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The Impact of Mobile Wireless Technology on Student Attitudes in Higher Education Classrooms*

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Our research employed both quantitative and qualitative research methodologies to explore the impact of mobile wireless technology (MWT) on student attitudes. This study provided empirical evidence that in higher education classrooms where MWT was used on a regular basis, the robustness of supporting infrastructure played an important role in positively or negatively influencing student attitudes. In classrooms where MWT devices were used for special purpose applications, perceived MWT value, as well as the relationship between MWT usage and grades, was found to impact on student attitudes. This study also found that previous MWT experience did not necessarily impact on student attitudes towards MWT and MWT usage.

Keywords: mobile wireless; student attitude surveys

INTRODUCTION

MOBILE WIRELESS TECHNOLOGY (MWT)—primarily personal digital assistants (PDAs), laptops, personal response systems (PRS) and other customized devices—have been used in classrooms at all levels from primary school to professional education with the goal of improving the quality of teaching and learning. Examples of some of the common applications of MWT in learning environments include class exercises, group work and in-class quizzes. Previous research has focused on the challenges of application development and implementation of MWT in various environments. A review of the literature revealed only limited previous research focused on evaluating the impact of MWT on teaching and learning processes. Furthermore, even though higher education institutions have committed to using MWT, few studies evaluating the impact of MWT on the higher education classroom have been published. Most published research has focused on K-12 classrooms. However, the evaluation methodologies used in other areas, such as the evaluation of web-based applications or computer-aided instruction (CAI), are relevant to a study of the impact of MWT in higher education classrooms.

Student attitudes towards computers have been found to play an important role in the success of computer-related programs [1]. It is expected that student attitudes could also play a role in the success of integrating MWT in higher education classrooms. There are numerous previous studies on student attitudes in related areas, such as the use of CAI and of the Internet in classrooms. For instance, Winsler and Manfra [2] used pre- and post-course evaluations to assess the extent to which using a variety of standard and instructor-modified modules within WebCT were effective in increasing student learning, motivation, communication and technology use and skill, while decreasing student technology anxiety and fear. Significant pre- and post-changes were observed for student technology use, skill and enjoyment, and a reduction in student computer anxiety was also observed. Similarly, Mitra and Steffensmeier [3] studied changes in student attitudes and student computer use in a computer-enriched environment using data from three years of a five-year study. The results indicated that a computer-enriched environment was positively correlated with student attitudes towards computers in general, their role in teaching and learning, and their ability to facilitate communication. In addition, there were few changes in attitudes for students who did not have access to the network. In the same way, Buckley [4] compared a traditional classroom, a web-enhanced and a web-based nutrition course. A survey of student opinions was used to evaluate student perceptions. In addition, student comments were elicited to identify the strengths and weaknesses of the course. Although the web-based course received the lowest mean evaluation scores and was significantly different from the scores of the other two instructional methods,

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qualitative comments revealed both positive and negative aspects of online instruction. In another study, however, Waker [5] found no correlation between the use of computers at school and student attitudes towards school.

This research focused on studying the impact of MWT on higher educational student attitudes towards technology and technology usage in the classroom. Two research questions were investigated. The first research question was developed to determine if the use of MWT in the classroom improved student attitudes towards MWT and the use of MWT. The second research question was developed to determine if previous experience with mobile technology affected student attitudes. The implementation of MWT was studied for multiple courses in a higher education setting. Each course included in the study had unique learning objectives and student populations.

METHODOLOGY

This research study utilized both quantitative and qualitative research methodologies. Surveys were used to evaluate the impact of the use of MWT on student attitudes, and qualitative methods, including interviews and focus groups were used to gain a deeper understanding of survey results. Since actual courses in natural educational settings were used, it was not possible to randomly assign MWT devices to just some of the students in the same classroom nor randomly assign students from a common population to experimental or comparison groups. As a result, a quasi-experimental design was used.

Participants and course details

The participants in this study included instructors and students taking engineering and non-engineering classes at Oregon State University (OSU). All courses included in this study were offered only for undergraduate students, except Visual Programming (IE 411), which enrolled both undergraduate and graduate students.

The courses included in this study all used some type of MWT to enhance the learning experience of students. The courses were taught in at least one, ten-week term between January 2002 and June 2005. Table 1 provides details about the courses included in the study and the MWT used for each course.

Two usage models were identified for the set of courses included in this study (Regular Usage and Special Purpose Usage). In the first set of classes, MWT was used during lectures and on a regular basis, particularly for programming applications. MWT devices such as laptops were used as learning tools or resources (e.g. Internet research, spreadsheets, programming with standard software such as Visual Basic). MWT devices such as PDAs and laptops were used for 'drill and practice' after the concepts were presented. MWT devices were used for in-class exercises, group activities and to allow students to complete examples simultaneously with the instructor. In the second set of classes, MWT was used for special purpose applications, including student response analysis, data collection, and learning modules.

Engineering Orientation II (ENGR 112) is the second introductory course for engineering freshers and other students who are considering engineering as a possible degree option. The course was designed to expose students to a broad range of engineering problems and to demonstrate the critical problem solving and computing skills needed to address these problems. The course consisted of lectures supplemented with a weekly computer laboratory where students learned to apply off-the-shelf applications such as Microsoft Excel and Visual Basic to engineering problems.

Visual Programming for Industrial Application (IE 411) covers the concepts of object-orientated modelling, Unified Modeling Language, software development, file and database connectivity, and visual programming needed for developing industrial applications. The course consisted of only lectures. Laptops with wireless capability were loaned to students for the duration of the term and were used on a regular basis by students both in and outside the classroom.

General Physics (PH 202) covers a broad spectrum of classical and modern physics and primarily enrolled second-year, non-engineering students. The course consisted of lectures supplemented with weekly laboratories and recitations. PRS devices with wireless capability were loaned to students for a fee for the term. PRS units were used during lectures and allowed students to individually respond to instructor questions. Responses were collected, and summarized results were displayed as a histogram for the class to view.

Chemical Engineering Orientation (CHE 101) is an introductory course for first-year students interested in chemical engineering, bioengineering, or environmental engineering. The course consisted of lectures supplemented with weekly laboratories and recitations. Students used their own laptops in the laboratories and recitations for data collection, data analysis and group projects. Laptop usage was not allowed during lectures.

Introductory Chemical Engineering Computation (CHE 102) covers the application of programming to various topics in chemical engineering and was targeted at engineering freshers. The course consisted of lectures supplemented with weekly recitations. Students used their own laptops during lectures and recitations.

Introduction to Statistics for Engineers (ST 314) covers probability, common probability distributions, sampling distributions, estimation, hypothesis testing, control charts, regression analysis and experimental design. The course consisted of lectures only. Most students checked out laptops for in-class use, but some students brought their

Table 1. MWT course summary

Course Name	Term	Student Enrolment	MWT Device	Wireless Capability	MWT Distribution Method	Usage Model
ENGR 112 Engineering Orientation II	Winter 2002	72	PDA	No	Students checked out devices as they arrived and checked in devices before they left the classroom.	Regular Usage
	Spring 2002	52	PDA	No	Students checked out devices as they arrived and checked in devices before they left the classroom.	Regular Usage
	Winter 2003	73	PDA	Yes	Devices were loaned to the student for the duration of the term.	Regular Usage
	Spring 2003	36	PDA	Yes	Devices were loaned to the student for the duration of the term.	Regular Usage
	Winter 2004	137	Laptop	No	Students checked out devices as they arrived and checked in devices before they left the classroom. Groups of 2–3 students shared laptops in the classroom.	Regular Usage
	Winter 2005	85	Laptop	Yes	Students owned the devices used.	Regular Usage
IE 411 Visual Programming for Industrial Application	Winter 2004	25	Laptop	Yes	Devices were loaned to the student for the duration of the term.	Regular Usage
PH 202 General Physics	Winter 2004	480	PRS	Yes	Devices were loaned to the student for the duration of the term.	Special Purpose Usage
CHE 101 Chemical Engineering Orientation	Fall 2004	70	Laptop	Yes	Students owned the devices used.	Special Purpose Usage
CHE 102 Introductory Chemical Engineering Computation	Winter 2005	85	Laptop	Yes	Students owned the devices used.	Regular Usage
ST 314 Introduction to Statistics for Engineers	Spring 2005	103	Laptop	Yes	Students checked out devices as they arrived and checked in devices before they left the classroom.	Special Purpose Usage
CE 102 Civil Engineering I : Problem Solving and Technology	Spring 2005	120	Laptop	Yes	Students owned the devices used.	Regular Usage

own laptops. Three instructional lessons utilizing MWT were used during the term. Each lesson had different learning objectives. Students worked in groups of 2–4 and spent 30 minutes answering online questions for each lesson. Each group submitted its responses online.

Civil Engineering I: Problem Solving and Technology (CE 102) is a civil engineering orientation course for freshers. The course focuses on the use of technology to solve civil engineering problems. Course topics include units, homework professionalism, professional presentations, Internet tools, software for numeric methods and programming. The course consisted of only lectures. Students used their own laptops during lectures.

Student attitudes survey

The student attitude survey used in this study was modified from a previously-developed survey [6]. The original survey was developed to measure student attitudes toward PDAs and their usage in a traditional lecture setting. The questionnaire assessed attitudes towards PDAs in six different areas—confidence, liking, anxiety, enthusiasm, usefulness in general and usefulness in the classroom. The questions were modified to refer to laptops or PRS units and the use of laptops and PRS units rather than PDAs as appropriate. Students were asked to express agreement or disagreement with each survey item. A five-point Likert scale (strongly disagree, disagree, neutral, agree, strongly agree) was used for all survey items except for demographic information. Each term (except for Winter term 2002), a one-group pre-test and post-test design [7–8] was used. Pre-test and post-test surveys were used to study changes in student attitudes before and after integrating MWT into the classroom, except in Winter term 2002 where only post-test survey data were collected.

Four different surveys (survey 1, survey 2, survey 3 and survey 4) were used. All surveys were based on the same set of items. However, each survey had a different number of items in each scale. Survey 1 (post-test only) was used to collect data in ENGR 112 in Winter term 2002. Survey 2 was used to collect data in ENGR 112 in Spring term 2002. Survey 3 was used to collect data

Table 2. Survey response rates for all courses

Course	Term	Pre-test/ Post-test	Number of Students Completing Surveys (n)	Response Rate	Number of Matched Surveys
ENGR 112	Winter 2002	Pre-test	N/A	N/A	N/A
		Post-test	50	70%	
	Spring 2002	Pre-test	35	67%	10
		Post-test	24	46%	(19%)
	Winter 2003	Pre-test	60	82%	31
		Post-test	46	63%	(42%)
	Spring 2003	Pre-test	28	78%	21
		Post-test	23	64%	(58%)
	Winter 2004	Pre-test	81	59%	32
		Post-test	70	51%	(23%)
	Winter 2005	Pre-test	77	91%	43
		Post-test	61	72%	(51%)
IE 411	Winter 2004	Pre-test	21	84%	19
		Post-test	19	76%	(76%)
PH 202	Winter 2004	Pre-test	356	74%	90
		Post-test	252	53%	(19%)
CHE 101	Fall 2004	Pre-test	55	79%	32
		Post-test	62	89%	(46%)
CHE 102	Winter 2005	Pre-test	84	99%	43
		Post-test	70	82%	(51%)
ST 314	Spring 2005	Pre-test	37	36%	17
		Post-test	46	45%	(17%)
CE 102	Spring 2005	Pre-test	79	66%	55
		Post-test	96	80%	(46%)

N/A = Not applicable

in (1) ENGR 112 in Winter term 2003, Spring term 2003, Winter term 2004, Winter term 2005, (2) IE 411 in Winter term 2004, (3) CHE 101 in Fall term 2004, (4) CHE 102 in Winter term 2005, (5) ST 314 in Spring term 2005, and (6) CE 102 in Spring term 2005. Survey 4 was used to collect data in PH 202 in Winter term 2004.

In addition to the attitude items, one item was included on the pre-test survey to determine if students had previously used a given type of MWT. This item was included in pre-test surveys beginning in Spring term 2003. The item was not included in pre-test surveys for ENGR 112 in Spring term 2002 or Winter term 2003. In the student pre-test surveys for all courses beginning Winter term 2004 or later, students were asked to share their thoughts on the use of MWT devices in the classroom. Before Winter 2004, students were asked to share their thoughts on the use of MWT devices in the classroom in both the pre-test and post-test surveys.

All surveys were completed using paper and pencil. The surveys were administered early in the quarter and again at the end of the quarter. A facilitator (other than the instructor) distributed and collected surveys during a regularly scheduled class period. Participation was voluntary. The facilitator provided each student with both an informed consent form and a survey. The surveys were coded by the student with the last four digits of the student's ID to enable matching of pre and post-surveys.

Focus group and instructor interviews

Focus groups have been used extensively as a data gathering tool in qualitative research [9]. The objective of the focus group discussion for this study was to identify unanticipated or missed points related to MWT usage and the role of MWT on student attitudes. A moderator facilitated a one-hour discussion with a group of seven volunteer students from ENGR 112 after Winter term 2005. The focus group session was conducted outside of the classroom after completion of the course. The focus group interview was recorded on audiotape and field notes were taken. Interviews with course instructors were used to collect opinions on the impact of MWT on student attitudes in courses where MWT was integrated and to assess if or how MWT impacted on the teaching and learning processes.

RESULTS

Response rates

Table 2 summarizes the number of students completing surveys, the response rates and the number of matched surveys (pre-test and post-

Table 3. Student demographics (in percentages) for all courses

	Gender		Age		Ethnicity		
Course	Female	Male	$\leq$ 23 years old	$\geq$ 23 years old	White	Asian	Other
ENGR 112							
Winter 2002	28	72	92	8	76	11	13
Spring 2002	29	66	86	6	80	0	11
Winter 2003	18	82	100	0	83	8	8
Spring 2003	13	87	90	6	71	19	6
Winter 2004	11	88	95	4	86	10	2
Winter 2005	21	78	95	4	82	3	13
IE 411	19	81	29	71	48	0	48
PH 202	52	44	84	10	74	8	10
CHE 101	30	65	96	0	75	15	7
CHE 102	37	61	93	6	73	12	14
ST 314	27	70	73	22	81	3	11
CE 102	10	85	91	4	75	9	8

test) for each course. Response rates varied from 36–99 per cent. However, the number of surveys used for determining average values varied for different survey scales because some surveys were incomplete. If a student did not complete all items for a scale, the data for that entire scale were not used in any subsequent evaluation or analyses. Response rates for matched surveys varied from 17–76 per cent.

Participant demographics

Table 3 summarizes student demographics for each course. The data were taken from the post-test surveys of ENGR 112 in Winter term 2002 and from the pre-test surveys of the remaining courses. Some surveys were incomplete. The majority of students in the courses studied were male, less than 23 years old, and white. In PH 202, however, over half of students were female. In IE 411, the majority of students were older than 23 years old and about half of students were white and about half were other.

Attitudes scale reliability analysis

Cronbach's Alpha was used to estimate the reliability of the survey. The reliability coefficient and the number of survey items for each scale for all the different surveys are included in Table 4.

Reliabilities were determined based on the entire set of respondents for each survey. Guidelines regarding acceptable reliabilities for scales state that Cronbach's Alpha below 0.60 are unacceptable, between 0.60 and 0.65 are undesirable, between 0.65 and 0.70 are minimally acceptable [10]. However, the degree of reliability needed in a measure depends on the use of the results [11]. The need for accurate measurements increases as the consequences of decisions and interpretation become more important. If the measurement results are to be used for making a decision about a group or for research purposes, coefficients in the range of 0.50

Table 4. Survey reliability analysis

	Survey 1[a]		Survey 2[b]		Survey 3[c]		Survey 4[d]	
Survey scale	Number of Items	Reliability	Number of Items	Reliability	Number of Items	Reliability	Number of Items	Reliability
Pre-test survey			N = 35		N = 406		N = 356	
Confidence	N/A	N/A	4	0.85	4	0.75	3	0.53*
Anxiety	N/A	N/A	5	0.89	5	0.87	5	0.84
Liking	N/A	N/A	4	0.70	4	0.70	4	0.83
Enthusiasm	N/A	N/A	3	0.82	3	0.77	3	0.75
Usefulness in general	N/A	N/A	3	0.70	5	0.74	1	N/A
Post-test survey	N = 50		N = 24		N = 351		N = 252	
Confidence	5	0.77	4	0.83	4	0.74	3	0.55*
Anxiety	11	0.95	5	0.88	5	0.86	5	0.87
Liking	7	0.84	4	0.87	4	0.67	4	0.84
Enthusiasm	3	0.79	3	0.67	3	0.81	3	0.80
Usefulness in general	7	0.73	3	0.61*	5	0.79	1	N/A
Usefulness in classroom	6	0.91	5	0.92	10	0.87	10	0.87

[a] Survey 1 was used to collect data in ENGR 112 Winter 2002.
[b] Survey 2 was used to collect data in ENGR 112 Spring 2002.
[c] Survey 3 was used to collect data in (1) ENGR 112 Winter 2003, Spring 2003, Winter 2004, Winter 2005 (2) IE 411 Winter 2004 (3) CHE 101 Fall 2004 (4) CHE 102 Winter 2005 (5) ST 314 Spring 2005, and (6) CE 102 Spring 2005.
[d] Survey 4 was used to collect data in PH 202 Winter 2004.
* Scale internal reliability less than 0.65.
N/A: Not applicable

to 0.60 are acceptable. Given the nature of this study, the reliabilities for all scales for all surveys were considered to be acceptable, as none was lower than 0.50.

Student attitude analyses

Results from Levene's Tests for equality of variances indicated that variances were not significantly different. Results from normal Q-Q plots indicated that the attitude data used for this study were not normally distributed. Since the data were not normally distributed and the range of possible responses was limited from 1 to 5, non-parametric statistical methods were used. Because the full data set contained a mix of paired and non-paired data, both a Wilcoxon Signed-Rank Test for paired data and a Mann-Whitney Test for two independent samples were used on the paired data to determine if the results of the analysis assuming dependent data differed from an assumption of independent data. The p-values in the Wilcoxon Signed-Rank Test were dramatically different from the Mann-Whitney Test for all paired data sets in this study indicating significant covariance due to pairing effects. This indicated that pairing was an important aspect. As a result, Wilcoxon Signed-Rank Tests for paired data were used to determine if the use of MWT in the classroom impacted student attitudes towards MWT and the use of MWT. If a student did not complete both a pre-test and a post-test, or if it was not possible to match a pre-test with a post-test, the data for that survey were not used in the analysis. Decisions on the statistical significance of results were made using an alpha (α) of 0.05.

Summary results from the paired data analysis of all courses included in this research are shown in Table 5.

An entry of 'Yes' indicates that significant differences ($p = 0.05$) were found. A '+' sign represents a significant difference where post-test attitude scores were higher than pre-test attitude scores. A '-' sign represents a significant difference where pre-test attitude scores were higher than a post-test attitude score. An entry of 'No' indicates that no significant difference was found.

Results of this study provided evidence for differences in the impact of MWT on student attitudes. For courses using MWT on a regular basis, MWT usage was found to either have no impact or to result in increased student confidence and decreased student anxiety. In some cases, the use of MWT was found to decrease student liking, enthusiasm and student views of the general usefulness of MWT.

Although the number of previous studies is limited, the results of this research are consistent with results from related research looking at student attitudes towards the use of the Internet in classrooms [2, 4] and a study of changes in student attitudes and student computer use in a computer-enriched environment [3]. The increase in student confidence and decrease in student anxiety seen in some of the courses, i.e. ENGR 112 in Spring 2002 and CHE 102, is consistent with previous research in K- 12 courses [12, 13]. These studies found that participation in a laptop programme and routine use of laptops increased the level of student comfort and enjoyment in using technology. Students were more motivated to learn when using laptops.

Student liking, enthusiasm and assessments of the general usefulness of MWT were found to be diminished in some of the courses included in this study, i.e. ENGR 112 in Winter 2003, IE 411, and CE 102. Qualitative data from student surveys and the focus group discussion were used to provide context for interpreting these results. One reason for this negative impact on student attitudes appears to be related to problems with wireless access. For example, in ENGR 112 in Winter 2003, the wireless installation was a pilot installation. The wireless system was installed locally for only this particular classroom, and wireless access was not available campus-wide. Given the nature of the installation, infrastructure such as helpdesks and security systems were not in place. Students experienced many problems with the robustness of the wireless system during this term. Students also had problems accessing and logging on to the system. Students were also logged off the wireless system during class periods.

In IE 411, similar to ENGR 112 in Winter 2003,

Table 5. Paired data analysis of student attitude data

Course	Term/ Device	Significant Differences Identified by Attitude Scale				
		Confidence	Anxiety	Liking	Enthusiasm	Usefulness in general
ENGR 112	Spring 2002/ PDA	Yes(+)	Yes(+)	No	No	No*
	Winter 2003/ PDA	No	No	Yes(−)	Yes(−)	Yes(−)
	Spring 2003/ PDA	No	No	No	No	No
	Winter 2004/ Laptop	No	No	No	No	No
	Winter 2005/ Laptop	No	No	No	No	No
IE 411	Winter 2004/ Laptop	No	No	No	Yes(−)	No
PH 202	Winter 2004/ PRS	No*	No	Yes(−)	No	No*
CHE 101	Fall 2004/ Laptop	Yes(+)	No	No	No	No
CHE 102	Winter 2005/ Laptop	Yes(+)	No	No	No	No
ST 314	Spring 2005/ Laptop	No	No	No	No	No
CE 102	Spring 2005/ Laptop	No	No	No	Yes(−)	Yes(−)

* Scale internal reliability was less than 0.65.

the use of term loaned laptops with wireless capability decreased student enthusiasm. In this course, students complained about problems with a remote server. Students used a specific application by connecting to a remote server. Students did not have access to the application directly on their laptops without the remote, wireless-enabled access. When there were problems with the wireless network, students could not use the program, and this made it difficult for students to follow along with the instructor. Since this course was a programming class, students depended on the availability of the program.

Similarly, in CE 102, students experienced problems logging on to the wireless network. One of the three sections of this course was held in a small classroom. The wireless capability installed in that particular classroom did not seem to be adequate for the number of students logging on to the wireless network at the same time. These issues resulted in decreased levels of student enthusiasm and a decrease in student evaluation of the usefulness of MWT in general. Overall, these results provide evidence that the use of MWT devices may increase student confidence and decrease student anxiety. However, the robustness of the supporting infrastructure, such as the wireless network, appears to play an important role in positively or negatively influencing other student attitudes including liking, enthusiasm and student assessment of MWT usefulness.

These findings are consistent with the findings of one previous study [14]. In this study, it was found that when the technology was used properly and class time was not spent resolving technical problems, laptop students had a more positive learning experience. When technical problems arose during the laptop implementation, however, the average instructor/course evaluation score as evaluated by students for the laptop section was lower (more negative) than the non-laptop section. By contrast, when technical issues were not experienced, the average course evaluation score for the laptop section was higher (more positive) than the non-laptop section.

In one of the classes, ST 314, where MWT was used for special purpose applications, it was found to have no impact on student attitudes towards MWT or MWT usage. In this course, laptops were used only three times for the entire term. The lack of change in student attitudes is not unexpected given this low usage of MWT in the overall course structure.

The use of MWT for special purpose applications was found to increase student confidence for students enrolled in CHE 101. Laptops were used only in the laboratories and recitations for CHE 101. Many students (about 45 per cent) indicated that the laptops were seldom used and 40 per cent of students indicated that laptops were used about half of the time. From the attitude surveys, the use of laptops did result in increased student confidence even with moderate usage.

The use of MWT was also found to result in a decrease in student liking in PH 202. The use of MWT was found to decrease student liking. Qualitative data from student surveys indicated that students felt that PRS units did not enhance their learning and also took up class time for set up and use. One concern voiced by students is that they were charged a technology fee for the PRS units. Since the PRS units were designed for the special purpose of communicating with an instructor in a single classroom, the devices were not of value outside the classroom nor in other classrooms. As a result, most students indicated that the value of the device was not worth the fee they were required to pay.

Furthermore, students indicated that because PRS usage did not impact on a student's grade in the course, many students did not take device usage seriously. Results from this research are inconsistent with the findings of previous research evaluating a handheld device specifically designed for high school-level classroom testing [15]. The device was designed for the sole purpose of testing and communicating with the teacher. All other functions (e.g. sending answers to other students and Internet access) were disabled. The author found that students were enthusiastic about using the device to take quizzes, and that students studied harder for quizzes. The students found the immediate feedback provided by the application to be useful and enjoyed competing with each other. The author reported that student scores improved each day. The difference in results between this previous study and the current study may be a function of students feeling that the value of the devices was minimal and the knowledge that device usage or non-usage would not directly impact their grades.

Effects of previous MWT experience on student attitudes

In two of the courses included in this study (ENGR 112 Winter term 2004 and ENGR 411) only a small number of students did not have previous experience with the mobile technology being used. These courses were not included in the analysis of data to study the relationship between student attitudes and student experience with mobile technology. Students with and students without previous MWT experience were treated as independent samples. A Mann-Whitney statistical test was used to evaluate whether or not significant differences existed between the attitudes of students with and students without previous MWT experience.

Summary results from this analysis are shown in Table 6.

An entry of 'Yes' indicates that significant differences ($p = 0.05$) existed. A '+' sign represents significant differences where the students with previous MWT experience had attitude scores that were higher than the students without previous MWT experience. A '–' sign represents

Table 6. Analysis of the impact of previous MWT experience on student attitudes

Course	Term	Device	Significant Differences Identified by Attitude Scale				
			Confidence	Anxiety	Liking	Enthusiasm	Usefulness in general
ENGR 112	Spring 2003	PDA	Yes(+)	Yes(+)	No	No	No
	Winter 2005	Laptop	No	No	No	No	No
PH 202	Winter 2004	PRS	Yes(+)*	No	No	No	No*
CHE 101	Fall 2004	Laptop	Yes(+)	Yes(+)	No	No	No
CHE 102	Winter 2005	Laptop	No	No	No	No	No
ST 314	Spring 2005	Laptop	No	No	No	No	No
CE 102	Spring 2005	Laptop	Yes(+)	Yes(+)	Yes(+)	No	No

* Scale internal reliability was less than 0.65.

significant differences where the students without previous MWT experience had attitudes scores that were higher than the students with MWT experience. An entry of 'No' indicates that no significant differences were found.

The results of this study indicate that previous experience does not always impact on student attitudes. Results from previous studies in related work, e.g. computer enriched classrooms, indicated that previous usage of computers was a significant factor on student attitudes related to the usefulness of computers [16–19]. In the MWT environment, the teaching pedagogy may be different from that of a traditionally taught course. In a previous study, the author argued that in order to effectively design an e-learning environment classroom, student needs and backgrounds have to be placed at the heart of the design [20]. It is difficult, however, to personalize education for each student. As a result, e-learning environment classroom design can be based on a 'common' group personality rather than purely individual personality [20]. Instructors, as facilitators of learning, need to plan and design activities that accommodate students with different levels of MWT experiences. In this study, one suggestion collected from student survey comments was that an exam (similar to a math placement exam) could be used to help place students in classes appropriate to their computer experience level. Providing tutorials for students without previous MWT experience was also suggested as a way to handle differing experience levels. In a MWT classroom, in addition to instructor planning, students must also plan. Besides reviewing prerequisites or class materials, students must also become familiar with the required MWT before coming to class and must also plan to bring the MWT devices to the classroom.

CONCLUSIONS

The results from this research indicated that, overall, students had positive perceptions about the use of MWT in higher education classrooms. Differences in student attitudes were identified, however, based on the details of the MWT implementation. Two types of MWT implementations were studied. In the first set of classrooms, MWT was used on a regular basis. The robustness of the supporting infrastructure appeared to play an important role in positively or negatively influencing student attitudes such as liking, enthusiasm and student views of the general usefulness of MWT in these classes. In the second set of classrooms, MWT was used for special purpose applications. The perceived value of the MWT, as well as the role of the MWT in impacting on student grades, was found to influence student attitudes.

The second major finding is that for higher education classes, previous experience does not always impact on student attitudes. Significant differences in student attitudes between students with and without MWT experience existed for some attitude scales in some of the courses studied. In these courses, students with previous MWT experience were more confident and less anxious than students without previous experience with mobile technology. In some cases, students with previous MWT experience also liked the use of MWT in the classroom more than the students without this experience.

Results of this study empirically validated that even moderate usage of MWT in a higher education classroom setting can impact student attitudes. The robustness of the supporting infrastructure, perceived technology value and device usage were found to influence student attitudes. To minimize any negative impact of differences in previous experience, placement exams and supplemental tutorial sessions may be necessary. Decision makers in higher education institutions must be willing to invest the necessary resources to create a robust infrastructure. Students must also support the use of the technology and become familiar with the required technology for a MWT implementation to be successful. Overall, the successful implementation of MWT in higher education classrooms must be considered from three perspectives—instructors, students and decision makers. The use of MWT to improve teaching and learning in higher education can only be accomplished if adequate time and resources are applied to the implementation, and if all stakeholders are committed to the implementation.

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REFERENCES

1. B. H. Loyd and C. Gressard, The effect of sex, age, and computer experience on computer attitudes. *AEDS Journal*, **18**(2), 1984, pp. 67–77.
2. A. Winsler and L. Manfra, Increasing student learning, technology use, and computer skills via use of WebCT in an undergraduate child development course: A pre and post course evaluation study. Presented at Ann. Conf. Am. Psychological Assoc., Chicago (2002).
3. A. Mitra and T. Steffensmeier, Changes in student attitudes and student computer use in a computer-enriched environment. *J. Research on Computing in Education*, **32**(3), 2000, pp. 417–433.
4. K. M. Buckley, Evaluation of classroom-based, web-enhanced, and web-based distance learning nutrition courses for undergraduate nursing. *J. Nursing Education*, **42**(8), 2003, pp. 367–370.
5. M. L. Waker, The predictors of student achievement in computer integrated learning environments, Doctoral dissertation, Wayne State Univ. (2001).
6. T. L. Doolen, J. D. Porter and J. Hoag, The relationship between PDA usage and student performance in an introductory engineering course. *J. Eng. Education*, **92**(3), 2003, pp. 263–268.
7. D. T. Campbell and J. C. Stanley, Experimental and quasi-experimental designs for research. Rand McNally & Company, Chicago (1966).
8. J. R. Fraenkel and N. E. Wallen, How to design and evaluate research in education. McGraw-Hill, New York (1993).
9. M. Q. Patton, Qualitative evaluation and research methods. SAGE Publications, California (1990).
10. R. F. DeVellis, Scale Development: Theory and Applications. SAGE Publications, California (2003).
11. D. Ary, L.C. Jacobs, and A. Razavieh, Introduction to research in education. Wadsworth/Thomas Learning, California (2002).
12. D. C. Cianfrani, A case study of the impact of technology on the academic achievement of students as a result of an elementary school and business partnerships, Doctoral dissertation, Univ. of North Carolina at Charlotte, (2002).
13. S. T. Dinnocenti, Laptop computers in an elementary school: Perspectives on learning environments from students, teachers, administrators, and parents, Doctoral dissertation, Univ. of Connecticut, (2001).
14. R. L. Kolar, D. A. Sabatini, and L. D. Fink, Laptops in the classroom: Do they make a difference. *J. Eng. Education*, 2002, pp. 397–401.
15. B. Hudgins, Leveraging handheld technology in the classroom. *T.H.E. Journal*, 2001, pp. 46–47.
16. D. M. Byrd and A. A. Koohang, A professional development question: Is computer experience associated with subjects' attitudes toward the perceived usefulness of computers? *J. Research on Computing in Education,* **21**(4), 1989, pp. 400–411.
17. R. Karsten and R. M. Roth, The relationship of computer experience and computer self-efficacy to performance in introductory computer literacy course. *J. Research on Computing in Education*, **31**(1), 1998, pp. 14–24.
18. B. H. Loyd and C. Gressard, The effect of sex, age, and computer experience on computer attitudes. *AEDS Journal*, **18**(2), 1984, pp. 67–77.
19. J. R. Necessary and T. S. Parich, The relationships between computer usage and computer-related attitudes and behaviors. *Education,* **116**(3), 1996, pp. 384–386.
20. B. B. Gillani, (2003). Learning theories and the design of e-learning environments. Univ. Press of America, New York (2003).

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