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ABSTRACT

Wireless technology has advanced significantly in recent years and has shown great potential and promise for use in education. To better understand the use of wireless technology in education, this research adopted a grounded theory approach to explore how students use wireless technology to support and facilitate their learning. We collected data by interviewing students regarding their experience and opinions of using wireless technology for education. The data were analyzed following the procedures of grounded theory: open coding, axial coding, and selective coding. By analyzing transcripts from the interviews, concepts and categories were segmented, and linkages between categories were identified. A substantive model depicting students' use of mobile technology to support learning was then developed, which shows the causal conditions, context conditions, actions/interactions, and consequences. Based on the model, propositions were presented and discussed. The results of this research not only help to develop a theoretical foundation for future research, but also serve as guidelines for educators and administrators in designing and formulating specific strategies for introducing wireless technology in educational settings.

Keywords

Wireless technology, learning, grounded theory

INTRODUCTION

Wireless technology has grown significantly in the recent years. The number of wireless connections worldwide is expected to increase from about 727 million at the beginning of 2001 to more than 1.7 billion in 2005 (Accenture, 2001); and the number of wireless Internet users is expected to exceed stationary PC users worldwide (Vetter, 2001). Advances in wireless technology have shown great promises for use in educational settings. Some researchers even believe that "each and every child should be provided with a $100 handheld device" (Soloway et al., 2001).

Realizing the tremendous potential of wireless technology in educational settings, efforts have been made to implement wireless technology in the educational settings to support teaching and learning. Educational materials can be delivered via SMS (Short Message Service) using mobile devices (Hoppe et al., 2003); handheld devices such as PDAs (Personal Digital Assistants) can be connected through a wireless network in the classroom to enable cooperative learning (Davis, 2003; Pinkwart et al., 2003); wireless technology can be implemented to create an ad-hoc and mobile classrooms where learning can take place either indoor or outdoor, even while students are traveling (Chang et al., 2003; Chen et al., 2003).

Although a number of studies have examined the use and impact of wireless technology in the learning and teaching context, most of them merely report on an application. Little research has been done to uncover how wireless technology can be used by students outside classroom to support and facilitate their learning and education. As wireless technology is an emerging technology and it has great promise and potential to be used in education, qualitative research is needed to explore the process of how wireless technology is used by students to facilitate learning.

This research will study how wireless technology can facilitate student learning by using a qualitative research approach to better understand the process, conditions, actions/interactions, and consequence of using wireless technology for supporting learning. The central question of this research is: "How can wireless technology facilitate student learning?" The goal of this research is to build a theory to explain the phenomenon of how wireless technology can be used to support student learning. To do this, a grounded theory approach (Strauss and Corbin, 1998) was used to develop a theory based on interviews from

students. Grounded theory approach provides a systematic way to analyze the interview data, and the resulting theoretical framework which is grounded in the viewpoints of the subjects, addresses the conditions, actions/interactions, and consequences of using wireless technology to facilitate student's learning.

This research will provide a conceptual and theoretical foundation to study and evaluate wireless technology in education. In addition, it will provide educators and administrators with findings that not only describe how wireless technology can support student learning but also help them design specific implementation strategies for wireless technology in the classroom and on campus.

RESEARCH METHODOLOGY

Grounded Theory

Grounded theory is a qualitative research method that uses a set of procedures to inductively develop a theory derived from data. The data is systematically gathered and analyzed throughout the research process (Strauss and Corbin, 1998). As the purpose of this research is to develop a theory to explain the process of using wireless technology to facilitate learning, grounded theory approach is an appropriate research methodology to serve the purpose.

Grounded theory not only provides researchers with analytical tools for handling masses of raw data, but also helps researchers consider alternative meanings of phenomena, as well as identify, develop, and relate the concepts which are the building blocks of theory. Developing a grounded theory involves collecting interview data, developing and interrelating categories of information, and either generating theoretical propositions or hypotheses for the research or presenting a visual picture of the theory (Creswell, 1998).

Sample and Data Collection

The use of questioning is one of the most important and effective analytical tools for conducting grounded theory research (Strauss and Corbin, 1998) - because by asking questions and providing subjects with ample opportunities to elaborate on their answers and perspectives, the development of evolving theory can be enhanced. Six subjects were interviewed to collect the data. Among the six subjects, five were male, and one was female. The subjects were all students in a large Midwestern University who have experience in using wireless technology (such as using wireless Laptop and PDA) for their learning and education purpose. The reason for selecting subjects with experience in using wireless technology for educational purpose is to ensure that the subjects can provide substantive information crucial to understanding the phenomenon under study.

Open-ended questions were asked during the interviews. Interview questions include general questions such as asking subjects to describe their use of wireless technology for learning, as well as sub-questions such as reasons for using wireless technology, when do they use it, and what are the consequences/results of using wireless technology. Since wireless technology is relatively new for educational use, benefits and limitations as well as potential ways of using wireless technology in educational settings were elicited from the subjects with the aim of generating a more complete picture of this phenomenon.

All the interviews were tape-recorded and then transcribed for data analysis. Notes were taken by the researcher conducting the interviews and they serve as an important resource for data analysis.

Data Analysis

All the six interviews were transcribed and analyzed following the coding procedures outlined by Strauss and Corbin (1998). The process of data analysis in grounded theory is systematic and follows a standard format: open coding is the "analytical process through which concepts are identified and their properties and dimensions are discovered in data" (Strauss and Corbin, 1998, p.101). Initial categories were formed by segmenting information from the raw interview data. Axial coding is the process of "relating categories to their subcategories and link categories at the level of properties and dimensions" (Strauss and Corbin, 1998, p.123). Because the linkages between categories can be very subtle and implicit, a coding paradigm involving conditions, context, action/interactions, and consequences can help to organize the connections among the categories. Selective coding is the process through which the researchers identify the key category and integrate the other categories around the key categories to tell a storyline (Strauss and Corbin, 1998, p.128).

Verification in grounded theory is very important as it is "an active part of the process of research and becomes part of the standards one should use to judge the quality of the study" (Creswell, 1998, p.209). In this research, a number of verification techniques were applied. First, we followed the standard procedures of grounded theory for data analysis, that is, open coding, axial coding, and selective coding. Second, prior literatures were used for "supplemental validation"– references from

prior literature provide validation for the accuracy of the findings or possible explanations as to why the findings differ from the published literature (Creswell, 1998, p.209). Third, throughout the data analysis, findings were verified by constantly referring back to the data and comparing the data with the emerging categories, relationships, and integrated narrative of the phenomenon.

RESEARCH RESULTS

Open Coding - Use of Wireless Technology

According to Strauss and Corbin (1998), data analysis of grounded theory research starts with open coding in which "data are broken down into discrete parts, closely examined, and compared for similarities and differences" (p.102). In this initial stage of data analysis, the researcher reviewed the interview transcripts and looked for "discrete incidents, ideas, events, and acts" and then gave names (called "conceptual labels") for those concepts (Strauss and Corbin, 1998, p.105). Throughout the data analysis, the researcher performed constant "comparative analysis", that is, when the objects, events, acts, or happenings share some common characteristics, they will be grouped together and form a category which captures their shared characteristics. Categories "are concepts, derived from data that stand for phenomena" (p.114). Categories have properties and dimensions. Properties are the 'general or specific characteristics or attributes of a category", and dimensions "represent the location of a property along a continuum or range" (Strauss and Corbin, 1998, p.117). By doing so, the researcher was able to reduce the vast amount of raw interview data into smaller, more manageable pieces of data.

When subjects were asked about their experiences and opinions about using wireless technology in the educational context, they highlighted a number of different ways of using wireless technology. These different ways of using wireless technology to support students' learning can be classified into four main categories using open coding (see Table 1). The categories are: **(1) communicate; (2) organize; (3) access/search information; (4) use as PC (Personal Computer)**.

(1)   Communicate

As mentioned by subjects during the interviews, communication is the main use of wireless technology. Using wireless Internet-enabled devices, students are able to communicate with fellow students, team members, and professors at any time, any where. They can communicate by sending e-mails, by sending instant messages, or by calling each other over mobile phone. For example, as one subject stated, *"communication could be increased greatly (by using wireless technology). Let's say you have a question for your professor, you could ask them instantly, or [if] you forgot to forward your paper to your professor, you could do it right there."* Another subject mentioned about using wireless technology to communicate with team members when doing group assignments, *"if you get any sources, ideas or topics, you can just email to them, it is really just in couple of seconds."*

(2)   Organize

Most of the wireless-enabled devices have functions such as calendar, scheduling, or alert, which can allow students to organize their school activities. Instead of recording their activities in multiple devices or notebooks, students can now *"consolidate everything in one device"* – i.e. a device that has organizer functions, wireless capability, and scheduling functions so that you can access, plan around, update information, and *"keep track of everything"*. As one subject mentioned, *"it is nice to have everything stored, say on a palm pilots, as opposed to using a planner, your desktop at home, or a calendar … you can just have everything consolidated here".*

(3)   Access/search information

During students' learning, they constantly need to access course related information or search for new information to complete school assignments. Wireless technology can help students to access or search for information by providing *"instant access to course files, to course website, to Internet... to everything"*. They can access the information they want *"at any time"*, even when they are *"walking"* or *"commuting"*; whenever they need to search for some information, they can *"always do it right there and then"*. So they don't need to wait until they get to computer labs or home to be able to use computers.

Category	Properties	Dimensionalized examples
Communicate	Time	*"anytime, anywhere"*
	Person	*"communicate with team members and classmates"* *"communicate with professors"*
	Type	*"e-mail"* *"instant message"* *"talk"*
Organize	Type of activities	*"organize schedule"* *"keep track of everything"*
	Type of devices used	*"consolidated in one device"*
Access/Search information	Type of information	*"access to Internet"* *"access to files"* *"access to everything"*
	Time to access	*"any time"* *"instant access"*
	Place to access	*"any place"* *"everything ready at hand"*
Use as PC	Types of activities	*"write papers"* *"use excel"*
	Time to use	*"any time"* *"during travel"*
	Place to use	*"anywhere"* *"in the car"*

Table 1: Open coding: students' use of wireless technology in learning

(4)   Use as PC

As some subjects mentioned, wireless technology is "an extension of regular technology". Therefore, it can also provide the functions that wired technology provides, that is, to function as a regular computing device. Students can use their laptops for writing papers, to carry out mathematical modeling or analysis on a spreadsheet, just as they can do using desktop computers. However, using wireless technology, students are not confined to specific locations such as the libraries or computer labs; they can work on their school assignments and research at any time and at any place. As one subject mentioned, "*when you have lots of papers to do... I have to work, and in between work, I have break time that I can use the laptop to continue with the paper I was working on*". "*Sometimes when I travel, I have to do my homework; if I never had a laptop, I wouldn't be able to do my work*". When they say they can work anywhere, they mean it. One subject said "*lots of time when I go on trips, I use my laptop either to study or type papers in the car*".

Information technology has revolutionized the ways people learn. In general, information technology can affect learning in at least two ways: it can deliver some routine activities more efficiently, and it can facilitate engaging, participatory activities for students (Niederman and Rollier, 2001). In the paper by Leidner and Jarvenpaa (1995), they identified different ways information technology can be used in education to facilitate: (i) automating, (ii) providing instructors access to information, (iii) providing students greater access to information, and (iv) transforming to virtual continuous learning spaces. This is in line with the results of this study, where wireless technology, as an example of information technology and an extension of wired technology, can enable students to communicate, organize their school activities, access/search information, or use as regular computing device.

However, wireless technology, as one of the most promising and emerging technologies for supporting learning, can provide features and functions that facilitate learning in unique ways. Wireless technology extends the properties of current technology to greater dimensions - to enable communication "anytime, anywhere", to organize school activities using one device where "everything is consolidated", to access/search information "from any where at any time", and to use as a wireless devices as a PC wherever and whenever a students needs it.

Selective Coding – Some Scenarios

Selective coding in grounded theory is the process to integrate and refine the theory (Strauss and Corbin, 1998). During this step, a central category or phenomenon is identified and a "story line" can be formed to integrate concepts. Although Strauss and Corbin (1998) suggest that selective coding is done after axial coding, it may not necessarily be so. Creswell and Brown's (1992) grounded theory research reversed the order by presenting selective coding first followed by axial coding, which makes the paper flow more logically and easier to understand. In this research, the Creswell and Brown's (1992) approach was adopted.

The central phenomenon in this study is students' use of wireless technology. Table 1 provides a list of different ways of using wireless technology by students, as well as the properties and dimensions. It provides a useful but incomplete picture of how wireless technology can be used to facilitate students' learning, in other words, it does not describe the process involved.

In this step, we then analyzed students' use of wireless technology in different contexts. Using selective coding procedures by Strauss and Corbin (1998), the researchers identified a few scenarios where students used wireless technology for learning to assemble a "story" of how they utilized wireless technology to facilitate learning.

(1)   When students are doing group projects…

When students are working on group projects, they need to constantly communicate with each other, research on the assignments, exchange ideas with each other, and meet to discuss the assignments. With the help of wireless technology, they can communicate with each other more efficiently and effectively by being reachable at any time no matter where they are. They can use wireless technology to access course materials and Internet to search for relevant information, and they can share their ideas with team members instantly. They use wireless-enabled devices to organize their schedules, and to remind themselves about deadlines and group meetings. For their group meetings, they can go to the student union building, the library, or coffee shop where wireless technology is enabled; they can type or write ideas from discussion on to laptops (such as Tablet PCs), and they can revise the paper or the report right on the spot. The result is a better management and use of time, more efficient communications, more flexibility in meeting venues, and more productivity.

(2)   When students are away from their computers…

Students travel, so sometimes, they are away from their computers. When they are on a trip, they still need to complete their school assignments: e.g., they need to search for relevant information in order to write a report or paper, they need to ask questions to professors or fellow students regarding the assignment. All these were not possible without the help of wireless technology and wireless-enabled devices when they are traveling. As one subject mentioned, "*you can't carry a desktop around. It is nice to have a laptop when you are driving. I was writing a paper while driving before, I have been writing in the car, you know, on vacations, something like that. Or in the airport, when you are just waiting around, it is nice to have them.*"

(3)   When students don't want to be stuck in the computer lab all the time…

When students study, they don't want to be confined to one place all the time, like in the library or computer lab. Occasionally they want to "*change study environment*" where they would feel more refreshed and comfortable. As one subject mentioned, "*when you study a lot, you don't want to be in the same place all the time, you will get sick of it, you will get tired of it.*" So "*there is no extra good reason, I just want to change my study environment for a while*".

When equipped with wireless-enabled devices, students can gain more freedom in terms of where to study. They can go anywhere they want but are still able to study or complete school assignments with the help of wireless technology. Like one subject said, "*if you think it is too cold in the Union, you can just go out to the fountain…by the fountain…while enjoying the weather, and do your homework*".

Axial Coding – Presenting a Substantive Model

Axial coding is the process of "relating categories to subcategories along the line of their properties and dimensions" (Strauss and Corbin, 1998, p.124). By relating categories with each other, one can answer questions about the phenomenon such as

when, where, why, who, how, and with what consequences, thus giving the concepts greater "explanatory power" (Strauss and Corbin, 1998, p.125). To help organize the categories, Strauss and Corbin (1998) suggested a "paradigm" to integrate and organize the data, which includes conditions, actions/interactions, and consequences. This paradigmatic model facilitates making connections between a central phenomenon and its subcategories. As the central phenomenon in this study is students' use of wireless technology to facilitate learning, the paradigm (see Figure 1) depicts the process of use of wireless technology by students, that is, the causal conditions to use wireless technology, the context in which students use wireless technology, and the consequences of using wireless technology for learning.
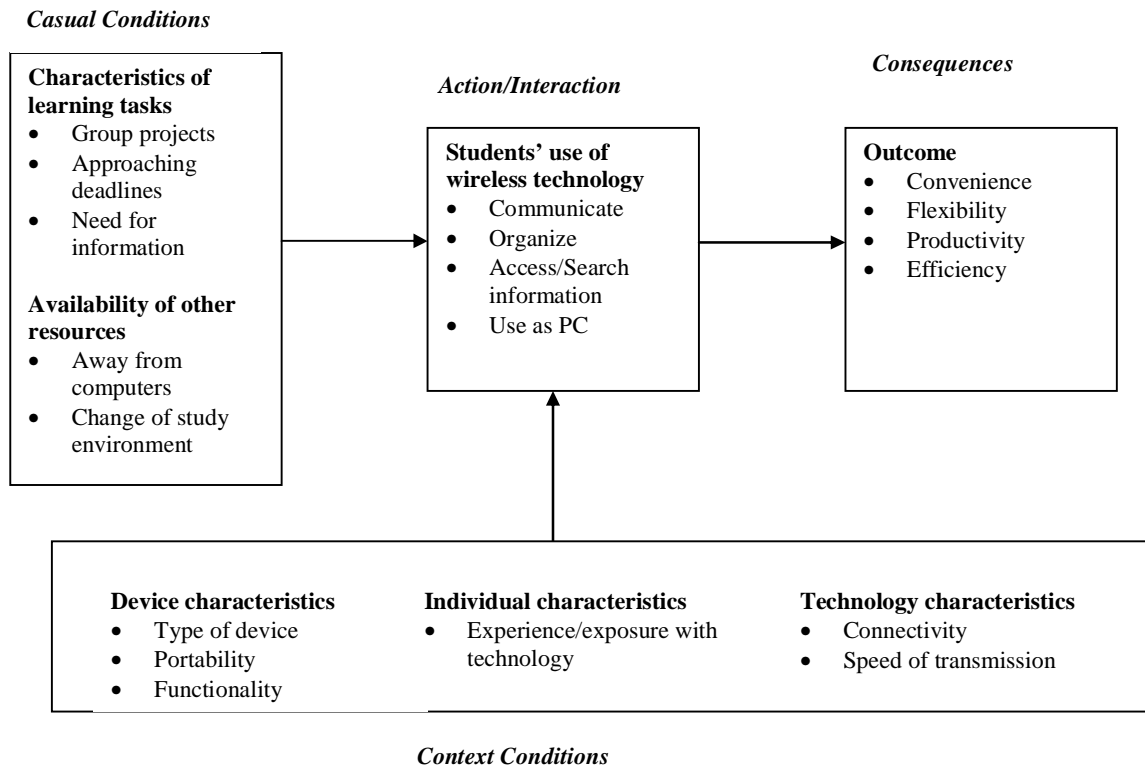
Casual Conditions

Action/Interaction

Consequences

Characteristics of learning tasks
- Group projects
- Approaching deadlines
- Need for information

Availability of other resources
- Away from computers
- Change of study environment

Students' use of wireless technology
- Communicate
- Organize
- Access/Search information
- Use as PC

Outcome
- Convenience
- Flexibility
- Productivity
- Efficiency

Device characteristics
- Type of device
- Portability
- Functionality

Individual characteristics
- Experience/exposure with technology

Technology characteristics
- Connectivity
- Speed of transmission

Context Conditions

Figure 1: Axial coding: a substantive model of student's use of wireless technology to facilitate learning

Causal conditions usually represent "sets of events or happenings that influence phenomena" (Strauss and Corbin, 1998, p.131). Students' use of wireless technology is determined by the characteristics of their learning tasks and availability of other computing resources. When the learning tasks are group projects, when they need to complete assignments in limited time as the deadline is approaching, when they are in urgent need of relevant information, they can turn to wireless technology to perform those tasks in a more efficient and effective way. When students are away from other computing resources, that is, when they are traveling and away from their desktops and when they want to change their study environments, wireless technology is a good alternative as it provides the functions that a regular computing device provides, plus the unique features of ubiquity and accessibility.

Contextual conditions are the "specific set of conditions that intersect dimensionally at this time and place to create the set of circumstances or problems to which persons respond through actions/interactions" (Strauss and Corbin, 1998, p.132). In this study, three types of contextual conditions have been identified, namely, (1) device characteristics; (2) individual characteristics; (3) technology characteristics.

Type of devices, functions provided by the devices, and portability of wireless-enabled devices are the factors that influence students' use of wireless technology. Most of students have the experience of using laptops as it has a similar interface and offers similar functions as desktops. Although other devices, such as cell phones and PDAs, are more portable compared to laptops, they are limited in terms of functions and user interface.

Individual student's experience or exposure to computer technology is also a contextual factor that influences student's use of wireless technology. As one student mentioned, "*I am not a technology guy really, I got more exposure to technology here. Because where I am from, we don't need to type a paper, like here; I know that doing a paper is something that you have to do all the time. That's why I bought my laptop when I moved here.*" When they became more experienced with the use of wireless technology, they also chose to use more functions of wireless technology or try other types of devices.

According to the interviews, the outcome of using wireless technology is quite positive. Subjects have mentioned a number of advantages and benefits of using wireless technology to facilitate their learning, including more convenience, greater flexibility, more efficiency, and increased productivity. This is in line with prior literatures where researchers identified the benefits of wireless technology: it can engage students in learning activities, and facilitate group collaborative learning (Liu et al., 2003).

Propositions

The substantive model derived from axial coding (Figure 1) shows the conditions for students to use wireless technology, the central phenomenon (students' use of wireless technology), and the consequences of using wireless technology. This understanding leads to several propositions that suggest "how phenomena might possibly be related to one another (Strauss and Corbin, 1998, p.102).

P1: Portability of wireless-enabled devices is the main reason for students to use wireless technology.

As mentioned by subjects, wireless technology is just "an extension" of existing technology, and there is almost "*no difference*" in terms of functions. What makes wireless technology more useful is the portability features provided. It allows students to carry around their laptops and PDAs and use them "anytime, anywhere". Therefore, it is proposed that portability is the main reason for students to use wireless technology.

P2: Some of the learning tasks are more suitable for using wireless technology.

P2-1: When students are doing group assignments, wireless technology is useful.

P2-2: When students are in urgent need of information, wireless technology is more likely to be used.

This proposition suggests that the characteristics of the learning task will influence the way students use wireless technology. That is, there must be a "fit" between task characteristics and technology characteristics in order for the technology to be used. Wireless technology is suitable for completing group assignments. Also, when students are in urgent need of information, the "anytime, anywhere" access to the wireless Internet would provide them the ability to access or search the information needed.

P3: Students' experience with technology will influence their use of wireless technology.

Interviews with subjects have indicted that students' experience or exposure with technology is a factor influencing their use of wireless technology. When students are more experienced with technology, they will be more likely to turn to wireless technology and use it.

Future research can be carried out to test these hypotheses. Survey or experimental studies can be conducted to verify the hypotheses.

CONCLUSIONS AND CONTRIBUTIONS

This research applied the grounded theory approach to study how students use wireless technology to facilitate their learning. After interviewing six subjects, the data collected were analyzed using open coding, selective coding, and axial coding. The result is a substantive model that depicts causal conditions, contextual conditions, actions/interaction, and consequences of using wireless technology.

This research is still in progress. More interviews can be carried out to refine the theory and to make sure that theoretical saturation has been reached, and the various aspects of categories have been covered or identified. Future research can also extend this research by testing the hypotheses proposed in this study. This research, therefore, opens up some new directions for future research.

This research can also benefit practitioners, that is, educators and administrators, by providing a better understanding of how wireless technology can be used or provided to facilitate learning. The theoretical model presented in this research can provide some guidelines to practitioners in making decisions on wireless technology implementations on a campus.

Researchers (e.g. Vogel and Klassen, 2001) have suggested educational trends including individualized learning that focus on the ability of students to select the mode and timing of course delivery, cooperative learning that encourages students to learn from each other, and a more flexible assessment portfolio. Wireless technology, according to the results derived from this study, can support students completing group assignments and allow students to access educational materials at anytime, anywhere. It is no doubt that wireless technology is a necessary technology to meet future trends in education. More research in this area is, therefore, warranted.

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