4
25	[PE] Researchers use R&E networks because they provide the bandwidth and data security critical for research activities.	0		3	1
15	[PE] Use of R&E resources can increase the quantity of research output for the same amount of effort.	0		0	5
4	[PE] Looking ahead to the next five years, research at my institution will become increasingly more dependent on the use of R&E resources.	0		1	5
50	[FC] Our researchers feel that using R&E resources fits into their work schedule.	-2		-1	-1
39	[SI] Researchers who use R&E resources tend to have more prestige than those who do not.	-2	C	-2	-2
40	[SI] Researchers at our institution who use R&E resources have a higher profile within their research community than those who do not.	-3	D	0	3
47	[FC] Researchers feel that timely and skilled support is available for assistance when system difficulties arise.	-3	D	4	1
46	[FC] Researchers feel that specialized and timely instruction on using R&E resources is available at our institution.	-4	D	2	-1
44	[FC] Our researchers have the knowledge necessary to use R&E resources available at our institution.	-4	D	3	0
34	[SI] The culture at our institution encourages researchers to explore and use R&E resources.	-4	D	1	0
42	[SI] I would rank my institution as an early adopter of R&E network resources.	-4	D	-1	1
	Lowest Ranked Statements				
30	[EE] Our institution has dedicated staff and guidance available to support researchers in selecting and using R&E resources.	-5	D	-2	2
28	[EE] Our institution has streamlined the process for R&E use, so researchers spend less time doing administrative tasks, and more time on research.	-5	D	2	-1
43	[SI] I would rank our researchers as early adopters of R&E network resources for research.	-5	D	-1	-2

[a] Each statement has a prefix in square brackets. These indicate the construct upon which each statement is based: PE = performance expectancy, EE = effort expectancy, SI = social influence, FC = facilitating conditions.

[b] Some statement rankings are tagged: C = consensus statement, D = distinguishing statement.

Table 4.9

All Distinguishing Statements for Factor 1

S#	Statement	Ranks in arrays		
		F1	F2	F3
18	[PE] Researchers are most likely to consider use of an R&E resource if they can decide when and how it will be used.	5	1	1
13	[PE] Researchers feel most comfortable adopting a new R&E resource for their research when they know it is already in use by others at your institution.	4	1	1
9	[PE] Researchers rely on the input of key individuals when they have questions about the value/benefits of R&E resources.	3	0	-2
36	[SI] Our researchers hesitate to use R&E resources because use of these resources by other faculty is low or non-existent.	3	-4	-2
35	[SI] Our researchers consider the attitudes of their colleagues when deciding if and how to incorporate R&E resources into research.	2	-1	-3
12	[PE] There are individuals at our institution who typically serve as leaders in adopting or rejecting new, innovative R&E resources.	2	-1	-1
33	[SI] Researchers are influenced by their colleagues to use R&E network resources (such as XSEDE, GlueX, data transfer nodes).	1	-2	4
20	[PE] Use of R&E resources helps researchers complete research tasks more quickly and efficiently.	0	5	4
37	[SI] Our researchers hesitate to use R&E resources because they receive little encouragement from Institutional leadership and senior faculty.	-1	-4	-3
49	[FC] Our researchers feel that using R&E resources fits well with their work style.	-1	-3	1
29	[EE] Researchers can customize the resources and tools available through R&E networks to do what they want them to do.	-2	-1	-4
40	[SI] Researchers at our institution who use R&E resources have a higher profile within their research community than those who do not.	-3	0	3
47	[FC] Researchers feel that timely and skilled support is available for assistance when system difficulties arise.	-3	4	1
46	[FC] Researchers feel that specialized and timely instruction on using R&E resources is available at our institution.	-4	2	-1
44	[FC] Our researchers have the knowledge necessary to use R&E resources available at our institution.	-4	3	0
34	[SI] The culture at our institution encourages researchers to explore and use R&E resources.	-4	1	0
42	[SI] I would rank my institution as an early adopter of R&E network resources.	-4	-1	1
30	[EE] Our institution has dedicated staff and guidance available to support researchers in selecting and using R&E resources.	-5	-2	2
28	[EE] Our institution has streamlined the process for R&E use, so researchers spend less time doing administrative tasks, and more time on research.	-5	2	-1
43	[SI] I would rank our researchers as early adopters of R&E network resources for research.	-5	-1	-2

Note. All ranks are derived from standardized factor scores. The standardized factor scores for the distinguishing statements from Factor 1 are all significant ($p < .05$).

Figure 4.3

Theoretical array for Factor 1

-5	-4	-3	-2	-1	0	1	2	3	4	5
30	**46**	26	**29**	32	**20**	6	**35**	2	**13**	11
28	**44**	**40**	50	48	25	*17*	14	**9**	5	23
43	**34**	*16*	*27*	**37**	7	22	**12**	*24*	38	**18**
	42	**47**	*39*	41	15	*19*	10	**36**	*1*	
			21	**49**	31	**33**	*3*			
				8	4	45				

Note: Statement numbers are shown in the response table, and rank scores are shown at the top of the columns. Distinguishing statements are shown in boldface and highlighted in blue; consensus items are shown in italic and highlighted in grey.

Demographic Profile

Four participants indicated they have a small IT staff (20 or fewer), two reported medium (21 to 50), and six responded with large (more than 50). Six of the twelve institutions are land grant, and four of those six land grant institutions are also a Tribal College or University. Three of the twelve are located in communities with a population above 50,000. Three of the twelve are located in communities with a population between 21,000 and 49,000. Five of the six remaining institutions are located in communities with a population of 20,000 or below. The population information for the remaining institution could not be determined due to the dispersed model of locations across a region of the state.

Interpretation of Factor 1 by UTAUT Constructs

Performance Expectancy (PE)

Respondents indicated strong agreement with several statements from this construct that discuss existing access to and use of R&E network resources as having a positive impact on user's adoption levels (11: +5; 13: +4; 9: +3; 12: +2; 6: +1). These items were ranked highest by respondents in this factor and also ranked higher by this factor than all other factors.

Perceptions relative to ease of use in terms of remote collaboration (23: +5) and ability to customize (18: +5) received the highest rankings. Item 18 is identified as a distinguishing statement for this factor. Following closely were positive rankings on the advantage of the convenience for research (5: +4), the ability to improve research performance (1: +4) and economic value (3: +2), and also improved access to advanced research tools (24: +3). Also, notable findings for this construct are the negative rankings relative on value gained by the institution and researcher as a result of the use of R&E network resources (21: -2).

Statements by respondents provide further substantiation of these perspectives:

Statement 1 comment:

> "…Researchers use the network heavily and naturally throughout the research process…It would not surprise me if many [researchers] see it like any ubiquitous tool – like the telephone, desk or fax – and not related to the research process."

Statement 2 comment:

> "R&E network resources are becoming more ubiquitous, with faculty coming from grad programs where the faculty member had experienced with advanced resources."

Statement 3 comment:

> "One-offs for every research need is expensive."

Statement 4 comments:

> "I believe that this is a nationwide trend."
>
> "The university has established research and scholarly success as a goal in the university strategic plan."

Statement 5 comment:

> "Communication matters…"

Statement 7 comment:

"Researchers here look to their outside colleague's experiences because we have such a small faculty and often have departments of one."

Statement 8 comment:

"We have no formal or informal communication plan."

Statement 9 comment:

"Many times researchers have limited experience and need more information and look to key people for that information."

Statement 13 comment:

"They definitely love stories of how others are using the R&E resources, particularly when they know/respect that colleague's work."

Statement 18 comment:

"They want control – anything that sounds 'prescribed' to them will be a barrier to use."

Statement 23 comment:

"Networks are for communication above all else (i.e. tools, data, etc). The universal availability of the network thus makes collaboration allowable world-wide."

Effort Expectancy (EE)

Rankings of statements in this construct are notable since they primarily landed on the negative end of the array. While respondents may perceive that their end users possess the skills and commitment to integrate R&E network resources into the research process (31: 0; 32: -1), they feel that it is not easy for researchers to improve their skill on learning to access and use R&E network resources, nor that the process itself is clear and understandable (27: -2; 26: -3).

Ranking at the extreme negative end of the array are two statements from this construct that address the capacity of the institution to support the use of R&E network resources through the availability of dedicated staff and guidance and streamlined processes (30: -5; 28: -5). Items 30 and 28 are identified as distinguishing statements for this factor.

Statements by respondents provide further substantiation of these perspectives: Statement 28 comments:

> "We have not streamlined the process."
>
> "We have not invested what we need to invest to make this happen. Faculty spend way too much time on administrative tasks."

Statement 30 comment:

> "We have not invested in any – zero – dedicated staff."

Social Influence (SI)

Relative to the responses to statements aligned to Performance Expectancy, additional insights that support the viewpoint of this factor relative to social influences are evidenced from their responses to statements in this construct. Again, respondents in this factor perceive that the attitudes of colleagues, the level of use by others at the institution, and access to a cohort of researchers in developing research design and methodology all play a positive role in the adoption levels of these resources at their institution (38: +4; 36: +3; 35: +2). This factor is less likely to be influenced by perceptions that use of R&E network resources increases the prestige of users (39: -2). An even stronger negative response results when asked about the adoption category for researchers at their institution (43: -5). Item 43 is identified as a distinguishing statement for this factor.

Statements by respondents provide further substantiation of these perspectives:

Statement 34 comment:

> "Between lack of resources and communication challenges, researchers do not know who to reach out to or what is available."
>
> "Though researchers by definition are explorers, the culture of the university limits pure exploration and encourages tightly defined exploration that brings an important and direct return on investment for the researcher's campus job status (e.g. department status, tenure track, etc). Exploring what the network can and cannot do for a researcher, feels like two or three layers away from that value proposition. So whether the campus directly or indirectly intends to discourage exploration…in my opinion… they do."

Statement 35 comment:

> "How other researchers view R&E resources and the support structure is very important – because of our small faculty and their limited amount of time, so they have a high need to achieve success with minimal effort."
>
> "With our lack of communication, researchers rely on each other's experiences."
>
> "Peer review and peer resources are important to faculty."

Statement 43 comments:

> "Our researchers simply are not on the leading edge."

Facilitating Conditions (FC)

For this factor, those statements in this construct indicating notable rankings are all distinguishing statements with a z-score that indicates significance at $p < .01$ These statements again address the capacity and readiness of the institution and the end users to integrate R&E network resources into research processes. This factor shows a lower level of confidence in the

institution's ability to provide timely and skilled support when system difficulties arise (47: -3), and also its ability to provide specialized and timely instruction on the use of R&E network resources (46: -4). While respondents showed some confidence in end user knowledge and skills as indicated by responses to statements in the construct for Effort Expectancy, the viewpoint expressed through this construct was somewhat stronger, ranking the knowledge necessary to use R&E network resources even lower (44: -4).

Statements by respondents provide further substantiation of these perspectives:

Statement 44 comments:

> "Established faculty have not trained themselves on how to use these resources. Those who do, often delegate use of these resources to graduate students. I expect this to change as younger faculty move up the ranks."
>
> "Researchers need a lot more information about this."

Statement 46 comments:

> "There are not enough resources to dedicate to R&E."
>
> "I am sure [researchers] do not feel this exists, since nobody has really communicated such services on an ongoing basis."

Statement 48 comment:

> "Most all disciplines could find a use for R&E resources. Not all do, but I expect the number of disciplines that use these resources to increase in the future."

Interpretation for Factor 2: Facilitating

The character of Factor 2 is best described as pragmatic. While respondents indicate that their institutions have made efforts to improve capacity to facilitate the use of R&E network resources (47: +4), and that end users have the skills and capacity to integrate R&E network

resources (44: +3), they also indicate indifference or a lack of urgency that exists to increase the use of these resources (43: -1; 21: -2). Factor 2 has an eigenvalue of 3.0 and explains 13% of the study variance. Seven participants are significantly associated with this factor.

Table 4.10

Factor 2 Theoretical Array Characteristics: Relative Ranking of Statements

S#	Statement[a]	Ranks in arrays			
		F2[b]		F1	F3
	Highest Ranked Statements				
23	[PE] Use of R&E resources make it easier to collaborate on research with peers remotely, regardless of their location.	5		5	3
20	[PE] Use of R&E resources helps researchers complete research tasks more quickly and efficiently.	5		0	4
11	[PE] Researchers are most likely to access national and international R&E resources (such as XSEDEnet, etc.) if they know that the institution already has access.	5		5	2
	Positive Statements Ranked Higher in the Factor 2 Array than in Other Factor Arrays				
5	[PE] Researchers use R&E resources if they know they provide an advantage in convenience for research activities.	4		4	-5
47	[FC] Researchers feel that timely and skilled support is available for assistance when system difficulties arise.	4	D	-3	1
2	[PE] Use of R&E network resources makes it easier to conduct research.	4		3	-3
1	[PE] Using R&E resources to support research improves the job performance of researchers.	4	C	4	3
44	[FC] Our researchers have the knowledge necessary to use R&E resources available at our institution.	3	D	-4	0
10	[PE] R&E resources provide an advantage to improving the reputation of research conducted at our institution.	3		2	0
25	[PE] Researchers use R&E networks because they provide the bandwidth and data security critical for research activities.	3		0	1
24	[PE] Use of R&E resources increases researchers' access to advanced research tools.	3	C	3	2
19	[PE] Use of R&E resources for research has the potential to achieve significantly different and improved processes and results.	2	C	1	0
28	[EE] Our institution has streamlined the process for R&E use, so researchers spend less time doing administrative tasks, and more time on research.	2	D	-5	-1
46	[FC] Researchers feel that specialized and timely instruction on using R&E resources is available at our institution.	2	D	-4	-1
3	[PE] Using R&E resources provides an advantage in economic terms (e.g., cost to conduct research; operational or overall cost to the institution).	2	C	2	0
34	[SI] The culture at our institution encourages researchers to explore and use R&E resources.	1		-4	0
7	[PE] Researchers consider the experiences and opinions of colleagues outside of our institution when deciding to use R&E resources.	1		0	-5

Table 4.10. *Factor 2 Theoretical Array Characteristics: Relative Ranking of Statements* (continued)

S#	Statement[a]	Ranks in arrays			
		F2[b]		F1	F3
	Negative Statements Ranked Higher in the Factor 2 Array than in Other Factor Arrays				
14	[PE] Use of R&E resources can decrease the time needed for important research responsibilities.	0	D	2	5
15	[PE] Use of R&E resources can increase the quantity of research output for the same amount of effort.	0		0	5
12	[PE] There are individuals at our institution who typically serve as leaders in adopting or rejecting new, innovative R&E resources.	-1		2	-1
33	[SI] Researchers are influenced by their colleagues to use R&E network resources (such as XSEDE, GlueX, data transfer nodes).	-2	D	1	4
39	[SI] Researchers who use R&E resources tend to have more prestige than those who do not.	-2	C	-2	-2
48	[FC] The use of R&E resources is compatible with all aspects of research.	-2		-1	4
41	[SI] Institutions that demonstrate high use of R&E resources have more prestige that those who do not.	-3		-1	3
8	[PE] Relevant news and information communicated to researchers on our campus contributes to increased adoption of R&E resources.	-3		-1	0
49	[FC] Our researchers feel that using R&E resources fits well with their work style.	-3	D	-1	1
27	[EE] It is easy for researchers to improve their skill at using R&E network resources.	-4	C	-2	-4
16	[PE] R&E resources are not compatible with other systems currently used by researchers to work on their research.	-4	C	-3	-4
36	[SI] Our researchers hesitate to use R&E resources because use of these resources by other faculty is low or non-existent.	-4	D	3	-2
37	[SI] Our researchers hesitate to use R&E resources because they receive little encouragement from Institutional leadership and senior faculty.	-4	D	-1	-3
	Lowest Ranked Statements				
32	[EE] Our researchers feel that it takes too long to learn how to use the system to make it worth the effort.	-5	D	-1	-1
45	[FC] The cultural norms of our institution sometimes serve as a barrier to adoption of new R&E resources.	-5	D	1	2
31	[EE] Our researchers feel that working with the system is so complicated, it is difficult to understand what is going on.	-5	D	0	-2

[a] Each statement has a prefix in square brackets. These indicate the construct upon which each statement is based: PE = performance expectancy, EE = effort expectancy, SI = social influence, FC = facilitating conditions.

[b] Some statement rankings are tagged: C = consensus statement, D = distinguishing statement.

Table 4.11

All Distinguishing Statements for Factor 2

S#	Statement	Ranks in arrays		
		F1	F2	F3
47	[FC] Researchers feel that timely and skilled support is available for assistance when system difficulties arise.	-3	4	1
44	[FC] Our researchers have the knowledge necessary to use R&E resources available at our institution.	-4	3	0
28	[EE] Our institution has streamlined the process for R&E use, so researchers spend less time doing administrative tasks, and more time on research.	-5	2	-1
46	[FC] Researchers feel that specialized and timely instruction on using R&E resources is available at our institution.	-4	2	-1
14	[PE] Use of R&E resources can decrease the time needed for important research responsibilities.	2	0	5
9	[PE] Researchers rely on the input of key individuals when they have questions about the value/benefits of R&E resources.	3	0	-2
40	[SI] Researchers at our institution who use R&E resources have a higher profile within their research community than those who do not.	-3	0	3
29	[EE] Researchers can customize the resources and tools available through R&E networks to do what they want them to do.	-2	-1	-4
33	[SI] Researchers are influenced by their colleagues to use R&E network resources (such as XSEDE, GlueX, data transfer nodes).	1	-2	4
30	[EE] Our institution has dedicated staff and guidance available to support researchers in selecting and using R&E resources.	-5	-2	2
49	[FC] Our researchers feel that using R&E resources fits well with their work style.	-1	-3	1
36	[SI] Our researchers hesitate to use R&E resources because use of these resources by other faculty is low or non-existent.	3	-4	-2
37	[SI] Our researchers hesitate to use R&E resources because they receive little encouragement from Institutional leadership and senior faculty.	-1	-4	-3
32	[EE] Our researchers feel that it takes too long to learn how to use the system to make it worth the effort.	-1	-5	-1
45	[FC] The cultural norms of our institution sometimes serve as a barrier to adoption of new R&E resources.	1	-5	2
31	[EE] Our researchers feel that working with the system is so complicated, it is difficult to understand what is going on.	0	-5	-2

Note. All ranks are derived from standardized factor scores. The standardized factor scores for the distinguishing statements from Factor 2 are all significant ($p < .05$).

Figure 4.4

Theoretical array for Factor 2

-5	-4	-3	-2	-1	0	1	2	3	4	5
32	*27*	41	**33**	**29**	**14**	18	*19*	**44**	5	23
45	*16*	26	**30**	50	6	4	38	10	**47**	20
31	**36**	8	*39*	12	**9**	34	**28**	25	2	11
	37	**49**	21	35	15	7	**46**	*24*	*1*	
			48	43	22	*17*	*3*			
				42	**40**	13				

Note: Statement numbers are shown in the response table, and rank scores are shown at the top of the columns. Distinguishing statements are shown in boldface and highlighted in blue; consensus items are shown in italic and highlighted in grey.

Demographic Profile

Two participants indicated they have a small IT staff (20 or fewer), while five responded with large (more than 50). Four of the seven institutions are land grant, and two of those four land grant institutions are also a Tribal College or University. Five of the seven are located in communities with a population above 50,000. One of the seven is located in a community with a population between 21,000 and 49,000. One of the seven is located in a community with a population of 20,000 or below.

Interpretation of Factor 2 by UTAUT Constructs

Performance Expectancy (PE)

Three statements that Factor 2 ranked the highest for their Q-sorts originate in the construct for performance expectancy. Collectively they focus on perceptions of characteristics that facilitate the use of R&E network resources, including remote collaboration, efficiency, and capacity of their home institution to support the use of these resources (23: +5; 20: +5; 11: +5). This attitude is further confirmed by positive rankings on statements that address convenience for research, ease of conducting research, and ability to improve job performance (5: +4; 2: +4;

1: +4). While not ranked as high, this viewpoint remains consistent as evidenced by positive rankings for statements on topics of improving research and institutional reputation (10: +3), ability to provide needed bandwidth and data security (25: +3), and access to advanced research tools (24: +3). The ability to improve processes and results and provide an advantage in economic terms were also ranked positively (19: +2; 3: +2).

Comments by respondents provide further substantiation of these perspectives:

Statement 2 comment:

"Increased access allows for more convenient transfer of data/knowledge."

Statement 3 comment:

"Every time we've looked, the costs for R&E resources have been at least an order of magnitude less expensive than commercial resources."

Statement 4 comment:

"Big data, specialized instruments in remote locations, team science, it all adds up to more importance for R&E network resources."

Effort Expectancy (EE)

Four of the five statements included in the list of extreme rankings (highest, higher than other factors and lowest) also make the list of distinguishing statements for Factor 2. The respondent indicates that the institution has tried to improve facilitation by streamlining the process for access to and use of R&E network resources (28: +2). Stronger opposition to several statements indicates a viewpoint that while R&E network resources are not as clear and understandable as they could be (26: -3), time required to integrate R&E network resources and level of complexity are not major challenges to adoption (32: -5; 31: -5).

Comments by respondents provide further substantiation of these perspectives: Statement 32:

> "Our researchers feel that it takes too long to learn how to use the system to make it worth the effort."

F2 ranked this item at -5. The comments from respondents explained their responses in the statements below:

> "Adoption is high, and onboarding is supported."
>
> "Most researchers us the services we have and they seem to get up to speed pretty quickly."

Social Influence (SI)

Challenges to adoption based within this construct received only a minor share of the spotlight by Factor 2. Only two statements on social influence are included in the list for relative ranking of statements, and their scores are placed more neutrally within the array. Respondents indicated some agreement that the culture of the institution encourages the exploration and use of R&E network resources for research (34: +1). A similar ranking was provided in response to whether to identify researchers at their institution as early adopters (43: -1). In comparison to Factor 1 where social influence is perceived to hold a high level of importance when it comes to adoption levels, Factor 2 indicates an opposite viewpoint. For this factor, three statements within the Q-set that refer to collegial support and mentoring were ranked negatively and are listed as distinguishing statements (33: -2; 36: -4; 37: -4). The message that appears to surface as a result of these responses is that end users at these institutions tend to operate more independently of collegial or administrative support. More of the focus is on simply having access to the resources needed.

Statements by respondents provide further substantiation of these perspectives: Statement 37 comment:

"Our researchers hesitate to use R&E resources for their own research because

Institutional leadership and senior faculty do not encourage use of R&E resources." F2 ranked this item at -4. The comment from one participant explained their response in the statement below:

" Research is highly valued, and R&E use is ubiquitous."

Facilitating Conditions (FC)

Institutional capacity and user skill are ranked positively for statements aligned to this construct (47: +4; 44: +3; 46: +2). Rejected by respondents is the perception that users feel that using R&E network resources fits well with their work schedule (50: -1). Strong disagreement is indicated by a negative ranking of the statement that the social/cultural norms of the institution sometimes serve as a barrier to adoption, indicating that institutional culture is not perceived to be a challenge to adoption (45: -5).

Interpretation for Factor 3: Performance

More than the others, this factor articulates a dichotomous environment for the represented institutions. Respondents indicate a fairly positive viewpoint of the overall value and benefits of R&E network resources use (15: +5; 4: +5), while at the same time indicating that users are more indifferent and less capable in their ability to adopt and integrate these resources (42: +2; 43: -1). Factor 3 has an eigenvalue of 1.7 and explains 7% of the study variance. Three participants are significantly associated with this factor.

Table 4.12

Factor 3 Theoretical Array Characteristics: Relative Ranking of Statements

S#	Statement[a]	Ranks in arrays			
		F3[b]		F1	F2
	Highest Ranked Statements				
15	[PE] Use of R&E resources can increase the quantity of research output for the same amount of effort.	5	D	0	0
4	[PE] Looking ahead to the next five years, research at my institution will become increasingly more dependent on the use of R&E resources.	5	D	0	1
14	[PE] Use of R&E resources can decrease the time needed for important research responsibilities.	5		2	0
	Positive Statements Ranked Higher in the Factor 3 Array than in Other Factor Arrays				
17	[PE] Researchers are likely to be interested in adopting this resource if it can be changed or modified to fit their needs.	4	C	1	1
33	[SI] Researchers are influenced by their colleagues to use R&E network resources (such as XSEDE, GlueX, data transfer nodes).	4	D	1	-2
48	[FC] The use of R&E resources is compatible with all aspects of research.	4	D	-1	-2
40	[SI] Researchers at our institution who use R&E resources have a higher profile within their research community than those who do not.	3	D	-3	0
41	[SI] Institutions that demonstrate high use of R&E resources have more prestige that those who do not.	3	D	-1	-3
30	[EE] Our institution has dedicated staff and guidance available to support researchers in selecting and using R&E resources.	2	D	-5	-2
45	[FC] The cultural norms of our institution sometimes serve as a barrier to adoption of new R&E resources.	2		1	-5
42	[SI] I would rank my institution as an early adopter of R&E network resources.	1		-4	-1
49	[FC] Our researchers feel that using R&E resources fits well with their work style.	1	D	-1	-3
8	[PE] Relevant news and information communicated to researchers on our campus contributes to increased adoption of R&E resources.	0	D	-1	-3
	Negative Statements Ranked Higher in the Factor 3 Array than in Other Factor Arrays				
19	[PE] Use of R&E resources for research has the potential to achieve significantly different and improved processes and results.	0	C	1	2
3	[PE] Using R&E resources provides an advantage in economic terms (e.g., cost to conduct research; operational or overall cost to the institution).	0	C	2	2
10	[PE] R&E resources provide an advantage to improving the reputation of research conducted at our institution.	0	D	2	3
22	[PE] Use of R&E resources helps researchers design more extensive studies than they can without them.	-1		1	0
12	[PE] There are individuals at our institution who typically serve as leaders in adopting or rejecting new, innovative R&E resources.	-1		2	-1
39	[SI] Researchers who use R&E resources tend to have more prestige than those who do not.	-2	C	-2	-2
9	[PE] Researchers rely on the input of key individuals when they have questions about the value/benefits of R&E resources.	-2	D	3	0
35	[SI] Our researchers consider the attitudes of their colleagues when deciding if and how to incorporate R&E resources into research.	-3		2	-1

Table 4.12. *Factor 3 Theoretical Array Characteristics: Relative Ranking of Statements* (continued)

S#	Statement[a]	Ranks in arrays			
		F3[b]		F1	F2
6	[PE] Researchers consider the experiences and opinions of their department colleagues when deciding to use R&E resources.	-3	D	1	0
2	[PE] Use of R&E network resources makes it easier to conduct research.	-3	D	3	4
27	[EE] It is easy for researchers to improve their skill at using R&E network resources.	-4	C	-2	-4
29	[EE] Researchers can customize the resources and tools available through R&E networks to do what they want them to do.	-4	D	-2	-1
16	[PE] R&E resources are not compatible with other systems currently used by researchers to work on their research.	-4	C	-3	-4
21	[PE] Use of R&E resources improves likelihood of research publication.	-4	D	-2	-2
	Lowest Ranked Statements				
5	[PE] Researchers use R&E resources if they know they provide an advantage in convenience for research activities.	-5	D	4	4
26	[EE] Learning to access and use R&E network resources is clear and understandable.	-5	D	-3	-3
7	[PE] Researchers consider the experiences and opinions of colleagues outside of our institution when deciding to use R&E resources.	-5	D	0	1

[a] Each statement has a prefix in square brackets. These indicate the construct upon which each statement is based: PE = performance expectancy, EE = effort expectancy, SI = social influence, FC = facilitating conditions.

[b] Some statement rankings are tagged: C = consensus statement, D = distinguishing statement.

Table 4.13

All Distinguishing Statements for Factor 3

S#	Statement	Ranks in arrays		
		F1	F2	F3
15	[PE] Use of R&E resources can increase the quantity of research output for the same amount of effort.	0	0	5
4	[PE] Looking ahead to the next five years, research at my institution will become increasingly more dependent on the use of R&E resources.	0	1	5
33	[SI] Researchers are influenced by their colleagues to use R&E network resources (such as XSEDE, GlueX, data transfer nodes).	1	-2	4
48	[FC] The use of R&E resources is compatible with all aspects of research.	-1	-2	4
40	[SI] Researchers at our institution who use R&E resources have a higher profile within their research community than those who do not.	-3	0	3
23	[PE] Use of R&E resources make it easier to collaborate on research with peers remotely, regardless of their location.	5	5	3
41	[SI] Institutions that demonstrate high use of R&E resources have more prestige that those who do not.	-1	-3	3
30	[EE] Our institution has dedicated staff and guidance available to support researchers in selecting and using R&E resources.	-5	-2	2
11	[PE] Researchers are most likely to access national and international R&E resources (such as XSEDEnet, etc.) if they know that the institution already has access.	5	5	2
47	[FC] Researchers feel that timely and skilled support is available for assistance when system difficulties arise.	-3	4	1
49	[FC] Our researchers feel that using R&E resources fits well with their work style.	-1	-3	1
8	[PE] Relevant news and information communicated to researchers on our campus contributes to increased adoption of R&E resources.	-1	-3	0
44	[FC] Our researchers have the knowledge necessary to use R&E resources available at our institution.	-4	3	0
10	[PE] R&E resources provide an advantage to improving the reputation of research conducted at our institution.	2	3	0
46	[FC] Researchers feel that specialized and timely instruction on using R&E resources is available at our institution.	-4	2	-1
28	[EE] Our institution has streamlined the process for R&E use, so researchers spend less time doing administrative tasks, and more time on research.	-5	2	-1
36	[SI] Our researchers hesitate to use R&E resources because use of these resources by other faculty is low or non-existent.	3	-4	-2
9	[PE] Researchers rely on the input of key individuals when they have questions about the value/benefits of R&E resources.	3	0	-2
37	[SI] Our researchers hesitate to use R&E resources because they receive little encouragement from Institutional leadership and senior faculty.	-1	-4	-3
6	[PE] Researchers consider the experiences and opinions of their department colleagues when deciding to use R&E resources.	1	0	-3
2	[PE] Use of R&E network resources makes it easier to conduct research.	3	4	-3
29	[EE] Researchers can customize the resources and tools available through R&E networks to do what they want them to do.	-2	-1	-4
21	[PE] Use of R&E resources improves likelihood of research publication.	-2	-2	-4
5	[PE] Researchers use R&E resources if they know they provide an advantage in convenience for research activities.	4	4	-5
26	[EE] Learning to access and use R&E network resources is clear and understandable.	-3	-3	-5
7	[PE] Researchers consider the experiences and opinions of colleagues outside of our institution when deciding to use R&E resources.	0	1	-5

Note. All ranks are derived from standardized factor scores. The standardized factor scores for the distinguishing statements from Factor 3 are all significant ($p < .05$).

Figure 4.5

Theoretical array for Factor 3

-5	-4	-3	-2	-1	0	1	2	3	4	5
5	*27*	35	**36**	32	34	18	*24*	*1*	*17*	**15**
26	**29**	**37**	31	50	**8**	25	38	**40**	**33**	**4**
7	*16*	**6**	*39*	22	*19*	**47**	**30**	**23**	20	14
	21	**2**	**9**	12	*3*	42	45	**41**	**48**	
			43	**46**	**44**	**49**	**11**			
				28	**10**	13				

Note: Statement numbers are shown in the response table, and rank scores are shown at the top of the columns. Distinguishing statements are shown in boldface and highlighted in blue; consensus items are shown in italic and highlighted in grey.

Demographic Profile

One participant indicated they have a small IT staff (20 or fewer), while two responded with large (more than 50). All three institutions are land grant, and one of them is also a Tribal College or University. All three are located in communities with a population above 50,000. None of the three are located in communities with a population between 21,000-49,000. One is located in a community with a population of 20,000 or below.

Interpretation of Factor 3 by UTAUT Constructs

Performance Expectancy (PE)

Respondents in this factor indicate a positive viewpoint toward the value and benefits to users (4: +5; 15: +5; 20: +5). Two of the highest-ranking statements also serve as distinguishing statements for this factor (4: +5; 15: +5). Additional value perceived favorably by this group includes time efficiency for research responsibilities and the ability to modify resources to fit research needs (14: +4; 17: +2). Although it is given a more neutral ranking, another distinguishing statement for this factor addresses efforts by the institution to increase adoption through enhanced communication efforts (8: +1). Strongly rejected by respondents in this factor

is the assumption that researchers are dependent on convenience, or collegial experiences and opinions when deciding whether to integrate R&E network resources into their research (5: -5; 7: -5). These statements also serve as distinguishing statements for this factor.

Comments by respondents provide further substantiation of these perspectives: Statement 20 comments:

"Use of R&E resources helps researchers complete tasks more quickly and efficiently."

"Time and time again this is the answer we get, why they are using the resource. It helps them move more quickly to promotion and tenure."

Effort Expectancy (EE)

The response by this factor to the third statement included in the list of those statements ranked lowest by Factor 3 in comparison to the other factors serves to reject the viewpoint that learning to access and use R&E network resources is clear and understandable (26: -5). Also ranked negatively by the other factors, this item serves as a distinguishing statement for this factor.

On a more positive note, another distinguishing statement for this factor is the ranking of a statement that confirms the institution has dedicated staff and guidance available to support researchers in selecting and using R&E network resources (30: +3). More neutrally ranked items for this construct relate to perceptions by users that the system is too complicated and to takes too long to learn how to use (31: 0; 32: -1). A less extreme ranking for these two items by the provider may confirm a level of indifference or lack of urgency to adopt.

Statements by respondents provide further substantiation of these perspectives: Statement 30:

"Our institution has dedicated staff and guidance available to support researchers in selecting and using R&E resources."

"Having dedicated [staff] has tripled the numbers of researchers coming for help because we are viewed as partners."

Social Influence (SI)

For this construct an anomaly appears upon analysis of the perceived value of collegial relationships on research activities. While several other items (7: -5; 6: -3; 37: -3; 9: -2) based in other constructs are ranked negatively by this factor, rejecting the notion that collegial relationships are important to adoption, two items indicate almost the complete opposite (38: +4; 33: +3). Yet responses to two other statements in this construct appear to support the perception that researchers will function independent of influences by other faculty or institutional leadership (36: -2; 37: -2). Three distinguishing statements confirm the more broadly positive viewpoint of performance that addresses the value and benefits to users (40: +3; 41: +3; 42: +2).

Facilitating Conditions (FC)

Corroborating evidence previously suggested the perception of a dichotomy between perspectives in this factor, and several items from this construct appear in the list of distinguishing statements. Respondent's viewpoints provide positive rankings indicating that they believe R&E network resources are compatible with all types of research and that timely and skilled support is available for assistance as needed (48: +4; 47: +2). Their responses become more neutral when asked to rank the existence of specialized and timely instruction for users, researcher knowledge about use of R&E network resources, and researchers' perspectives on how R&E resources fit into their work schedules (46: -1; 44: 0; 49: +1).

Consensus Statements

In stark contrast to distinguishing statements, there are a set of statements that provided little information in regard to the distinctions among the three factors. These statements represent the "common ground" among the different perspectives. These statements are given in Table 4.14.

Table 4.14

Consensus Statements

S#	Statement	Ranks in arrays		
		F1	F2	F3
1	[PE] Using R&E resources to support research improves the job performance of researchers.	4	4	3
3	[PE] Using R&E resources provides an advantage in economic terms (e.g., cost to conduct research; operational or overall cost to the institution).	2	2	0
16	[PE] R&E resources are not compatible with other systems currently used by researchers to work on their research.	-3	-4	-4
17	[PE] Researchers are likely to be interested in adopting this resource if it can be changed or modified to fit their needs.	1	1	4
19	[PE] Use of R&E resources for research has the potential to achieve significantly different and improved processes and results.	1	2	0
24	[PE] Use of R&E resources increases researchers' access to advanced research tools.	3	3	2
27	[EE] It is easy for researchers to improve their skill at using R&E network resources.	-2	-4	-4
39	[SI] Researchers who use R&E resources tend to have more prestige than those who do not.	-2	-2	-2

Summary of Factor Interpretations

The framework used to address the study's research questions is guided primarily by three theoretical models that provide the context for discussion surrounding adoption of R&E network resources by higher education institutions in the identified region. Roger's theory on the diffusion of innovations is one of the most popular models for exploring diffusion and adoption of new technology innovations (Sahin, 2006). While the diffusion research studied by Rogers (2003) was initially developed to describe adoption of ideas and innovations in a broad sense,

including technology, the Technology Acceptance Model (TAM; Davis, 1986), developed several decades later had the specific adoption of technology tools and resources as its primary context. A successor of TAM, the United Theory of Acceptance and Use of Technology (UTAUT; Venkatesh et al., 2003) is one of the more recent extensions of TAM and is the result of empirical research focused on achieving a more parsimonious model consisting of much fewer constructs compared to the lengthy list of those employed across existing models at the time it was developed.

This study applied Q methodology to the UTAUT framework through the development of a concourse of statements intended to explore the challenges to adoption rates of research and education network technologies by institutions of higher education across the regional Northern Tier Network. At the time of this study, no other studies are known to exist that serve to meld the UTAUT framework with Roger's adoption theory and apply it to a study specifically in the context of adoption of R&E network technologies. Analysis and initial findings relevant to each factor have been presented. Now, the discussion continues with summaries of each of the factors, highlighting their differences, and how these findings can serve to uncover and more fully explain the challenges to adoption experienced by respondents in the study.

Demographics collected for this study provided insights into additional characteristics that can play a role in access to R&E network connections. While this study does not intend to focus specifically on elements related to community, culture, or socio economics, the insights provided by the minimal information conveyed by the post-Q-sort demographics questions suggests possible relationships between geographic proximity to regional backbone networks and adoption levels based on cost of access to the institution.

It is also important to emphasize that while Roger's theoretical framework plays a significant role in the study design, use of data collected to assign labels to institutions or individuals indicating their adopter category is not the intent. The purpose of the study is to advance efforts to identify challenges to adoption of R&E network resources. It is not assumed that findings will result in broad sweeping recommendations that can be applied generally across institutions and users, and even less so across geographic regions. The intent is to inform the R&E community about existing challenges experienced by their institutions and to consider those challenges across the life cycle of network design and deployment.

The following sections further describe and characterize each of the three factors extracted in the analysis. This is achieved by inspecting the patterns displayed in the factor array in an effort to more clearly and accurately portray the perspectives shared by those study participants whose Q-sorts loaded significantly on each factor. Discussion for each factor begins with an overview of the unique characteristics of each factor followed by a discussion highlighting important issues specific to that factor. As applicable, comments from post-sort interviews are included to further substantiate interpretations. A summary concludes the discussion for each factor.

Factor 1: Social

This factor is characterized by the strong sentiment of attachment by users to the collegial research community, where relationships that include modeling and positive opinions from others in a peer group carry substantial weight in adoption decisions. The characteristics of Factor 1 very closely match descriptions of the important role that communication channels play in the diffusion process. Rogers illustrates this in his discussion on findings from diffusion investigations that indicate most individuals do not evaluate an innovation on the basis of

scientific studies or its consequences. Rather, people are more likely to depend on the subjective evaluation of an innovation that is shared with them by others like themselves who have already adopted the innovation. Analysis of Factor 1 aligns to this concept, where the dependence on the experience of close peers and colleagues suggests that modeling and mentoring are at the heart of the diffusion process, further emphasizing that diffusion is a very social process (Rogers, 2003: 18). In comparison to both of the others, this factor articulates the strongest alignment to the role that interpersonal relationships and communication channels play in the adoption process.

Important Issues Around Which Factor 1 is Polarized

Additional elements that uniquely characterize this factor include an overall general awareness and positive attitude about the value of use of R&E network resources. This includes an indication of general consensus on the value of and ability to opportunities for remote collaboration on research activities. Positively ranked in comparison to the other factors is the perception that adoption will occur when customization is available. Respondents in this group consider users to be early adopters of these tools. Users tend to act independently when determining which resources to use for their work, although they revert to a preference for collegial work, modeling and mentoring when considering use.

The theoretical array for Factor 1 indicates that perceptions on the current phase of adoption at this institution are fairly consistent across the range of topics included in the Q-set. Also consistently represented in this factor is the perception that the institution is not as prepared or as supportive in its attitude to advance the adoption of use of R&E network resources as it should be. A review of the distinguishing statements for this group further supports evidence of this viewpoint, where negative rankings are given in response to statements about availability of timely and skilled support, instruction and streamlined processes. Perceptions on supportive

institutional culture and user knowledge on integration of R&E network resources for research activities also hold negative rankings.

Summary of Factor 1

Initial analysis might indicate that the respondents in this group may be relatively new in their involvement in this community, or regardless of length of time, they remain peripherally engaged. Some complacency is indicated by lower rankings relative to campus culture, a lacking of campus level resources, and also low motivation by faculty researchers. Opinions are strong that institutional culture is not perceived to be conducive to adoption. In some cases, inadequate bandwidth may be an issue due to geographic distance from a network backbone. Overall, there appears to be a strong sentiment that access to and use of the resources is challenging, indicating a likely barrier to stronger levels of adoption.

In general, all responses are very consistent in perspectives and attitude. While IT leadership indicated a positive attitude and general awareness of the value proposition of R&E network resources, the responses to this group of questions indicates the institution is not prepared nor supportive in its attitude to advance the adoption of R&E network resources.

Factor 2: Facilitating

Two words were noted in comments resulting from a first pass at analysis of this factor: indifferent, yet pragmatic. Ranking of the various items in the factor array indicate the institutional perspective is that technical support and capacity are in place to scaffold users in their access and use of R&E network resources for their research. Attitudes about the knowledge and skills of users to integrate these resources into their research activities are also positive, indicating there is little concern that complicated processes or other issues are a challenge to adoption. Based on rankings of statements in the array, respondents indicate little evidence of

individual-blame bias in their viewpoints. Instead, the message that surfaces is related more to an attitude of indifference on the part of the both the users and the institution. Rankings indicate a pragmatic approach to how and why efforts have been made to make R&E network resources available, and the high level of confidence in the capacity of the institution and its users to employ R&E network resources. At the same time, there exists a lack of urgency to use.

Important Issues Around Which Factor 2 is Polarized

In comparison to Factor 1 where collegial relationships and communication was central to the characteristics of that factor, Factor 2 perceptions lean distinctively toward independency of users. Respondents indicate that a general awareness and positive attitude toward R&E resources exists and the value they provide to research activities on campus is appreciated by users and leadership. Rankings of items in the array indicates that users are more than capable and willing to consider the use of R&E resources, although motivation to adopt appears to be lacking.

While the general attitude of this factor related to potential benefits is positive, statements related to the impacts on the researcher and the institution's prestige and profile gained as a result of use of R&E network resources were consistently ranked more neutral, indicating that users are less likely to be influenced by such factors when making adoption decisions. Pragmatism is evidenced by responses to statements on facilitating conditions related to preparedness and capacity of institutional support for adoption. This is further implied by rankings rejecting any indication that institutional culture or complicated access and use are potential challenges to adoption.

Summary of Factor 2

The analysis together with a review of demographics indicates this group consists of institutions that have been engaged in the R&E network community for a while. The perspective on facilitating conditions may explain the level of institutional and infrastructure maturity indicated in the responses to the capacity and preparedness of this institution. In strong comparison to the others, Factor 2 rejects statements indicating that the complexity of the system creates a significant challenge to adoption. Again, in deference to the attitude of pragmatism characteristic of this group, while respondents are willing to acknowledge challenges that exist, those sentiments are balanced by higher confidence for capacity in other areas.

Factor 3: Performance

Dichotomous is the word to describe this factor and by association, the self-reported difference in perspectives between the study respondents and the end users at their institutions. Shared by respondents grouped into this factor is the favorable opinion relevant to the benefits of R&E network resources as they relate to the individual user and the institution. Conflicting with this perspective are more negatively ranked items that pertain to user knowledge and skills, and the ease in access and usability of the resources, all of which can serve as barriers to adoption. Respondents also indicate lower confidence in the capacity and preparedness of the institution to support integration of R&E network resources. Both statements related to the institution and the end user as early adopters were given a neutral ranking. Respondents perceive that users tend to act independently of influence or guidance when it comes to adoption decisions.

Important Issues Around Which Factor 3 is Polarized

Factor 3 was unique across the three groups to agree that increased dependency on the use of R&E network resources will increase in the next five years. A review of demographics

indicate that this opinion may be tied to geographic proximity to network backbone. IT leadership indicates a general positive awareness and attitude toward the value of R&E network resources for research, although they recognize that awareness of advantages may not play a major role in adoption decisions. Identified as a distinguishing statement for this group, Factor 3 is alone in placing the highest ranking on the efficiency provided by use of R&E resources. Ranked higher by this group than the others are those statements related to the positive benefits of prestige and profile to users and institutions that integrate R&E network resources. Also unique, Factor 3 responded with the highest ranking of all three groups in its agreement to the statement indicating the institution has dedicated staff and guidance available to support researchers in selecting and using R&E resources.

Summary of Factor 3

This group may include a higher number of institutions that have been engaged in R&E network community for a longer period of time or have a general awareness of the resources due to the indicated level of confidence in available support and the perceived value of R&E resources and their contribution to research.

Respondents indicate a high level of awareness of R&E value, and yet perceive some key issues such as resource accessibility and institutional culture that may be barriers to adoption. The perception holds that users function independently and yet are conscious of the level of use by colleagues and peers, which may result in a cautious attitude toward adoption. Respondents feel that their institutions have dedicated efforts to ensure some capacity is in place to support the need of research that engages in the R&E community, although they admit that challenges in areas such as communication, training and streamlined processes can be improved. Although this group ranked the potential for benefits to prestige and profile the highest across three factors,

there is indication of more indifference of perceptions related to resulting value to increased publication.

Results Summary

This chapter has stepped through the process of this research study, outlining the method and process developed to complete data collection and statistical analysis. Results were provided, followed by interpretation of the findings aligned to the root constructs identified in the UTAUT framework that served as a foundation to this study. The next chapter discusses these findings and interpretation in alignment to the research study questions, identifying implications for use by the R&E network community and the scholarly research community of Q methodology. Limitations of the current study and considerations for additional and extended studies on this topic will also be discussed.

CHAPTER 5. DISCUSSION

This study was designed to identify salient and compelling opinions of end users on the challenges to adoption of research and education (R&E) network resources at their local higher education institutions. Study participants represented Information Technology (IT) leadership at higher education institutions across the footprint of the Northern Tier Network Consortium (NTNC), a regional network that connects to the larger national U.S. R&E network infrastructure. This study applied the use of Q methodology to a modified UTAUT technology adoption model in order to identify opinions of institutional IT leadership regarding challenges to the adoption of R&E network resources for teaching and research at their local institutions.

This study is guided by a focus on the following research questions:

- What are salient challenges to adoption of Research & Education (R&E) network resources experienced by higher education institutions across the Northern Tier Network Consortium?
- How can knowledge of these challenges serve to inform those who advocate for the use and expansion of these resources, both in the NTNC and peer networks across the U.S.?

The discussion in this chapter will move forward from the detailed discussion on each factor provided in chapter four to the broader perspective of the context of this study as indicated by its research questions. The four constructs used in the study provide the framework for this chapter, where a discussion of each of the factors and their viewpoints is highlighted. Additional insights obtained through post-sort interviews that are relative to each of the constructs and the factor groups is included, followed by a section on implications for theory and practice in this field. Limitations of the current study and recommendations for future research are included.

Research Question 1

What are salient challenges to adoption of Research & Education network resources experienced by higher education institutions across the Northern Tier Network Consortium?

The data from this study has provided valuable insights into the concerns and challenges institutions are experiencing related to research support. The characteristics of the three extracted factors serve to highlight challenges unique to their subset, and at the same time confirm that certain challenges are shared and common by the majority of institutions. The institutional type, demographics and geographic locations of respondents were not a primary focus of this study. The information was collected in order to demonstrate the diversity of institutions and locations represented, affirming that specific challenges are not necessarily correlated to specific institutions.

Before proceeding with a summary of the findings for each construct, a simple list of the viewpoints of respondents from all three groups will help frame the discussion.

Salient viewpoints from across all three factor groups:

- Support for the value of a collegial environment that provided opportunities for modeling, mentoring, and partnering on research design and project activities.
- The existence of pro-innovation bias and individual-blame bias exists more for some institutions than others. If not acknowledged and addressed, it has the ability to widen the gap between the change agent and the user.
- Institutional capacity and preparedness to support research efforts is important to users.
- Access to and use of R&E network resources is challenging and can serve as a barrier to adoption.

An additional understanding of commonalities across the factor groups is provided by a review of the consensus statements identified from statistical analysis. Relevant to the items below, initials are used to represent each of the constructs, where PE represents performance expectancy, EE represents effort expectancy, SI represents social influence, and FC represents facilitating conditions.

Consensus statements ranked consistently positive by all factors:

- [PE] Using R&E resources to support research improves the job performance of researchers.
- [PE] Using R&E resources provides an advantage in economic terms (e.g., cost to conduct research; operational or overall cost to the institution).
- [PE] Researchers are likely to be interested in adopting this resource if it can be changed or modified to fit their needs.
- [PE] Use of R&E resources for research has the potential to achieve significantly different and improved processes and results.
- [PE] Use of R&E resources increases researchers' access to advanced research tools.

Consensus statements ranked consistently negative by all factors:

- [PE] R&E resources are not compatible with other systems currently used by researchers to work on their research.
- [EE] It is easy for researchers to improve their skill at using R&E network resources.
- [SI] Researchers who use R&E resources tend to have more prestige than those who do not.

Tables 5.1 through 5.4 presents a summary of the contrasting viewpoints aligned to the study constructs across the three factors.

Table 5.1

Summary of Factor Comparison in the Context of Performance Expectancy

Factor 1: Social	Pos.	Strong sentiment of alignment to the research community, where modeling and mentoring or fellowship among users is perceived to hold high value for end users. Strong agreement that access to and use of R&E network resources has a positive impact on users' adoption levels. Ease of use and the ability to customize. R&E resources are compatible with existing systems.
	Neg.	Indifferent/negative to value gained by the institution and researcher as a result of use.
Factor 2: Facilitating	Pos.	Strong agreement on items related to improved access to remote collaboration, improved efficiency, and capacity of the institution to support the use of R&E network resources. Also positive is convenience for research, ease of conducting research, ability to improve job performance, improving research and institutional reputation, ability to provide needed bandwidth and data, and access to advanced research tools. The ability to improve processes and results and provide an advantage in economic terms were also ranked positively. Positive about cultural norms at institution. R&E resources are compatible with existing systems.
	Neg.	Neutral or negative regarding the role of colleagues or peers who serve as leaders in adoption and model use for others. News and information are not communicated to researchers.
Factor 3: Performance	Pos.	Positive viewpoint toward the value and benefits to users. Also positive are time efficiency for research responsibilities and the ability to modify resources to fit research needs. Recognizes efforts by the institution to increase adoption through enhanced communication efforts. R&E resources are compatible with existing systems.
	Neg.	Researchers are not dependent on convenience, or collegial experiences and opinions when deciding whether to integrate R&E network resources into their research.

Table 5.2

Summary of Factor Comparison in the Context of Effort Expectancy

Factor 1: Social	Pos.	Neutral on the perception that users possess the skills and commitment to integrate R&E network resources into the research process.
	Neg.	Not easy for researchers to improve their skill on learning to access and use R&E network resources. The process is not clear and understandable. Low confidence on the capacity of the institution to support the use of R&E network resources through the availability of dedicated staff and guidance. No streamlined processes.
Factor 2: Facilitating	Pos.	Recognizes that the institution has tried to improve facilitation by streamlining the process for access to and use of R&E network resources. Time required to integrate R&E network resources and level of complexity are not major challenges to adoption.
	Neg.	R&E network resources are not clear and understandable.
Factor 3: Performance	Pos.	Confirms the institution has dedicated staff and guidance available to support researchers in selecting and using R&E network resources. Neutral – less concern that the system is too complicated and to takes too long to learn how to use.
	Neg.	Learning to access and use R&E network resources is not clear and understandable.

Table 5.3

Summary of Factor Comparison in the Context of Social Influence

Factor 1: Social	Pos.	Attitudes of colleagues, the level of use by others at the institution, and access to a cohort of researchers in developing research design and methodology all play a positive role in the adoption levels of these resources at their institution.
	Neg.	Less likely to be influenced by perceptions that use of R&E network resources increases the prestige of users. Neither the institution nor users are early adopters of these resources.
Factor 2: Facilitating	Pos.	Some agreement that the culture of the institution encourages the exploration and use of R&E network resources for research. End users at Factor 2 institutions tend to operate more independently of collegial or administrative support. More emphasis is on having access to the resources needed.
	Neg.	Neutral attitude for both institution and users as early adopters. Value of collegial support and mentoring ranked low.
Factor 3: Performance	Pos.	Conflicting responses on the value of collegial modeling and mentoring. Support for the perception that researchers will function independent of influences by other faculty or institutional leadership. Confirms the positive viewpoint of performance that addresses the value and benefits to users.
	Neg.	Users tend to be cautious in decisions to adopt if they perceive low use of resources by colleagues, and there is little encouragement by leadership at their institution. Institution ranks higher as an early adopter while users are ranked much lower.

Table 5.4

Summary of Factor Comparison in the Context of Facilitating Conditions

Factor 1: Social	Pos.	Some agreement (+1) that cultural norms of the institution can serve as a barrier to adoption of new R&E resources.
	Neg.	Lower level of confidence in the institution's ability to provide timely and skilled support when system difficulties arise, and also its ability to provide specialized and timely instruction on the use of R&E network resources. Low confidence that users have the knowledge necessary to use R&E network resources.
Factor 2: Facilitating	Pos.	Institutional capacity and user skill are ranked positively. Institutional culture is not perceived to be a barrier to adoption.
	Neg.	Users do not feel that using R&E network resources fits well with their work style.
Factor 3: Performance	Pos.	Respondents believe R&E network resources are compatible with all types of research and that timely and skilled support is available for assistance as needed.
	Neg.	Rankings are lower/neutral on confidence in the existence of specialized and timely instruction for users, researcher knowledge about use of R&E network resources, and researchers' perspectives on how R&E resources fit into their work schedules.

Construct: Performance Expectancy

Rankings across the factors indicate an overall positive perception of the value of R&E network resources and the benefits obtained for both individual research and the institution. This is further substantiated by the consensus statements. Of the eight Q-set items identified as consensus statements for this study, six are based in the performance expectancy construct. Themes of these items relate to improved job performance, improved advantages in economic terms to the research and the institution, increased interest in use when resources can be modified to fit research needs, improved potential to achieve different and improved results, and improved access to advanced research tools that are otherwise likely to be unavailable. Respondents also rejected a statement on compatibility, indicating positive opinions about R&E resources being compatible with other systems currently in use for research.

Identified Challenges

One critical theme in this construct that is emphasized by Factor 1: Social, is the importance of a collegial environment to support mentoring and modeling, as well as access to a cohort for feedback on research design and integration of R&E network resources. Because Factor 1 consists of over half of the institutions represented in this study it is notable that this singular theme is valued highly across this group. Factor 1 respondents represent a variety of institutions reflecting varying institution type and size and community populations. It is interesting to note that similar sentiments also surfaced in statement rankings and post-sort interviews by participants that aligned to the other factors.

> "…lots of times, research methods are all new so they don't have many colleagues to lean on."

"They definitely love stories of how others are using the R&E resources, particularly when they know/respect that colleague's work."

At the same time, a common reaction surfaced from participants aligned to all three factors as indicated in both statement rankings and post sort interviews. This sentiment highlights the characteristics of strong independence and self-sufficiency of faculty researchers regardless of the high value placed on collegial work, and how this frequently overrides loyalty to the institution. Expressed in various ways by all post-sort interviewees, a challenge to those providing support for end users is the need to recognize the freedom and flexibility required to advance research processes.

"They want to be independent, they are afraid we're going to put constraints on them."

"[They are] very centric to themselves and their work, not relative to the institution…"

"There is very much a sense of insulation, where researchers are very insulated from a lot of things on campus…so if a researcher gets a grant they are afraid to cough up any funds…so they hold their work close to hold on to what they have."

Construct: Effort Expectancy

Again, for this construct, Factor 1 stands alone in stating most definitively that not only do users struggle with use of R&E network resources, but that the institution does not have the capacity in place to support users when assistance and training is needed. Factor 2 and Factor 3 indicate higher levels of confidence in the institution to provide the capacity and support needed by users. While some contradicting rankings appear by respondents across the factors and across statements based in different constructs, there appears to be consensus on concerns that access and use is not as transparent as it could be.

Identified Challenges

Only one statement from this construct appears in the list of consensus statements although it may concisely summarize the overarching attitude of all respondents. Indicated by a negative response by all factors, which is interpreted as a rejection of the item, is the statement that reads, "it is easy for researchers to improve their skill at using R&E network resources." Whether the respondents are of the opinion that their institution has done more or less to address infrastructure and support systems needed for use of R&E network resources to flourish, a consistent sentiment surfaces across all three groups indicating an undercurrent of frustration in this area.

"They prefer to default to the tools they know and are comfortable with."

Construct: Social Influence

Along with the construct on performance expectancy, rankings by respondents for statements in this construct indicated distinctive viewpoints on the attitude toward the value of mentoring, modeling and partnering on research activities among colleagues. Factors 2 and 3 report much less concern for this value in contrast to Factor 1, where statements related to partnerships with colleagues rank consistently positive.

"They are opportunistic so when they see models they haven't thought of they are quick to jump on it. They respect their colleagues – if respected, they are way more likely to take advantage of it."

Rankings of the institution and the end users affirm the characteristics defined by each factor. When asked to rank the institution and the individual users as early adopters of R&E network resources, Factor 1 ranks both the institution and the user more negatively, indicating lower confidence for both. Factor 2 confirms its more pragmatic approach, providing both with

slightly higher rankings. And Factor 3 again exemplifies the dichotomous perspective in that group as indicated by responses to other statements, when a higher ranking is given to the institution in comparison to the ranking given to users.

"..[They prefer] tried and true – don't like [new tools and resources] for it may fail."

The single consensus statement based in the social influence construct refers to the level of prestige achieved by researchers who use the resources was ranked negatively consistently across all three factors.

"They don't care about the university or prestige."

Identified Challenges

Challenges identified through responses to statements in this construct mirror perspectives indicated in the performance expectancy construct where interactions with colleagues are positively ranked. The varying perspectives of the three factors may be indicators of a gap between those considered to be pro-innovation and those who are more tentative in their attitudes toward adoption of new resources. Closing the gap may not be something that can be achieved on its own without dedicated attention.

"Yes, definitely the institution is an early adopter…a fishbowl area was constructed to showcase the blinking [network] connections to the R&E networks."

"Efforts attract grad students and helps to drive the mission of partnerships with external research groups."

"They trust more to look inside, not really looking for collaborations across the institution."

Construct: Facilitating Conditions

Low confidence in the capacity and preparedness of the institution to provide support needed is again a primary concern by those respondents in Factor 1. Factor 2 also indicates concerns and yet provides higher rankings on similar issues. In highest contrast, Factor 3 ranks statements on institutional capacity and preparedness the highest, while ranking the capacity of users more negatively. In a review of distinguishing statements, only Factor 1identifies culture at the institution as a concern for exploration and use of R&E network resources. No statements from this construct are included in the consensus statements for factors in this study.

Identified Challenges

Institutional capacity and preparedness to support research efforts is important to institutions and their researchers across all three factors. However, the perception of a strong contrast between capacity of the institution verses capacity of the researcher is most evident in responses from Factor 3 to statements from this construct. This dissidence aligns to the description of pro-innovation bias explained by Rogers (2003). As exemplified by the groups in the three factors of this study, pro-innovation bias exists more for some institutions than others. If not acknowledged and addressed, it has the ability to widen the gap between the change agent and the user.

> "It's about central IT and research [offices] doing a better job of sharing. We do not have an 'advanced cyberinfrastructure facilitator' so outreach is lacking."

Individual-blame bias also emerges as a characteristic viewpoint in this study. Individual-blame bias is closely related to diffusion research and defined by Rogers (2003) as the tendency to hold the individual responsible for his or her problems, rather than the system of which the individual is a part. In this study, data analysis from one of the factor groups showed evidence of

a stronger emphasis on individual-blame bias in comparison to the other two factors. Individual-blame bias, as the name implies, focuses on the shortcomings of the individual rather than the system. In many cases, the challenges to adoption can stem from the system level to which the individual belongs. Efforts to clarify the distinction between the two is critical, as placing blame solely on the individual will do little to address any challenges within the larger context of the system.

> "They are creatures of habit – many are advanced, but they are the exceptions. Most don't want to invest their own time, cycles, resources to use what we have to offer."
>
> "…new hires will say, "I've used this in my post doc or doctoral program so that's what I need to use", they do not want to use things the university already has paid for. Instead they want to use what they are used to regardless of if they would have support in place…"

Research Question 2

How can knowledge of these challenges serve to inform those who advocate and champion the use and expansion of these resources, both in the NTNC and peer networks across the U.S.?

Findings resulting from Q methodology studies are by nature more general. In the discussion to this point, a variety of perspectives and viewpoints have been examined and can be considered generally representative of the whole group of respondents. An effort has been made to provide details and a holistic view that more closely expresses the individual viewpoint. This application as defined by Stephenson (1953) implies that subjectivity of the individual serves as an operant, an indication of behavior or activity. In particular, the use of Q methodology for this study provides insights into participants' intention to use and their usage behavior, as articulated

through the viewpoint expressed in each individual Q-sort (Watts & Stenner, 2012). These collective viewpoints have been reduced to a more parsimonious description of key perspectives through the process of factor extraction. The implications for innovation adoption activities posited here are not intended to broadly predict or guarantee the success of specific interventions. Rather, salient themes regarding the challenges suggested by the results are discussed in relation to the study's four root constructs.

Performance Expectancy: Implications for Adoption

Due to the emphasis placed on the value of collegial relationships for mentoring, modeling and collaborative work on research by the majority of participants in this study, it is practical for institutions to consider this topic as a primary consideration in their planning for development and deployment of access to R&E network resources. Regardless of location, size or institutional mission, awareness and attitude users have toward integration of these resources may be positively impacted through the deliberate planning of activities that support and strengthen user collaboration. Asserted by himself and others, Rogers includes this finding in his list of characteristics of adopter categories where he states, "An individual is more likely to adopt an innovation if more of the other individuals in his or her personal network have adopted previously" (Rogers & Kincaid, 1981; Valente, 1995).

> "…if we can show them that they are more productive, their research will be completed more quickly, they are ecstatic."
>
> "…absolutely it's true…it shows that peers are doing it so it must be ok. Unless the research is so new, so cutting edge, so exploratory, they are looking for something that's proven."

Additional comments provided through post-sort interviews reflect on the impact that efforts to engage in at least some level of high-impact activities helps to increase the perceived value of the resources. Messages from institutional leadership are heard and noted by end users and worth consideration in planning for support of research.

> "For those researchers who do use these resources, we have had some pretty high visibility projects over the years…our [IT] shop plumbed the concert hall in preparation."

Effort Expectancy: Implications for Adoption

Historically, and still too frequently, employment of R&E network resources is perceived as available to only those conducting research with requirements for advanced scientific hardware and extensive computing cycles. Because of this many of the IT leaders that participated in this study, along with their peers around the world can provide anecdotal stories of researchers who assume their research would not qualify for use of these resources. By association, the motivation and urgency to access and learn about the systems may not be as evident. As research capacity continues to expand, and the types of research conducted across all disciplines are faced with analysis of larger and larger data sets, the lack of urgency may be replaced with increased concern since the sheer size of many data sets demand the use of high-performance clusters to complete the computations required. Institutions will be challenged to find ways to enhance and expand the support and assistance available. With budgets continuing to tighten across this country's higher education institutions, a vision for shared network resources and computational services across larger regional areas is beginning to take shape. These services are working to provide personal support and help desk services remotely in a way that further compliments and enhances support services at the local institution. If successful, this

model has the potential to ease some of the challenges an institution may face in working to deploy these services on their own.

> "Some are becoming evangelists for us – these guys can help you, and this is what they've done for my research."
>
> "Those who are not in the physical sciences tend to assume they are not part of this community…needs to be clarified and discussed."

Social Influence: Implications for Adoption

Similar to the implications defined for the construct of performance expectancy where collegial partnerships are perceived as critical to expanded use, this construct mirrors those sentiments and implications for adoption could be addressed in similar fashion.

Additionally, the indifference toward increased prestige and reputation by the researcher and the institution surfaces in this construct. In light of this characteristic, it might be worthwhile for an institution to consider devoting more resources toward collegial partnerships among the users as a first priority.

> "The Chancellor is pushing faculty to increase their visibility through publications…so that is something that colleges are aware of."

Facilitating Conditions: Implications for Adoption

As indicated previously in the discussion on the challenges identified for themes within this construct, acknowledging its existence and addressing pro-innovation and individual-blame bias in efforts of diffusion and adoption should be considered and recognized as a necessary challenge.

Comments from post-sort interviews provide guidance on elements to consider in supporting adoption.

"Adoption is high and on-boarding is supported."

"They have to see that we are willing to remove barriers and that we are willing to support them."

Implications for Theory

Both Rogers' diffusion theory (2003) and the UTAUT model (Venkatesh, Morris, G. Davis, F. Davis, 2003) served as a foundation for the framework of this study. At the time of this study, a review of literature did not yield existing studies that applied the UTAUT model to the context of the R&E network community. The primary focus and intent of UTAUT and its many predecessors was to identify determinants impacting the acceptance of information technology. Results of the UTAUT study served to condense the number of determinants down to a more manageable number. Those determinants were used as the framework for this study and to develop the Q-set of statements. A comparison of UTAUT's findings and those from this study provide useful insights.

The performance expectancy construct was found by UTAUT to be a determinant of intention to use. According to UTAUT researchers (Venkatesh, Morris, G. Davis, F. Davis, 2003) this construct consistently emerged as the strongest predictor of intention to use. Although this study did not include a focus on other moderating influences such as time or voluntariness, results from the study indicated consistent acknowledgement of elements in the performance expectancy construct that are perceived as critical to the users.

Effort expectancy is the result of three constructs from other technology adoption models that were merged to address the elements of perceived ease of use, complexity and ease of use. UTAUT researchers report that these effort-oriented constructs are expected to be more salient in the early stages of adoption of a new innovation and decrease as users become more comfortable

and begin to focus efforts on still newer processes. This may provide insights in this study where introduction to the access to R&E network resources is still in the beginning stages for an institution. It should be clarified though, that the focus of this study was not restricted to a specific application or process that is siloed in its scope and use. The process of research is defined by continuous exploration so it should be understood that it's unlikely any user will reach a completely static comfort level for too long. Technology continues to change and by association, so do the tools and resources available. Each new resource will likely require some effort dedicated toward new learning.

The construct of social influence was been found by UTAUT researchers to influence the level of adoption at different rates depending on if the use is voluntary or mandatory. These moderators were also not included in the scope of this study, so the concept of pressure from social influence in order to align to mandatory requirements directed by colleagues is not as relevant to this study. The characteristic of social influence most strongly tied to the findings in this study relates to the ability of users to engage in a community of peers when looking for existing models of use, requesting the guidance of users with established skills, and partnering with others in the process to design and implement research studies that incorporate these tools.

The construct of facilitating conditions is defined by the UTAUT researchers (Venkatesh, Morris, G. Davis, F. Davis, 2003) as a composite of characteristics from previous studies and is operationalized to reflect the capacity of an institution or environment designed to remove barriers to use. Modification of the framework in preparation for this study resulted in the addition of statements to other constructs that carried similar themes. If used in future studies, a refined definition of this construct may be helpful and clearer for study participants.

The decision by the researcher to meld the foundation of Rogers' innovation theory with the UTAUT framework provided a practicable guide for the development of the concourse in this study. The themes experienced and identified by the researcher as challenges to adoption of R&E network resources were easily matched to the categories implied by the constructs. In the context of the technology addressed in this study, there is some overlap of themes among the four constructs and these should be reviewed and considered in the design of future studies to determine relevance to the given research topic. Additional discussion applicable to implications for theory are addressed below.

A critical element associated with the diffusion process as defined by Rogers (2003) is that of time. Time impacts and is impacted by the diffusion process in several key areas. Time is elemental in the progression of an individual or unit to move from first knowledge or awareness of an innovation through to the behavior that reflects adoption or rejection. In the diffusion process, time is also impacted by the level of innovativeness of the individual or organization tasked with adoption. In reference to Roger's adopter categories, less time will be required for early adopters to move to acceptance in comparison to late adopters. Another metric for adoption relative to the element of time is simply to account for the number of individuals or members in a system who complete adoption within an identified time period. For this study, all settings for adoption were considered voluntary, where no specific parameters were mandated for type or frequency of use. In addition, participants represented institutions with a wide range of maturity in their deployment and use of R&E network resources. The perspectives of study respondents were self-reflections of current and past experiences captured at one specific point in time. Since the element of time used for Roger's diffusion theory aligns primarily to the deployment of an innovation where there is a specific beginning and end with which to measure adoption, the lack

of those parameters for this study make it challenging to infer a correlation between time and adoption. It is not uncommon for an IT unit to complete the required upgrade to network design and infrastructure without the end user even being aware that the level of resources has changed. Therefore, to the end user, there essentially is no way to demarcate a starting point at which adoption can begin. Also, given the nature of how technology resources are designed and deployed, the ultimate goal is always for these resources to function in a way that is transparent to the user. As indicated in the Q-sort rankings and open-ended responses by respondents in this study, respondents frequently referenced the lack of communication to end users regarding the existence of the resources and how to access and adopt their use in support of academic and research activities. All of these dynamics yield a much different scenario than one in which the time to adopt can be measured when a planned deployment of a new technology application is launched on a specific date and the directive to begin use of the resource is mandated by management.

This setting for voluntary usage also hints at the direction for themes of expanded studies. Future research could explore the impact of voluntariness as a moderator where mandatory settings and deployment efforts were equal in their definition and process across user groups. Such a scenario might include metrics that focus on defined types of resources to be adopted as well as the designated end users. For example, a specific set of resources could be identified for use within an undergraduate class exploring access to remote science instruments used for specialized data collection followed by analysis and visualization. The measurement of how quickly and extensively the resources were adopted could be among the data points captured and provide insights into how the different settings impacted adoption challenges.

Implications for Practice

A discussion exploring the implications for practice based on the results of this study will benefit from revisiting the original planned scope of the study. Based on the literature review completed prior to beginning this research, two key differentiating elements between the goals of this study and those existing in this field were identified. First, this study proposed to focus on the specific technological innovation of R&E network resources along with the services they support and enable. The studies found to exist on the topic at the time of this study focused on adoption of technology innovations specific to business office applications or technologies, using business office settings as a source for study participants. In addition, other studies used students in undergraduate classes as participants. These settings for adoption in comparison to those of an R&E network and its resources clearly evidence the unique objectives and scope of this study. Second, an equally important distinction between this study and those conducted previously, is that the identified unit or system targeted in this study refers to any of the various community anchor institutions (CAIs) defined earlier, with primary focus on higher education institutions. The application of the study framework to this specific and distinguishable unit expands the implications for practice. While these unique qualities speak to implications for future studies, they also provide a glimpse at studies that could be conducted at a more granular level rendering implications for both theory and practice. A deeper dive into topics such as adoption of mobile and cloud applications verses workstation interfaces could assist in identifying challenges to adoption of cloud resources that frequently depend on data transfer from remote sites to a data center for computation and analysis. By its nature, the constant evolution and advancement of technology tools and resources will continue to provide ample opportunities for researchers to

apply the theoretical framework of this study to a variety of specific innovations relative to research practices served by R&E network resources.

Other areas that may benefit practically from the insights provided by this study were also discussed earlier. For the community of target participants, the viewpoints that emerged as primary characteristics of the three factor groups can help decision makers determine plans for expansion and upgrades in terms of ongoing investment of technical and human resources. Today's higher education academic and research community confronts many challenges, and findings from this study, while not intended to be perceived as predictors for adoption success, can help to inform those who work to plan and develop programs across a broad spectrum of themes.

Formalized instruction on the use of R&E resources and related topics on research cyberinfrastructure through program coursework is an area of growing interest across many disciplines and is driving the momentum by academic programs to include at least a portion of related course content. The growth and evolution of big data applies across disciplines, where sizable repositories and data sets originating in fields from social sciences to physics and engineering draw the attention of academic leadership as they work to strengthen elements of degree programs, including both curriculum and research experiences. Not to be taken lightly is the application of advanced security tools and practices that strengthen the capacity of the networks and their members institutions to continuously ensure data integrity.

Dependent on partnerships spanning education and industry, workforce development is a shared theme across both areas and very relevant to the discussion on degree-granting programs and career preparation. Concerns continue to intensify regarding the critical need to tackle the emerging needs of contemporary research while addressing challenges for workforce

development aimed at meeting the needs of unresolved bottlenecks in scientific research. The National Science Foundation serves as a prime example of the concern in this community and the urgent need to address these challenges. With their national and global perspective, the NSF is steadfast in their determination to explore grant funded projects targeted at integrating core literacy and discipline-appropriate advanced skills in cyberinfrastructure. These efforts to advance fundamental research include the addition of computational and data-driven science and engineering into educational curriculum and instructional material that span undergraduate and graduate courses (National Science Foundation, 2019).

Also, with close ties to workforce development, research experiences and training is a topic that frequently and justifiably dominates the conversation on adoption of R&E network resources (Monaco et al., 2016). This effort focuses much of its attention on training intended to strengthen the capabilities of current and especially future generations of researchers. Training models cover the gamut of scenarios and not surprisingly, continue to evolve with current technologies. Models range from a focus on the individual campus to interinstitutional, and increasingly to a focus at the regional level. The expense of staffing and resources needed to provide adequate support for research activities, let alone the cost of the required hardware, software and network resources continues to push institutions to consider creative ways to not only engage their faculty researchers in the use of these tools, but also to ensure they have the capacity to support the path forward as research evolves.

The challenges experienced by individual institutions to ensure access to the tools needed and provide the timely support needed increases the emphasis on exploring options to creatively share resources and assets beyond just the institution's footprint. Shared cyberinfrastructure opens the door to collaborations by higher education institutions of all sizes and types, increasing

the potential for equitable access by faculty and students at all institutions. It also has the potential to strengthen the foundation of collegial mentoring and modeling found to be a critical concern for the largest and first factor group extracted in this study. While numerous white papers and publications point to the potential value of increasing collaboration on research project development across institutions and geographic regions, a much smaller, though growing emphasis specifically explores the value of strong ongoing collegial mentoring and modeling. A concerted effort focused on building and sustaining cohort relationships that can serve as a scaffold for the researchers themselves, and for their work across disciplines should be considered a critical benchmark in strategic planning and implementation.

Implications for practice are also evident in the themes chosen for use within the Q-set of the current study. Noting the reminder that Q methodology is not intended for use in predicting behavior, the rankings of statements, and thereby the themes of those statements can be analyzed to identify useful information about the likelihood of success of proposed innovations earlier in the planning stages of development and deployment, where such information has greatest value. Understanding how and why end users may perceive an innovation provides insights into challenges that may emerge in deployment. At a deeper level, results of the study can serve to inform those serving as change agents of salient factors that implicate both the intention and the behavior toward the use of the resources, as indicated by the constructs developed in the UTAUT (Venkatesh, Morris, G. Davis, F. Davis, 2003) framework and employed to guide this study.

And on a final note, with close ties to the contemporary issues surrounding broadband access in rural and remote areas, the findings of this research should help to further enlighten efforts toward improvement in this country and around the world. Regardless of institutional type or size or geographic location, efforts to expand Internet connectivity to education institutions,

residences and businesses in rural and remote areas is critical in supporting the populous with equitable access required to support today's economic, educational, public service and entertainment industries.

Limitations and Delimitations

A delimitation of this study addresses a decision by the researcher not to include additional moderators beyond the identified root constructs that may influence adoption decisions and the rate of adoption. Although defined and included in the UTAUT (Venkatesh, Morris, G. Davis, F. Davis, 2003) research, the moderators of gender, age, voluntariness and experience were not included in this study due to the nature of the data and data collection process. At the time this research was conducted, no research had been identified that used the UTAUT framework to focus specifically on the R&E network community. Subsequent research that uses this study as a foundation could be designed to focus on a different target audience, specifically faculty researchers. The demographics of such a study could appropriately reference one or more of the moderators.

Related to the decision not to include the moderators for this current study are concerns expressed by others in the field of technology adoption. These identified shortcomings should be recognized and addressed in an effort to improve research design and outcomes. Specific to the moderator of voluntariness, criticisms of UTAUT by Straub (2009) indicate that it is a model that measures adoption only in mandatory settings, as opposed to voluntary adoption. Since UTAUT is still new and relatively untested it has seen little use in subsequent studies since its development, with few resulting study publications. Because of this, there is concern about its appropriateness to environments such as educational institutions and informal learning situations.

Pro-innovation Bias

Without a doubt, underpinnings of pro-innovation bias are present in this study, by both the researcher and the respondents, and it is critical to note this element in a discussion on study limitations. Described by Rogers (2003) as one of the most serious shortcomings of diffusion research, pro-innovation bias is defined as the implication in diffusion research that an innovation should be diffused and adopted by all members of a social system, that it should be diffused more rapidly, and that the innovation should be neither re-invented nor rejected. A discussion on the causes of pro-innovation bias clearly matches several indicators of how pro-innovation bias is at work in this study. First, diffusion research is frequently subsidized or initiated by change-agencies, so the bias is an accepted element of the researchers' focus from the beginning. The researcher responsible for the design and implementation of this study fits the description of a change agent or a representative of a change agent. In addition, a successful diffusion or adoption process is easier to track, replicate and analyze in retrospect, in comparison to a diffusion that is unsuccessful, where little research has traditionally focused. By association, this communicates the message that within the research community, too little is really known about failed diffusions or adoptions. Emphasized by Rogers (2003), making the effort to gain more insights into this type of outcome could well provide valuable insights left uncovered by traditional diffusion/adoption research.

In the scenario for this study, the researcher and by assumption, the respondents, are considered to be aligned to the change agency that is promoting the adoption. Diffusion researchers can be criticized for operating under the assumption that the advantages and benefits of an innovation, in this case the R&E network resources, are perceived to be equally positively appreciated by all involved. Drilling down to the individual user level for a first attempt at more

clearly understanding the perceived value of the innovation by the individual could go a long way to shed light on how behavior and intention to use is approached by that individual and by the larger system.

Recommendations for Future Research

Previous discussion on identified delimitations and limitations of this current study provide insights into some general revisions that could be made in order to achieve a more granular perspective on participant viewpoints as they relate to underlying moderators. These results could assist in additional valuable guidance on actionable items that could positively influence adoption decisions.

Efforts to control or avoid pro-innovation bias should be considered within the process of study design and selection of study participants. To address this concern, suggestions by Rogers (2003) and others in the community offer suggestions for consideration. Ensuring the study design and deployment process engages and includes perspectives of both the researcher and participants in the identify study community is one way to give all perspectives a voice from beginning to end. Resulting refinements that may surface and be addressed in the design phase of the research are more likely to capture data that holds more clarity and specific implications. These may include one or more of the following: exploring the study of different types of units of analysis other than individuals; involving more units, both individual and system level, to engage in the process of framing and defining the diffusion challenges that may be beyond those defined only by the change agency; and considering other variables to include in the research, including social and communication structural variables. A variable or moderator related to consideration for the amount of time needed for diffusion and adoption could be explored in an effort to more clearly define the stages of adoption. Adding a moderator like time or some of the

others suggested by the UTAUT study should include consideration of how to appropriately assign beginning and ending markers to an innovation's adoption. We are reminded by Rogers (2003) that the innovation process does not happen immediately, even when a system's leadership is supportive of adoption. In the technology environment, the evolution of tools and process is continuous and thus a challenge to capture and precisely delimit.

Recommended by the authors of the UTAUT are suggestions appreciated from the context of this study, where a suggestion to design comparative studies that extend the research on UTAUT to include adoption of different technologies and the resources and tools made available by them. The researchers of the UTAUT study believe that studying adoption of other types of technologies can further strengthen the overall generalizability of UTAUT (Venkatesh, Morris, G. Davis, F. Davis, 2003).

Future research could also take a closer look at the systems that are perceived as successful by information technology standards to determine if they are perceived by the system or organization in the same way. The current study limited data collection to the specific target audience of information technology leadership at the identified institutions. Without the engagement and input provided by all involved stakeholders, this option could be challenging and possibly endanger interpretation of the results. This concern is primarily due to the nature of the unique circumstances and deployment of R&E network resources for research processes across institutions, across disciplines and across the research study life cycle. It would be wise to adopt a cautious approach to any study design that attempts to strictly frame and limit the definitions of success.

And finally, insights gained through in-person post-sort interviews provide additional clear options for future studies that look more closely at the nature of one specific, possibly dominant factor using interview data of participants that share this viewpoint.

Conclusions

The findings from this study have served to identify additional and in some cases new descriptions for the characteristics that describe challenges to adoption of R&E network resources by higher education institutions across the region of the Northern Tier Network Consortium. A modified model of UTAUT (Venkatesh, Morris, G. Davis, F. Davis, 2003) provided the framework for this Q methodology study. The choice of Q methodology as tool for data capture and analysis ultimately provided the foundation required to analyze *how* and *why* the variety of content articulated in the Q statements matter to the end users. The heart of Q methodology as intended by Stephenson (1953) is for the subjectivity of the participant to be operant, an indicator of activity and behavior. This is exemplified in completion of the Q-sort process itself. Application of the UTAUT constructs as a way to frame the discussion surrounding the specific technology tools and resources of R&E networks has resulted in completing the first step in a process to further refine an existing theoretical model for purposes that expand its original scope.

Findings from this study identified the emergence of three predominant themes that characterize challenges to adoption of R&E network resources. These themes include are exemplified by Factor 1: Social, with a group that is represented by half of the study participants and is characterized by a strong sentiment of alignment to the research community, where modeling and mentoring or fellowship among users is perceived to hold high value for end users. The participant group that makes up Factor 2: Facilitating, consists of slightly less than one third

of the study participants. takes a more pragmatic approach and admits that while the institution and end users have worked to put resources in place and obtain the skills needed to integrate them into research, there remains a sense of indifference or urgency to increase use. For Factor 3: Performance, the remaining participant group shows a distinguishing characteristic that focuses on the perception that while the institution has the capacity and resources to support use of R&E network resources, end users are less interested and definitely less capable of adopting and integrating these resources into their research activities.

While not intended to be used as a predictor of use, the resulting categories can provide timely insights both to those responsible for deployment of an intervention, as well as those who are the end users. It is hoped that the design and results of this study are helpful in directing future research on innovation adoption, and for the communities of regional research and education networks that work to advance scholarly and scientific research.

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APPENDIX A. ALIGNMENT MATRIX FOR THE THEORETICAL FRAMEWORK, ADOPTION CHALLENGES, AND Q-STATEMENTS

UTAUT User acceptance and usage behavior determinants	R&E technology adoption challenges believed to influence user acceptance and usage behavior	Q Statements
Major construct: Performance expectancy (PE) **Definition:** The degree to which an individual believes that using the system will help him or her to attain gains in job performance. **Related root constructs:** · Perceived usefulness · Extrinsic motivation · Job-fit · Re-invention · Relative advantage · Outcome expectations	**Challenge:** Performance expectancy relevant to the benefits for work/research is often at low levels for both researchers and IT personnel. **What does this look like?** Performance expectancy (by faculty) is often limited due to lack of adequate awareness and knowledge of available resources limits expectations by users. Performance expectancy (by IT staff) is often limited to a technical viewpoint only, without the perspective of uses that are discipline specific. **What does this look like in the context of R&E network resources?** Those primarily responsible for locally disseminating information and training on these resources are typically IT based personnel who perform specific technical and administrative tasks. The result is information that is disseminated and shared in less detail and/or with less focus on discipline-specific applications with a more limited audience of users and in a less timely manner. This has the potential to negatively impact advancement and use of the resources for academic and research activity.	1. Using R&E resources to support my research improves my job performance. 2. Use of R&E network resources makes it easier to do my research. 3. Using R&E resources provides an advantage in economic terms (i.e. cost to conduct my research; operational or overall cost to my institution). 4. Looking ahead to the next five years, research at my institution will become increasingly more dependent on the use of R&E resources. 5. I will use R&E resources if I know they provide an advantage in convenience for my research activities. 6. I consider the experiences and opinions of my department colleagues when deciding to use R&E resources. 7. I consider the experiences and opinions of colleagues outside of my institution when deciding to use R&E resources. 8. News and information communicated to researchers on our campus contributes to increased adoption of R&E resources. 9. I rely on the input of key individuals when I have questions about the value/benefits of integrating R&E resources into my research activities. 10. R&E resources will provide an advantage to improving the reputation of my research. 11. I am most likely to access national and international resources (such as XSEDEnet, etc.) to support my research for if I know that my institution is already considering its use. 12. There are one or more individuals at my institution who typically serve as leaders in adopting or rejecting new innovative resources such as those available via R&E networks.

UTAUT User acceptance and usage behavior determinants	R&E technology adoption challenges believed to influence user acceptance and usage behavior	Q Statements
		13. I feel most comfortable adopting a new R&E resource for my research when I know it is already in use by others at my institution.
		14. Use of R&E resources can decrease the time needed for important research responsibilities.
		15. Use of R&E resources can increase the quantity of (research) output for the same amount of effort.
		16. R&E resources are not compatible with other systems I use to work on my research.
		17. I am likely to be interested in adopting this resource if it can be changed or modified to fit my needs.
		18. I am most likely to consider use of a new resource for my research if I can make my own decisions on when and how it will be used.
		19. The use of R&E resources to support my research has the potential to achieve significantly different/improved processes and results in comparison to those I achieve with the use of existing resources.
		20. Use of R&E resources helps me complete research tasks more quickly and efficiently.
		21. Use of R&E resources improves likelihood of research publication.
		22. Use of R&E resources help me design more advanced research studies than I can without them.
		23. Use of R&E resources make it easier to collaborate on research with peers at other institutions and research sites, regardless of their location.
		24. Use of R&E resources increases my access to advanced research tools to which I don't otherwise have access.

UTAUT User acceptance and usage behavior determinants	R&E technology adoption challenges believed to influence user acceptance and usage behavior	Q Statements
		25. I use R&E networks because they provide the additional bandwidth and data security needed for my research activities.
Major construct: Effort expectancy (EE) **Definition:** he degree of ease associated with the use of the system. **Related root constructs:** · Perceived ease of use · Complexity · Ease of use	**Challenge:** Users (of R&E resources) frequently believe the level of effort required to access and obtain the service will be higher if they are located at smaller, more rural institutions. **What does this look like?** The availability or perceived lack of availability by a campus to provide access to these supporting resources can negate user interest and motivation in pursuing use of these resources. Ultimately this can challenge an institution's ability to attract and retain faculty and researchers whose work depends on them. **What does this look like in the context of R&E network resources?** Researchers are located at institutions of various sizes often in rural/remote areas. IT personnel located at these same institutions may also lack awareness of the R&E resources available, further reinforcing the perception that any attempts to incorporate these tools into existing infrastructure is almost insurmountable.	26. Learning to access and use R&E network resources is clear and understandable. 27. It is easy for me to improve my skill at using R&E network resources. 28. My institution has streamlined the process for using R&E resources, so I can spend less time doing mechanical operations (e.g. administrative, methodical, data input, etc.) and more time on actual research activities. 29. I can customize the system to do what I want it to do. 30. My institution has dedicated staff and guidance available to support me in selecting and using R&E resources. 31. Working with the system is so complicated, it is difficult to understand what is going on. 32. It takes too long to learn how to use the system to make it worth the effort.
Major construct: Social influence (SI) **Definition:**	**Challenge:** Institutional/discipline/collegial influences impact motivation of individual researchers to seek out these resources at their home institution. **What does this look like?**	33. Colleagues in my field (discipline) encourage me to access resources (such as XSEDE, GlueX, data transfer nodes, etc) accessible through R&E networks. 34. The culture at my institution encourages researchers to explore and use R&E resources.

UTAUT User acceptance and usage behavior determinants	R&E technology adoption challenges believed to influence user acceptance and usage behavior	Q Statements
The degree to which an individual perceives that important others believe he or she should use the new system. **Related root constructs:** · Subjective norm · Social factors · Image	At the institutional level, the attitudes and expectations by colleagues within the department, across the institution, and at the leadership level all play a role in motivation of an individual to integrate use of R&E resources into their research. Beyond the institution, a researcher is influenced by peers within her/his discipline to do the same. Individuals and/or groups within the higher education community view the ability to provide access to these resources as an indicator of status and standing for the institution among its peers. The availability or perceived lack of availability by an institution to provide access to these supporting resources can challenge an institution's ability to attract and retain faculty and researchers whose work depends on them. **What does this look like in the context of R&E network resources?** In a world where basic Internet access is now pushing the debate on defining access as a public utility, similar to electricity and water, the definition of access encompasses not just resources for specialized academics and research, but also equitable access for all populations to grow and train future workforces and expand their economies, regardless of location or proximity to highly urbanized areas. IT leadership engaged in the broader conversation and perspective of access are influenced by this environment and view it as incumbent on their institution to join a larger effort in expanding access efforts nationally and globally.	35. I consider the perceptions/attitudes of my department colleagues when deciding if and how to incorporate R&E resources into my research activities. 36. I hesitate to use R&E resources for my own research because use of these resources by other faculty at my institution is low or non-existent. 37. I hesitate to use R&E resources for my own research because Institutional leadership and senior faculty do not encourage use of R&E resources. 38. I would use R&E resources more frequently if I could lean on a cohort of other researchers when brainstorming research model design and methodology that incorporates R&E resources. 39. Researchers who use R&E resources have more prestige that those who do not. 40. Researchers at my institution who use R&E resources have a higher profile within their research community than those who do not. 41. Institutions that demonstrate high use of R&E resources have more prestige that those who do not. 42. I would rank my institution as an early adopter of R&E network resources for teaching and research. 43. I would rank myself as an early adopter of R&E network resources for teaching and research.

UTAUT User acceptance and usage behavior determinants	R&E technology adoption challenges believed to influence user acceptance and usage behavior	Q Statements
Major construct: Facilitating conditions (FC) **Definition:** The degree to which an individual believes that an organizational and technical infrastructure exists to support use of the system. **Related root constructs:** · Perceived behavioral control · Facilitating conditions · Compatibility	**Challenge:** Adequacy of IT resources to support advanced scientific research. **What does this look like?** Integrating R&E resources into the work of academics and research frequently requires support from personnel who hold the responsibility to manage these tools. Technology-based skills and knowledge are one element of this support. Critical technology challenges requiring increased skilled support include research data mobility, cybersecurity, and assurance of advanced information technology knowledge and skills attainment and transfer. A second and equally critical element involves discipline specific knowledge in order to frame the "cross-walk" that accurately connects the needs of the research to the right technological tools and resources for the task at hand. **What does this look like in the context of R&E network resources?** These tools and resources are seldom place-based. Society increasingly looks to higher education to perform leading-edge research. These teams of researchers may be located at institutions and research centers around the world, and yet are able to partner on specific tasks to complete needed research regardless of their location. Those supporting the technological resources on which these activities travel bear the responsibility to ensure work can take place securely and uninterrupted in an any time/any place model.	44. I have the knowledge necessary to use R&E resources available at my institution. 45. The social/cultural norms of my institution sometimes serve as a barrier to adoption of new and innovative (R&E) resources. 46. Specialized and timely instruction on using R&E resources is available to me. 47. Timely and skilled support is available for assistance when system difficulties arise. 48. The use R&E resources is compatible with all aspects of my research. 49. Using R&E resources fits well with my work style. 50. Using R&E resources fits into my work schedule.

APPENDIX B. BIVARIATE CORRELATIONS BETWEEN PARTICIPANTS (Q-SORTS)

P#	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	100	24	38	-17	20	8	22	22	21	26	27	-3	25	9	8	20	5	5	7	9	20	30	9
2	24	100	28	8	-2	-5	11	27	33	3	21	-18	29	28	18	0	14	12	-5	14	13	22	9
3	38	28	100	-17	12	16	56	15	50	22	54	32	40	36	24	34	18	15	8	21	46	43	22
4	-17	8	-17	100	-9	-40	-32	19	-23	-29	-20	-21	-20	-4	3	-32	-16	-13	-11	9	-32	-13	-9
5	20	-2	12	-9	100	64	-7	-10	20	56	24	-5	22	43	-12	32	28	-7	37	-22	40	42	37
6	8	-5	16	-40	64	100	5	3	34	62	37	11	21	33	-9	31	30	16	24	-11	44	42	41
7	22	11	56	-32	-7	5	100	12	47	13	21	32	19	7	5	13	3	13	-4	14	23	25	8
8	22	27	15	19	-10	3	12	100	22	18	22	-5	7	-4	38	13	29	29	5	36	16	19	11
9	21	33	50	-23	20	34	47	22	100	47	38	8	44	36	1	41	43	20	15	-9	46	47	25
10	26	3	22	-29	56	62	13	18	47	100	37	6	33	24	0	50	45	15	39	-12	40	59	57
11	27	21	54	-20	24	37	21	22	38	37	100	41	28	29	34	32	27	30	9	41	65	53	36
12	-3	-18	32	-21	-5	11	32	-5	8	6	41	100	5	4	28	7	17	33	-11	39	22	26	10
13	25	29	40	-20	22	21	19	7	44	33	28	5	100	25	1	21	18	13	19	-9	42	28	43
14	9	28	36	-4	43	33	7	-4	36	24	29	4	25	100	30	37	38	26	17	-7	51	32	13
15	8	18	24	3	-12	-9	5	38	1	0	34	28	1	30	100	3	4	50	-15	48	30	21	-7
16	20	0	34	-32	32	31	13	13	41	50	32	7	21	37	3	100	53	37	48	-23	49	36	41
17	5	14	18	-16	28	30	3	29	43	45	27	17	18	38	4	53	100	13	25	-2	46	28	30
18	5	12	15	-13	-7	16	13	29	20	15	30	33	13	26	50	37	13	100	6	11	41	25	15
19	7	-5	8	-11	37	24	-4	5	15	39	9	-11	19	17	-15	48	25	6	100	-41	25	38	50
20	9	14	21	9	-22	-11	14	36	-9	-12	41	39	-9	-7	48	-23	-2	11	-41	100	6	11	-12
21	20	13	46	-32	40	44	23	16	46	40	65	22	42	51	30	49	46	41	25	6	100	49	30
22	30	22	43	-13	42	42	25	19	47	59	53	26	28	32	21	36	28	25	38	11	49	100	47
23	9	9	22	-9	37	41	8	11	25	57	36	10	43	13	-7	41	30	15	50	-12	30	47	100

APPENDIX C. INITIAL (UNROTATED) FACTOR MATRIX FOR THE EIGHT CANDIDATE FACTORS

Q-sort	F1	F2	F3	F4	F5	F6	F7	F8
01	0.374	0.1382	0.2322	0.3645	0.2521	0.0204	-0.0611	0.6223
02	0.2648	0.2957	0.637	0.2347	-0.0948	0.188	0.0054	-0.0849
03	0.624	0.3683	-0.0181	0.4101	-0.0442	0.0814	0.1571	-0.0554
04	-0.3679	0.1077	0.5492	-0.2754	0.1725	0.1058	0.2286	-0.3286
05	0.533	-0.5046	0.0043	-0.1505	0.2017	0.4474	-0.0502	0.0937
06	0.6119	-0.3518	-0.2522	-0.141	0.1818	0.2499	-0.2629	0.0465
07	0.3654	0.333	-0.2443	0.5976	-0.0657	-0.2083	-0.0449	-0.0787
08	0.2671	0.405	0.4871	-0.2235	0.2249	-0.4163	-0.3089	0.0384
09	0.6815	0.0326	0.1437	0.3542	-0.1944	-0.0863	-0.2267	-0.2427
10	0.725	-0.3301	-0.0089	-0.0754	0.2876	-0.0964	-0.1781	0.0412
11	0.6909	0.3604	-0.137	-0.0966	0.227	0.1629	0.0688	-0.0483
12	0.2843	0.4406	-0.6431	-0.103	0.0765	-0.0565	0.1351	-0.2466
13	0.5314	-0.0447	0.1833	0.3452	-0.0291	0.0512	0.31	-0.1201
14	0.5508	-0.0043	0.1621	-0.1746	-0.4789	0.4893	0.0487	-0.0326
15	0.2312	0.6776	0.0743	-0.4243	-0.1189	0.0685	0.1261	0.225
16	0.664	-0.2381	-0.0238	-0.1281	-0.31	-0.3356	-0.0304	0.1314
17	0.5676	-0.1167	0.1075	-0.2391	-0.1959	-0.1581	-0.4539	-0.3263
18	0.4074	0.3637	-0.077	-0.3881	-0.3347	-0.2752	0.204	0.2247
19	0.4184	-0.5346	0.1265	-0.1331	0.0202	-0.3273	0.3448	0.0674
20	0.0315	0.7687	-0.0826	-0.1642	0.3911	0.1133	-0.145	-0.089
21	0.7797	0.1015	-0.0874	-0.1366	-0.209	0.1524	0.0153	0.0434
22	0.7407	0.0327	0.0285	-0.0484	0.2948	0.0266	0.1521	-0.0078
23	0.5879	-0.3082	0.0579	-0.0776	0.3342	-0.2281	0.3425	-0.2293
Eigen.	6.392427	2.987912	1.693387	1.65819	1.297215	1.235375	0.999508	0.95522
PVE	28%	13%	7%	7%	6%	5%	4%	4%
CPVE	28%	41%	48%	55%	61%	66%	70%	74%

APPENDIX D. FACTOR SCORES AND THEORETICAL ARRAY RANKINGS FOR ALL STATEMENTS BY ALL FACTORS

S#	Statement	Factor 1		Factor 2		Factor 3	
		Z	*Q*	*Z*	*Q*	*Z*	*Q*
1	[PE] Using R&E resources to support research improves the job performance of researchers.	1.107	4	1.054	4	1.004	3
2	[PE] Use of R&E network resources makes it easier to conduct research.	1.072	3	1.081	4	-0.964	-3
3	[PE] Using R&E resources provides an advantage in economic terms (e.g., cost to conduct research; operational or overall cost to the institution).	0.607	2	0.545	2	0.297	0
4	[PE] Looking ahead to the next five years, research at my institution will become increasingly more dependent on the use of R&E resources.	0.062	0	0.510	1	1.710	5
5	[PE] Researchers use R&E resources if they know they provide an advantage in convenience for research activities.	1.204	4	1.174	4	-1.807	-5
6	[PE] Researchers consider the experiences and opinions of their department colleagues when deciding to use R&E resources.	0.536	1	0.145	0	-0.842	-3
7	[PE] Researchers consider the experiences and opinions of colleagues outside of our institution when deciding to use R&E resources.	0.290	0	0.383	1	-2.327	-5
8	[PE] Relevant news and information communicated to researchers on our campus contributes to increased adoption of R&E resources.	-0.596	-1	-0.938	-3	0.320	0
9	[PE] Researchers rely on the input of key individuals when they have questions about the value/benefits of R&E resources.	1.056	3	0.138	0	-0.618	-2
10	[PE] R&E resources provide an advantage to improving the reputation of research conducted at our institution.	0.632	2	0.973	3	-0.178	0
11	[PE] Researchers are most likely to access national and international R&E resources (such as XSEDEnet, etc.) if they know that the institution already has access.	1.629	5	1.378	5	0.587	2
12	[PE] There are individuals at our institution who typically serve as leaders in adopting or rejecting new, innovative R&E resources.	0.672	2	-0.017	-1	-0.377	-1
13	[PE] Researchers feel most comfortable adopting a new R&E resource for their research when they know it is already in use by others at your institution.	1.224	4	0.222	1	0.360	1
14	[PE] Use of R&E resources can decrease the time needed for important research responsibilities.	0.731	2	0.217	0	1.251	5
15	[PE] Use of R&E resources can increase the quantity of research output for the same amount of effort.	0.272	0	0.069	0	2.103	5

S#	Statement	Factor 1		Factor 2		Factor 3	
		Z	*Q*	*Z*	*Q*	*Z*	*Q*
16	[PE] R&E resources are not compatible with other systems currently used by researchers to work on their research.	-1.078	-3	-1.620	-4	-1.525	-4
17	[PE] Researchers are likely to be interested in adopting this resource if it can be changed or modified to fit their needs.	0.535	1	0.362	1	1.083	4
18	[PE] Researchers are most likely to consider use of an R&E resource if they can decide when and how it will be used.	1.585	5	0.531	1	0.545	1
19	[PE] Use of R&E resources for research has the potential to achieve significantly different and improved processes and results.	0.447	1	0.600	2	0.304	0
20	[PE] Use of R&E resources helps researchers complete research tasks more quickly and efficiently.	0.387	0	1.438	5	1.026	4
21	[PE] Use of R&E resources improves likelihood of research publication.	-0.907	-2	-0.465	-2	-1.543	-4
22	[PE] Use of R&E resources helps researchers design more extensive studies than they can without them.	0.466	1	0.065	0	-0.354	-1
23	[PE] Use of R&E resources make it easier to collaborate on research with peers remotely, regardless of their location.	1.591	5	1.973	5	0.931	3
24	[PE] Use of R&E resources increases researchers' access to advanced research tools.	0.955	3	0.860	3	0.874	2
25	[PE] Researchers use R&E networks because they provide the bandwidth and data security critical for research activities.	0.307	0	0.956	3	0.466	1
26	[EE] Learning to access and use R&E network resources is clear and understandable.	-1.031	-3	-0.723	-3	-2.103	-5
27	[EE] It is easy for researchers to improve their skill at using R&E network resources.	-0.765	-2	-1.159	-4	-1.452	-4
28	[EE] Our institution has streamlined the process for R&E use, so researchers spend less time doing administrative tasks, and more time on research.	-2.002	-5	0.582	2	-0.410	-1
29	[EE] Researchers can customize the resources and tools available through R&E networks to do what they want them to do.	-0.654	-2	0.020	-1	-1.452	-4
30	[EE] Our institution has dedicated staff and guidance available to support researchers in selecting and using R&E resources.	-1.642	-5	-0.380	-2	0.834	2
31	[EE] Our researchers feel that working with the system is so complicated, it is difficult to understand what is going on.	0.078	0	-2.471	-5	-0.505	-2
32	[EE] Our researchers feel that it takes too long to learn how to use the system to make it worth the effort.	-0.004	-1	-2.099	-5	-0.281	-1
33	[SI] Researchers are influenced by their colleagues to use R&E network resources (such as XSEDE, GlueX, data transfer nodes).	0.436	1	-0.320	-2	1.076	4

S#	Statement	Factor 1		Factor 2		Factor 3	
		Z	*Q*	*Z*	*Q*	*Z*	*Q*
34	[SI] The culture at our institution encourages researchers to explore and use R&E resources.	-1.474	-4	0.478	1	0.330	0
35	[SI] Our researchers consider the attitudes of their colleagues when deciding if and how to incorporate R&E resources into research.	0.829	2	-0.145	-1	-0.779	-3
36	[SI] Our researchers hesitate to use R&E resources because use of these resources by other faculty is low or non-existent.	0.844	3	-1.850	-4	-0.499	-2
37	[SI] Our researchers hesitate to use R&E resources because they receive little encouragement from Institutional leadership and senior faculty.	-0.153	-1	-1.865	-4	-0.818	-3
38	[SI] Our researchers would use R&E resources more frequently if they could lean on a cohort of other users when designing their research model.	1.203	4	0.590	2	0.853	2
39	[SI] Researchers who use R&E resources tend to have more prestige than those who do not.	-0.785	-2	-0.463	-2	-0.538	-2
40	[SI] Researchers at our institution who use R&E resources have a higher profile within their research community than those who do not.	-1.049	-3	0.062	0	1.004	3
41	[SI] Institutions that demonstrate high use of R&E resources have more prestige that those who do not.	-0.187	-1	-0.510	-3	0.930	3
42	[SI] I would rank my institution as an early adopter of R&E network resources.	-1.606	-4	-0.246	-1	0.370	1
43	[SI] I would rank our researchers as early adopters of R&E network resources for research.	-2.033	-5	-0.180	-1	-0.762	-2
44	[FC] Our researchers have the knowledge necessary to use R&E resources available at our institution.	-1.409	-4	0.974	3	0.169	0
45	[FC] The cultural norms of our institution sometimes serve as a barrier to adoption of new R&E resources.	0.412	1	-2.134	-5	0.628	2
46	[FC] Researchers feel that specialized and timely instruction on using R&E resources is available at our institution.	-1.350	-4	0.560	2	-0.409	-1
47	[FC] Researchers feel that timely and skilled support is available for assistance when system difficulties arise.	-1.133	-3	1.172	4	0.392	1
48	[FC] The use of R&E resources is compatible with all aspects of research.	-0.149	-1	-0.481	-2	1.021	4
49	[FC] Our researchers feel that using R&E resources fits well with their work style.	-0.471	-1	-1.043	-3	0.370	1
50	[FC] Our researchers feel that using R&E resources fits into their work schedule.	-0.689	-2	-0.007	-1	-0.297	-1

Note. *Z* = Standardized factor scores, *Q* = Sort rank from theoretical array.

APPENDIX E. Q-SORT OPEN-ENDED RESPONSES

For each study respondent, additional information collected via the online tool included the institution name, number of staff in the institution's Information Technology department, and a listing of the three lowest and three highest ranking statements as indicated in their Q-sort. For both of these categories, respondents were asked to provide additional information on reasons for their ranking of these statements. To protect respondent anonymity references to the institution and any other identifiable information has been removed. Not all respondents chose to provide feedback.

Statements are enclosed in parentheses where "s" refers to statement and is followed by the statement number (ex: s42). Refer to the statements and their relative construct in Appendix A.

PIN:	01
STAFF SIZE:	L (51 or more)
DATE/TIME:	2019-03-04 16:02:05
LEAST	(s43) More conservative as group. Must prove that it is worth while using.
	(s42) Tried and true. Don't like for it may fail.
	(s7) They look for within first before considering out side sources. More independent of external influences.
MOST	(s33) Using nationally normed programs drives many research to also use.
	(s30) Having dedicated has tripled the numbers researchers coming for help because we viewed as partners
	(s20) Time and time again this the answer we get why they are using the resource. Move quicker to promotion and tenure.

PIN:	02
STAFF SIZE:	M (21 to 50)
DATE/TIME:	2019-03-11 13:00:30
LEAST	(s21)
	(s7)
	(s26) We struggle to put in place a robust training program for our researchers especially those grad students who haven't experience HPC before.
MOST	(s15) Our tools have shown to decrease run time significantly and thus allow the researcher to get more output with the same amount of effort. In particular our new cluster has reduced run times from 3 weeks to 3 hours (roughly)
	(s11)
	(s4)

PIN:	03
STAFF SIZE:	L (51 or more)
DATE/TIME:	2019-03-12 12:35:53
LEAST	(s31)
	(s32)
	(s36)
MOST	(s38)
	(s24)
	(s20)

PIN:	04
STAFF SIZE:	S (20 or fewer)
DATE/TIME:	2019-03-21 15:50:18
LEAST	(s11)
	(s12)
	(s16)
MOST	(s13)
	(s31)
	(s42)

PIN:	05
STAFF SIZE:	S (20 or fewer)
DATE/TIME:	2019-03-25 11:38:41
LEAST	(s46) This information is not available.
	(s44) Researchers need a lot more information.
	(s43) Our researchers simply are not on the leading edge.
MOST	(s7) Researchers here look to their outside colleague's experiences because we have such a small faculty and often have departments of one.
	(s9) Many times researchers have limited experience and need more information and look to key people for that information.
	(s35) How other researchers view R&E resources and the support structure is very important again because of our small faculty and their limited amount of time so they have a high need to achieve success with minimal effort.

PIN:	06
STAFF SIZE:	S (20 or fewer)
DATE/TIME:	2019-03-25 11:53:26
LEAST	(s42)
	(s30)
	(s43)
MOST	(s9)
	(s12)
	(s6)

PIN:	07
STAFF SIZE:	S (20 or fewer)
DATE/TIME:	2019-03-25 13:20:43
LEAST	(s45)
	(s43)
	(s36)
MOST	(s44)
	(s24)
	(s19)

PIN:	08
STAFF SIZE:	S (20 or fewer)
DATE/TIME:	2019-03-25 14:11:43
LEAST	(s7) Feel strongly.
	(s6) Feel strongly.
	(s5) Feel strongly.
MOST	(s14) Feel strongly.
	(s13) Feel strongly.
	(s10) Feel strongly.

PIN:	09
STAFF SIZE:	S (20 or fewer)
DATE/TIME:	2019-03-25 15:30:37
LEAST	(s43)
	(s42)
	(s40)
MOST	(s5)
	(s18)
	(s1)

PIN:	10
STAFF SIZE:	S (20 or fewer)
DATE/TIME:	2019-03-26 11:05:28
LEAST	(s40)
	(s43)
	(s4)
MOST	(s19)
	(s11)
	(s36)

PIN:	11
STAFF SIZE:	L (51 or more)
DATE/TIME:	2019-03-26 15:29:57
LEAST	(s16)
	(s31)
	(s27)
MOST	(s1)
	(s5)
	(s13)

PIN:	12
STAFF SIZE:	S (20 or fewer)
DATE/TIME:	2019-04-01 11:24:21
LEAST	(s45) Cultural norms have no bearing on adoption of institutional resources here.
	(s8) This sounds like something engineered to justify a mailing list.
	(s31) They don't.
MOST	(s2) Increased access allows for more convenient transfer of data/knowledge.
	(s11) If you already have access to something of course people are going to use it.
	(s23) Increased access allows for more convenient transfer of data/knowledge.

PIN:	13
STAFF SIZE:	L (51 or more)
DATE/TIME:	2019-04-04 14:05:55
LEAST	(s44) Established faculty have not trained themselves well on how to use these resources. Those who do, often delegate use of these resources to graduate students. I expect this to change as younger faculty move up through the ranks.
	(s43) Use is often delegated to graduate students, not the faculty themselves. I believe faculty at other (larger) research institutions are further ahead.
	(s12) Unclear to me how much leadership is being given from faculty who do use these resources to other faculty who don't.
MOST	(s48) Most all disciplines could find a use for R&E resources. Not all do, but I expect the number of disciplines that use these resources to increase in the future.
	(s30) We do and have had so for years.
	(s4) I believe this is a nation wide trend.

PIN:	14
STAFF SIZE:	L (51 or more)
DATE/TIME:	2019-04-04 15:57:58
LEAST	(s46) I am sure they do not feel this exists, since nobody has really communicated such services on an ongoing basis.
	(s47) Service does not exist, so I am pretty sure they would not feel that it does.
	(s39) I just do not agree with the statement... many great researchers may not utilize R&E resources ever, for example.
MOST	(s18) They want control - anything that sounds 'prescribed' to them will be a barrier to use.
	(s13) They definitely love the stories of how others are using the R&E resources, particularly when they know/respect that colleague's work.
	(s3) One-offs for every research need is expensive.

PIN:	15
STAFF SIZE:	L (51 or more)
DATE/TIME:	2019-04-04 20:31:59
LEAST	(s26) Since we've automated most types of access, we don't spend much time on making this clear. The few research groups that do have to know the details get special treatment.
	(s31) This isn't something I've ever heard from our researchers
	(s32) Most researchers use the services we have and they seem to get up to speed pretty quickly.
MOST	(s28) We've automated the use of many aspects of access to R&E network resources so for many of them they don't have to any special.
	(s4) Big data, specialized instruments in remote locations, team science, it all adds up to more importance for R&E network resources
	(s3) Every time we've looked, the costs for R&E resources have been at least an order of magnitude less expensive than commercial resources.

PIN:	16
STAFF SIZE:	L (51 or more)
DATE/TIME:	2019-04-10 13:12:34
LEAST	(s46) not enough resources available to dedicate for R&E
	(s28) same as above. We have not streamlined the process
	(s34) between lack of resources and communication challenges, researches do not know who to reach out to or what is available.
MOST	(s35) With lack of communication, research rely on others' experiences.
	(s33) same as above
	(s5) communication matters

PIN:	17
STAFF SIZE:	M (21 to 50)
DATE/TIME:	2019-04-15 13:57:34
LEAST	(s34) Though researchers by definition are explorers, the culture of the university limits pure exploration and encourages tightly defined exploration that brings an important and direct return on investment for the researcher's campus job status (e.g. department status, tenure track, etc.). Exploring what the network can and cannot do for a researcher, feels like two or three layers away from that value-proposition. So whether the campus directly or indirectly intends to discourage exploration, it really doesn't matter, IMO [In My Opinion] they do.
	(s28) If I had to choose whether the network reduced administrative tasks or increased them, I would likely say increased them - indirectly. I say indirectly, because it is not really the network, but the applications that the network enables. Many of these applications are very disjoint and esoteric - though well intention. But as they say the road to hell is paved with those...Trying to sort through the SIS [Student Information System], the HRIS [Human Resource Information System], the administration applications for cataloging research

work etc. is a challenge as they all are unique and many not intuitive. I am sure they aid the campus, but I doubt they aid the researcher in saving time.

(s21) I am not sure the network can aid publishing at all. I do believe it helps in gaining research grants at times, but find it far afield that it aids in publishing.

MOST (s23) Networks are for communication above all else i.e. tools, data, etc. The universal availability of the network thus makes collaboration allowable world-wide.

(s1) It is almost impossible to find a job or task that doesn't use the network for ease of use and increased productivity. Researchers use the network heavily and naturally throughout the research process. Having said, I am not sure a researcher would answer this similarly. It would not surprise me if many see it like any ubiquitous tool - like the telephone, desk or fax - and not related to the research process.

(s5) That is just human nature. If it helps me - I will invest time in it to get the fullest value I can from the resource.

PIN: 18
STAFF SIZE: L (51 or more)
DATE/TIME: 2019-04-18 14:49:54
LEAST (s8)
(s45)
(s32)
MOST (s1)
(s4)
(s28)

PIN: 19
STAFF SIZE: M (21 to 50)
DATE/TIME: 2019-04-23 16:25:28
LEAST (s28) We have not invested what we need to invest to make this happen. Faculty spend way too much time on administrative tasks.

(s8) We have no formal or informal communication plan.

(s30) We have not invested in any - zero- dedicated staff.

MOST (s4) The university has established research and scholarly success as Goal #2 on the university strategic plan.

(s2) R&E network resources are becoming more ubiquitous, with faculty coming from grad programs where the faculty member had experience with advanced resources.

(s35) Peer review and peer resources are important to faculty.

PIN:	20
STAFF SIZE:	L (51 or more)
DATE/TIME:	2019-04-23 19:14:18
LEAST	(s45) Research is highly valued, and R&E removes a barrier despite remote location
	(s32) Adoption is high, and onboarding supported
	(s37) Research is highly valued, and R&E use is ubiquitous
MOST	(s42) twenty five years adoption
	(s25) [State] remote location makes this highly pertinent
	(s23) [State] remote location makes this highly pertinent

PIN:	21
STAFF SIZE:	L (51 or more)
DATE/TIME:	2019-04-24 06:57:06
LEAST	(s43)
	(s42)
	(s34)
MOST	(s9)
	(s5)
	(s3)

PIN:	22
STAFF SIZE:	L (51 or more)
DATE/TIME:	2019-04-29 10:13:32
LEAST	(s28)
	(s43)
	(s42)
MOST	(s25)
	(s24)
	(s23)

PIN:	23
STAFF SIZE:	L (51 or more)
DATE/TIME:	2019-05-06 13:20:05
LEAST	(s8)
	(s30)
	(s28)
MOST	(s11)
	(s23)
	(s18)