

Collaborative Learning through Wireless Grids

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Abstract

In this paper, we describe wireless grids, an emerging technology that enables ad hoc sharing of resources (such as screen, services and microphone) on edge devices (such as mobile Internet devices, laptops and mobile phones). As wireless devices have become common, and “smart,” wireless grids have become practical. To highlight the capabilities of wireless grids to support collaborative learning, projects at the K-12 and undergraduate levels illustrate that wireless grid theory is transitioning into practice. We hypothesize that wireless grids can transform how students learn, the content of courses, learning-related practices, classroom dynamics and relationships among students and faculty. The authors conclude that applications of this technology will bring about fundamental changes in the ways that students, schools and universities create and disseminate ideas, knowledge, and understanding. The mobile phone is no longer banned in the classroom; it becomes a tool for instruction and learning.

1. Introduction

Collaborative and distributed learning allow students and instructors to participate in learning activities anytime and anywhere. Much attention has already been paid to ‘distance’ learning systems, but that begs the question of whether location should be the primary factor in designing a learning system. We believe that as much as we wish for each individual student to achieve their best learning outcomes, in practice what we really wish for is for each student to be able to contribute to – a learning community. Therefore collaboration is a skill that should be built into student’s educational experience. While distributed learning provides an environment where resources can be shared and dispersed students may participate in learning, collaborative learning puts more emphasis on providing a shared workplace for students to interact and learn through cooperation. Learning technologies can offer a platform not only

for traditional students to conduct additional learning activities outside of the classroom, but also working adults or other nontraditional students to learn according to their own schedules. In this paper we highlight the capabilities of wireless grids to support collaborative learning. To illustrate, we describe briefly several projects which we are participating in collaborative teams to design evaluative studies at the K-12 and undergraduate levels.

A major problem in the research and development of distance learning systems is how to provide organized effective support for communication, interaction, and collaboration in networked virtual learning environments [1]. Mechanisms for collaborative virtual environments-based every-citizen learning communities need to be devised to support peer-to-peer communication, in addition to human-computer communication, where human users and software agents coexist and interact. Grid computing emerged as an effective model for harnessing the power of many distributed computing resources to solve problems requiring a large number of processing cycles and involving a huge amount of data [2], [3]. The grid connects computers, storages, sensors, and services via fixed-line or wireless Internet. One can say that the goals of grid computing include resource sharing and coordinated problem solving and enabling dynamic virtual organizations/world [4]. The advantages of grid include data and performance reliability (avoiding single point of failure), performance (avoiding network and computation bottleneck), and resilience (guaranteeing the existence of data and its backup). In the emergence of new grid concepts, distance learning can be considered as one important application of grid, and as a service to this emerging virtual world [5].

2. Rationale

Online learning has grown in both the corporate [6] and the educational fields [7]. As reported by the Sloan Consortium, “there has been no leveling of the

growth rate of online enrollments” and there has been a record growth in “both a numeric and a percentage basis” [7]. Successfully completing an online class is even becoming a requirement for graduation in some states [8]. This impact is being felt not only in the United States, but also worldwide [9] [10], changing the way educators and educational institutions conduct business [9].

Computer supported collaborative learning (CSCL) environments have been used successfully to promote learning achievements in distance education. CSCL environments are viewed as an important electronic learning medium for distance education. These environments can be described as a context where technology facilitates interactions among learners for acquisition of knowledge, skills and attitudes [11].

Any new generation of learning technology brings new conceptual issues that learning technologists must untangle in order to unlock the learning value of raw technological potential [12]. The field of CSCL has already addressed two key concerns: control and representation. The concern with control led to a definition of three possible roles for the technology component [13] as: (1) tutor, an algorithm or artificially intelligent agent is predominately in control of the student (2) tutee, the student exercises control by programming the technical component and (3) tool, where the teachers, activities and teams of students are the loci of control and the technology is a mediating object that is neither in control nor the object to be controlled.

Most wireless technologies for education in the literature today fall in the tool camp; they do not control learning, nor do students program them [14]. This is where wireless grids is poised to include this missing dimension, that is improving the process of interaction, negotiation and collaboration so that students have an active and constructive role in the learning process. Its use has the potential of improving working together while accomplishing a task. This is seen as a characteristic of a powerful learning environment, aiming at active construction of knowledge [15].

3. Proposed Exploration

Wireless grid researchers are ideally suited to benefit from, and contribute to the improvement of collaborative learning, as the subject of study and the digital objects engineered by the participating students, faculty, and firms are themselves intended to facilitate collaborative interaction across social grids of individuals and devices. For some time we

have been seeing the use of wireless technology resulting in escalating transformations of the educational world [16], [17]. For example the movement towards ubiquitous learning, the idea being learning environments will be accessed increasingly in various contexts and situations forcing new questions to arise regarding adaptation of learning spaces to contexts of use, so that they continue to enable and support learning processes [18], [19]. The collaborative learning wireless grid provides the infrastructure and social context for ubiquitous learning.

The question is how will the wireless technologies affect the learning environment and pedagogy? We propose the exploration of wireless grids technology to find possible solutions. Research in cognitive wireless networks and radios can contribute to intuitive, easy access to content, applications and devices for future educational objectives. These technologies will potentially provide, in a natural way, a support for both distance and traditional learning activities facilitating the experimentation and evaluation of new emerging didactical models based on the learning by doing approach.

4. Background of Wireless Grids Research

Broadband wireless network access in the United States and worldwide is experiencing continuing growth in both the consumer and business sectors [20]. Wi-Fi enabled consumer electronics devices are expected to grow from 40 million shipped in 2006 to 249 million shipped by 2011[21]. The commercial success of wireless technologies is evident with a global mobile communication penetration beyond 3 billion subscribers as well as the enormous success of wireless data communication through IEEE 802.11x and Bluetooth [22]. Users see the value in and are attached to wireless services despite their current limitations and difficulties in usability. Despite the popularity of Apple’s devices like the iPod personal music device, in a survey conducted by WiFi Alliance [23], 80% of respondents would rather give up their iPods rather than their home wireless local area networks.

While it is clear that wireless networks will continue to proliferate in the US and worldwide, their current implementation as a means of providing access to a wired network is narrowly focused. As these new wireless networks grow in reach and more wireless enabled devices join them, these wireless networks start to transform from simple methods of

enabling network access to components of wireless grids, which have shown great potentials in maximizing resource sharing among users.

Many of today's devices, such as laptops, mobile Internet devices and music players, are enabled to access and utilize Wi-Fi wireless networks. Future devices will arise due to advances in the semiconductor industry, power management, and manufacturing. Nanotechnology and biological systems may also fold into the wireless grids as means of improving technologies or finding new applications. They bring a wealth of features to a grid (wired or wireless) beyond mere computational power. Standards such as LTE, WiMAX and Zigbee are emerging, but the ability of such devices to be self-aware of their membership in virtual communities is still limited.

4.1. What are Wireless Grids?

Sharing resources between wireless devices allows them to solve a common problem or define new services [24]. Research in wireless grids has sparked the development of new types of applications to utilize the new services offered by its concept. It is a new type of resource-sharing network that connects sensors, mobile devices and other edge devices with each other and with wired grids. It can enable small and low-cost flexible wireless devices that can combine their sensing, communications and computations. One of the main advantages of wireless grids is that they can reach both geographic locations and social settings that computers have not traditionally penetrated. Thus, new services, that were nonexistent before, will be offered through wireless grids. However, the implementation is not without its obstacles. From the technical perspective a typical individual wireless device does not have enough resources to support sophisticated collaborative applications. For example, it has limited computational, communications, and battery power capabilities. It is also found in highly mobile ad-hoc contexts that are characterized by rapid, unpredictable changes in device availability and connectivity. The scope of wireless grids, in some ways, resemble networks already found in connection with agricultural, education, military, transportation, air-quality, environmental, health, emergency and security systems [24]. A range of institutions, from the largest governments to very small enterprises, is capable of owning and at least partially controlling wireless grids [24], [25].

A wireless grid creates an application overlay that allows for devices to seamlessly access features and applications of other devices on the grid, potentially

across multiple, non-interoperable wireless (and wired) networks. With a wireless grid, users would have access to the wide array of resources from devices on the grid including computational cycles (as seen with traditional grids), hardware features (audio, printers, storage, displays, etc.), as well as stored information. In a wireless grid, a device does not need to understand every protocol in order to accomplish a task (e.g. we don't need printer drivers to spool a print job; we can send that data to the device that understands the printer and that device can do the work.) The distributed intelligence of existing devices and their resident software may be used to benefit a broader device and user community, of the wireless grid.

Therefore, wireless grids can be defined as the ad-hoc dynamic sharing of physical and virtual resources among heterogeneous devices. See Figure 1 which shows that wireless grids connect the resources of edge devices with each other and with wired grids.

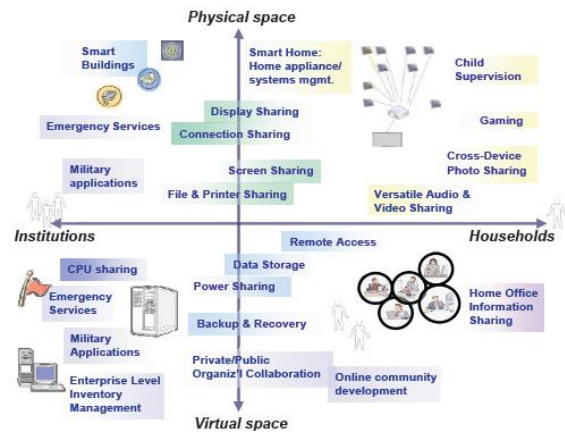


Figure 1.
Technology roadmap for wireless grids
(Courtesy of Wireless Grids Corporation)

There has been increasing acknowledgement of the nascent growth of wireless grids as a new engineering field of scientific inquiry and innovation [26]. The grid is seen as an emerging infrastructure that will fundamentally change the way we think about and use computing [24]. A broader understanding of the nature of the opportunities offered by grid computing and the technologies needed to realize those opportunities is required [27]. The concept of a virtual workspace, as a configurable execution environment can be created and managed by reflecting client requirements [27], [28]. The development of a testbed will stimulate a variety of groups to use this technology in ways that are beyond their present understanding. We hypothesize those grids of devices, data, and people can share

resources, and can help students in their own work. Inspired by findings from the prior National Science Foundation (NSF) project, we are organizing a global wireless grid consortium to facilitate industrial, academic, and government research and collaboration in this emerging field of study.

4.2. Foundation Wireless Grids Research

Our previous transformative NSF Partnership For Innovation (PFI) project (Virtual Markets and Wireless Communication and Computational Grids – NSF #0227879) led to the identification of the market mechanisms and usability features that can drive the adoption of these innovative solutions. The project identified the need for small grids, middleware and ‘edgware’. Market mechanisms for developed and developing countries were considered and usability features in the commercial, education, emergency, and medical sectors that can drive the adoption of new grid solutions were also identified. Related work included works on user and socio-technical perspectives and challenges [25], [29]; coordination of user and device behaviors [30]; future internet applications and bridging communicative channels [24], [31], [32].

Wireless grids software applications were implemented 2002-2005 within the Syracuse University (SU) Wireless Grids Lab. [31] under the NSF PFI grant #0227879. As a proof of concept the team developed a modest initial application call DARC* (pronounced "dark star"). The system allowed devices with no prior knowledge of each other to collectively record and mix an audio signal such as a concert, speech, lecture or emergency event. The project demonstrated the potential of wireless grids and distributed ad-hoc resource sharing to harness combined ability of mobile devices in social contexts [31].

4.2.1. Wireless Grids Summer Institute. This exploratory software development led to the first public controlled experiment also with NSF PFI (#0227879) support at the Museum of Science, Boston where a two week ‘Wireless Grids Summer Institute’ (WGSi) was held in July 2005. The experiment was done with 24 high school students from Malden, Medford, and Everett; three urban-rim school districts in Massachusetts. Two key research questions were (1) how do the students use Wireless Grids during the two week period of the summer course? (2) knowing the capabilities of the technology, what other applications besides screen- and audio-sharing do students think are viable for Wireless Grids? The program facilitated learning in

the Science, Technology, Engineering and Mathematics (STEM) disciplines through the use of Internet and wireless grid technologies. The twenty-four students were engaged in science-based activities that incorporated the facilities and exhibits available at the Museum of Science, Boston. Evaluation was done using pre (just prior to WGSi) and post (last day of WGSi) surveys. This instrument has been used in experiments related to intrinsic motivation and self-regulation and assesses participants’ interest and enjoyment, perceived competence, effort, value and usefulness, pressure and tension, and perceived choice while performing a given activity, thus yielding six subscale scores. Additionally, students took the same survey again 5 months after the WGSi experience to continue measuring perceptions and motivation, and content learning. Analysis showed that motivation was held constant during the WGSi period. Curiosity and content learning of information technologies significantly increased. Some representative direct quotes from students were as follows:

“I think experiencing the Display Sharing Application was fun because you actually do it on your own rather than just watch someone else doing it.”

“I [would] like to know more about the wireless grid because I want to see how useful this technology can be.”

Despite students being wildly excited about the technology and the future potential of wireless grids, overall analysis led us to conclude that there were no significant learning or behavioral changes over the two week period. In retrospect, it was perhaps naïve to think that a two-week experimental exposure to wireless grids would be sufficient time to observe a change in attitudes or measureable learning; but at that point in time that was all that could have been managed with the technology at its level of development.

4.2.2. Focus Groups and Dorm Trials. Continuing thereafter, focus groups have been held with wireless grid software demonstrations. Using the basic elements of Rogers’ 1995 model [33] for the diffusion of innovations, the aim was to assess the value of wireless grids outside the laboratory from a user perspective and its potential diffusion model [25]. Two focus group meetings were performed. Volunteers from three categories were invited; faculty members, staff members, and graduate students (Ph.D. and Master’s levels). Twenty

volunteers were divided into two separate focus group meetings. Because it was a new technology meetings began with a 20 minute introductory presentation about the technology with another 20 minutes to answer the participants' questions. During the 1-hour discussion, the participants were asked the same questions, which focused on the potential individual user's perceptions, attitudes, concerns and future intentions regarding wireless grid technology.

From the findings it was concluded that the introduction of wireless grids would not be a simple process. The results show, although people see the relative advantage of wireless grids, they feel reluctant to share the resources on their edge devices with people they hardly know or in a social context with which they are not familiar. Issues relating to security and privacy created a lack of trust. Drawing on theories that stress the introduction of new technology as a dynamic process, it was suggested that people would need to learn how to share their resources in a process of mutual adaptation. Therefore, the introduction of wireless grids should follow a step-wise process. In this process, critical mass is not reached once, but several times, in different situations, and with different technologies. It was also concluded that the technology has three immediate potential groups of users. The first group is the group of people who are already up to date with the latest wireless communication technologies. Such a group of people may include, but not be limited to, engineers, managers, faculty members, students, and IT professionals. This group was seen as one of the easiest groups to target. The second group was teenagers/digital natives, who are inclined to obtain new technologies in order to underline their social status. Based on the past examples of cell phones, digital cameras, and PDAs, we expect this group to behave similarly with regard to wireless grid technology and to show high interest in adding this technology to their other vogue technologies. A third opportunity was introduction of the technology within specific communities (e.g., hospitals, and emergency services).

The application infrastructure was being developed continuously over time and trademarked as Innovaticus. Trials of the updates were offered at the dorms at Syracuse University. The objective was to determine if people were willing to share resources, i.e. the condition that has to be fulfilled for the adoption of wireless grids [34]. The research approach was based on three research methods factorial survey, policy capturing or vignette studies, and conjoint measurement. Since students had little or no idea about the specific characteristics of the wireless grids and its possible applications, scenarios

were created for student to make decisions. An example of a scenario:

Suppose you and your good friend Jamie are at the Library using your laptops to work on your own writing assignment that is due shortly. All of a sudden the screen of Jamie's laptop goes down. Because the rest of the laptop seems to work fine, he asks you to share your screen so he can submit his assignment in time.

Participants (284 students) were given pen and paper questionnaires that consisted of 12 scenarios.

These dorm trials showed that people are only willing to share in a trusted context, but trust can be influenced. These studies show that concept of trust is key factor and a very complicated issue that would need to be addressed.

4.3. Wireless Grids Innovation Testbed

Building on prior research Syracuse University (SU) and Virginia Tech (VT) created the first national Wireless Grid Innovation Testbed (WiGiT). The project is currently supported by the National Science Foundation (NSF/PFI) grants, NSF # 0917973. WiGiT allows researchers to further experiment with grids available throughout the community. Major research activities focus on active and emerging topics including its various applications, power management, localization, communication protocols, security, and sensors. The objective is that WiGiT will help refine transformative technologies by bridging the gap between wireless network middleware and grid application layers, thus creating new markets and realigning existing ones. WiGiT will serve industry needs for intra-system, or crossover work bridging grid or cloud computing on one platform and wireless Internet on another, contributing to open standards and application programming interfaces for wireless grids. The WiGiT testbed and related courses, seminars, and workforce training will aim to accelerate commercialization of novel products and services, while accelerating partner community economic development.

Ultimately, WiGiT expects to be at the center of an emerging industry serving new markets through its distributed incubation of wireless grid applications, training and workshops. By incubating technology and teaching, both knowledge spillover and transfer between testbed partners and their real/virtual communities will flow, creating an "entrepreneurial ecosystem" that encourages exploitation of opportunities to transform user practices and system

designs into novel tools and products. For example, our technology diffusion model could be one of several artifacts produced by this project with wide applicability in other entrepreneurial ecosystems.

The uniqueness of this project lies in its combination of new technologies for 'edgware' for grid or cloud computing applications across edge devices, with wireless networking. The potential influence of this combination on current wireless connectivity standards will be explored. The project will also investigate the wireless grids' utility to digital communities (including open source technical development communities) in being able to work and collaborate in a distributed, mobile fashion. Businesses, government agencies educational institutional and private individuals will have new options for interacting and conducting business. The innovation testbed provides students, faculty, firms and representatives of government an opportunity to learn from and participate in the growth of this new market, which is growing in part from the prior PFI project mentioned previously. WiGiT involves participants globally and permits easy access to its main findings and activities, thereby benefiting individuals, researchers as well as companies including media worldwide, in both developed and developing countries, spurring further innovation and economic growth on top of these NSF-derived technologies.

The primary goal WiGiT is to bring together unique technical assets from SU and VT for further evaluation and to establish a baseline set of open or public interfaces, specifications, or standards, for wireless grids. Technical issues that are ripe for further research and analysis as part of this process will be supported by WiGiT, including design and manufacturing, application performance and optimization, characterization of networks for wireless grid applications, protocol development, policy and usability. Evaluation of service engineering simulations, user behavior trials, application tests, security models, and trust frameworks for wireless grids will be among the issues explored through the testbed, by faculty, students, and firms.

5. Conceptual Framework

Our study is guided by research that focuses on the sociological implications of pervasive communication tools on many aspects of life, including work and education. One such area is

CSCL which is based on the premise that computer tools and other devices alter the social arrangements amongst learners and result in new kinds of peer interaction and joint activities [12]. The argument for incorporation of learning technologies is not about making students do things faster, but rather about helping to learn better [35]. We are acutely aware that simply providing new technologies in a learning environment does not guarantee a learning community. As noted by Salmon the emergence of new technologies has, so far, done little to expand the conception of teaching as being "an individual and traditional craft" [36]. An online learning community is structured around four elements – communication, collaboration, interaction and participation [37]. It can be argued that frequent communication must occur among all students and instructors in an open manner to facilitate the development of group cohesion. Collaborative interaction and participation is central to the socio-constructivist perspective on learning; a perspective that undergirds much of CSCL research [38]. In other words social interaction is a prerequisite for collaboration and collaborative learning. One of the keys to the efficacy of collaborative learning is social interaction, and lack of it can result in negative effects [39]. We cannot assume that that social interaction will automatically occur because it is possible within the environment. Social interaction which is stimulated is usually restricted to the cognitive aspects of learning, ignoring/forgetting that social interaction is equally important for affiliation, impression formation, building social relationships and, ultimately, the development of a healthy community of learning [39]. For learning to flourish, trust is a basic prerequisite. This socialization process creates common understanding and development of trust within the group [40].

Keeping these concepts in mind we hypothesize that collaborative learning through wireless grids has the potential for supporting this constructive learning process by helping students find and organize information in context, construct their understandings, communicate those understandings to others and build and design applications together to meet their specific needs. Wireless environments also support "just-in-time" learning, an adoption by educators of successful industry technique that involves delivery of parts and finished products at precisely the time in which they are needed [19]. It is possible that the concept transfers well to education where students may receive context appropriate information or complete a skill-building task, at the most appropriate teachable moment.

6. Proposed Courses Characteristics

Within our current NSF funding our project will be the development within an interdisciplinary Electrical Engineering and Information Management senior capstone course of projects which will be developed using wireless grids for spring semester 2011. The course is presently being developed and will be piloted in fall 2010. It will be taught jointly among Syracuse University, Virginia Tech and Tufts University. We will teach this group of undergraduates how to use the wireless grid (at SU) and a cognitive radio network testbed (at VT) to run a variety of edgeware applications, or ‘gridlets.’ Students from each of the campuses will be able to remotely deploy experiments on the network at the other campus. Each project group will consist of students from all of the three campuses. It is also possible that participation from WiGiT partner, Portugal’s Instituto Superior Tecnico, and a Portuguese next generation network testbed operated by UMIC, may be integrated by the following year. Students will implement a web based user interface capable of acquiring data from wireless sensor networks. Wireless sensor network data will be acquired through an Ethernet based base station and Java code will be used to parse collected information and display them. To do this project, students will learn TinyOS, Java, sensor network and wireless grid topology. Once familiar with the sensor network topology, they will design a program that will be capable of reconfiguring a wireless sensor network. This is to be done through writing new code instructions to the wireless sensors, i.e. reprogramming wireless sensors. Therefore they will write a program that can inject commands into a sensor network via the WiGiT and we will run the localization application on the sensor network.

Another proposed three year project (awaiting funding) will introduce K-12 students to wireless grids technology to dynamically mesh devices, content, and users, permitting the formation of a network or grid of devices without a dedicated server needed to manage the network. The project team includes Syracuse University, State University of New York College of Environmental Science and Forestry, Syracuse City School District, Clear Channel Radio, and Wireless Grids Corporation [41]. We will use a wireless grids platform to develop an accessible, multimedia, distance learning course for upper level students in five urban high schools. Wireless grids will seamlessly integrate all required applications (e.g., distance learning, social media, gaming) and deliver a highly interactive, problem-based course, “The Global Environment and Human

Culture,” accessible through laptops and mobile technologies. The technology-rich course will be co-designed by high school students, environmental and information scientists, classroom teachers and school librarians. The course curriculum will require creative thinking, problem solving and digital literacy skills and address online safety issues integrated into environmental science and entrepreneurship content learning. Students will use social media to communicate within and across schools, and learn about and use wireless grids to work collaboratively in teams with students in other schools, sharing information and resources, creatively seeking solutions and business opportunities in environmental problems posed in the course. Using a user-centered iterative design approach throughout the instructional design process, during Yr 1 the project team will gather input from an Advisory panel of researchers, teachers, school librarians, and high school students to explore ways to integrate distance learning technologies and course content into independent learning modules with support applications within a wireless grids framework and test them initially with a single group of 15 students representing all the participating high schools. All instructors that are involved will receive professional development training in the technologies and in distance learning pedagogy. Students will learn how to develop “gridlets” that can be incorporated into the course design. In Yr. 2, course modules will be revised, social media, game and virtual buddy/e-mentoring components will be developed and integrated and tested across two wireless grids-enabled online classes in two of the high schools. In Yr. 3, a full pilot test of the revised course containing all functions, features and components will be implemented and evaluated across in an online class.

To allow students to share devices some preliminary solutions before the course will be explored and solutions will be articulated. Students in a variety of courses and through work at the associated labs will be provided with hands-on experience in the use of the wireless grid beta applications as they become available. The expectation is that in time, students will be able to easily develop their own wireless grid applications, building upon the platform provided. Through the testbed, students at participating institutions including high schools in participating communities will interact directly with each other and with participating firms, as they design and use a variety of wireless grid applications as they are introduced, whether as proof of concept or prototype.

7. Methods and Analysis

Our principle research question guiding our explorations is to what degree can wireless grid technologies can be used to successfully create a distributed, synchronous and asynchronous, collaborative learning environment. Both projects will be the development and testing of a wireless grids-based collaborative learning model in which student knowledge creation and acquisition is facilitated by the use of a variety of seamlessly integrated technologies for just-in-time learning. The application of this model during the iterative design process will provide data that will increase our understanding of whether and how (1) engagement in the design of and control over their own learning positively affects student learning and motivation outcomes; (2) social and technical factors affect the quality and quantity of interactions of virtual collaborative learning teams; (3) the use of specific technologies individually and collaboratively influence student learning and motivation; and (4) collaboration between instructors to provide learning support affects students' learning and motivation.

In addition to documenting how well the course components function individually and in combination throughout the iterative design process, data will be collected using a variety of data gathering methods including online surveys, individual interviews and focus groups, reflection documents, distance learning and social networking data logs, and knowledge tests to determine if specific project outcomes have been achieved. Tools such as SelectSurvey (an online survey data collection/analysis system); the Provalis Research Suite (QDA Miner, Wordstat, Simstat) for mixed methods analysis, social network analysis and visualization; SPSS (statistical analysis program); and AtlasTI (qualitative data analysis program) will be used by the project team to collect/analyze data.

8. Conclusions and Implications

Computing behavior, like any behavior, does not occur in a vacuum. Systematic investigation of the antecedents and consequences of these behaviors is imperative [42] if we ever hope to develop meaningful curriculum that integrates technologies in ways that facilitate the learning experience. Salomon questions whether technology is really making a difference and if it does not challenge educational practices [43]. Herring completes the question by shifting the emphasis to "under what circumstances, in what ways, and to what extent" technology is shaping communication and subsequently

educational practices [44]. With these questions in mind we plan to obtain insight into the factors that influence the use of wireless grid applications before a given technology is actually introduced on the market. The broader impact of the WiGiT comes from the benefits foreseen from novel wireless connectivity standards and specifications; the wireless grids' utility to diverse digital communities (including the open source community) in being able to collaborate in a distributed fashion without network overload. Firms and government partners can help wireless grid innovations stemming from WiGiT to achieve national global impact. Ultimately, it will be up to its users and application developers, if wireless grid technologies are to achieve its intended broad impact on future education, virtual collaboration and employment.

We believe that the findings from these studies will directly impact the intellectual capabilities of our higher education institutions by initiating a sustained dialog into the increasingly critical requirements advancing collaborative and distributed learning technologies. The ultimate vision of the wireless grid is that of an adaptive network with secure, inexpensive, and coordinated real-time access to dynamic, heterogeneous resources, across geographic, political and cultural boundaries without forsaking stability, transparency, scalability, control and flexibility. Better assessment of wireless grids protocols and applications will inform design, manufacturing and commercialization of these next generation information and resource sharing innovations. The testbed will support training and courses related to innovation, wireless grids technologies and business/social impacts opportunities. Our efforts will serve as a catalyst to build a broad-based community of researchers and students epitomizing collaborative learning.

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