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Examining potentialities of handheld technology in students' academic attainments

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An increasing number of K-12 school teachers have been using handheld, or palmtop, computers in the classroom as an integral means of facilitating education due to the flexibility, mobility, interactive learning capability, and comparatively inexpensive cost. This study involved two experiments in handheld computers: (a) a comparison of the process of learning English spelling in fourth grade students using handheld computers and fourth grade students who did not use handheld computers, and (b) a comparison between the test results of fifth grade students' dividing fractions using handheld computers and fifth grade students dividing fractions using paper-and-pencil. The results revealed that fourth grade students who used handheld computers to learn spelling had significantly higher test scores than those students who learned spelling without handheld computers. Fifth grade students who used handheld computers when taking a dividing fractions test scored significantly higher than those students who used paper-and-pencil for the same test. This study concluded that handheld devices could be an addition to learning technologies in elementary schools.

Untersuchung der Einsatzmöglichkeit von Handheld-Technologie beim Erreichen von akademischen Primarschul-Lehrer-Abschlüssen

Eine wachsende Zahl von K-12 Schullehrern verwenden Handhelds oder Palmtop-Computer im Unterricht als wesentliche erzieherische Hilfsmittel wegen ihrer Flexibilität Mobilität, interaktiven Kapazität und ihren vergleichsweise geringen Kosten. Diese Studie enthält zwei Experimente im Bereich "Handheld Computer". Die Ergebnisse zeigten, dass fourth-grade Studenten, die zum Erlernen der Rechtschreibung Handheld.-Computer benutzten, signifikant bessere Testergebnisse erreichten als die, die keine Handhelds verwendeten. Fifth-Grade Studenten, die Handhelds beim Lösen von Divisionsaufgaben benutzen haben beim Test signifikant besser abgeschnitten, als die, die nur Papier und Bleistift für den gleichen Test zur Verfügun hatten. Daraus folgt, dass Handheld Hilfsmittel eine zusätzliche Hilfe beim Lernen von Technologie in Grundschulen sein könnten.

Un examen du potentiel des technologies portables sur les résultats scolaires des élèves de l'école élémentaire

Un nombre croissant de professeurs des écoles utilisent les ordinateurs portables ou "palmtop" dans leurs classes comme outil intégré susceptible de faciliter

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l'enseignement, du fait de sa souplesse, de sa mobilité, de sa capacité à favoriser l'apprentissage interactif et de son prix relativement accessible. La présente étude a porté sur deux expériences impliquant des ordinateurs de poche. Les résultats ont révélé que les élèves de quatrième année qui utilisaient ces ordinateurs portables pour apprendre l'orthographe obtenaient aux tests des scores nettement plus élevés que les élèves qui apprenaient l'orthographe sans ordinateursde poche. Les élèves de cinquième année qui utilisaient des ordinateurs portables lorsqu'ils passaient un test sur la division des fractions obtenaient des résultats nettement plus élevés que les élèves qui utilisaient du papier et un crayon pour le même test. Cette étude a conclu que les technologies portables pouvaient apporter un plus aux technologies d'apprentissage dans les écoles élémentaires.

Un examen de las potencialides de las tecnologías portátilessobre los resultados académicos de los alumnos de primaria

Un número creciente de maestros de escuela usan ordenadores de tipo móvil o *handheld* en sus aulas como herramientas integradas para facilitar el aprendizaje, debido a su flexibilidad, movilidad, capacidad para facilitar el aprendizaje interactivo y su precio relativamente barato. El presente estudio incluye dos experimentos sobre los ordenadores de bolsillo. Los resultados han mostrado que los alumnos de cuarto año que habían usado esos ordenadores móviles para aprender la ortografía conseguían resultados claramente más altos que los alumnos que habían aprendido la ortografía sin ordenadores móviles. Los alumnos de quinto año que usaban los ordenadores móviles cuando pasaban un test de división de fracciones conseguían resultados claramente más altos que los de esos alumnos que habían usado papel y lápiz para el mismo test. La investigación concluyó que los aparatos portatiles podían constituir un valor agregado en las tecnologías de aprendizaje en las escuelas primarias.

Keywords: handheld computers; handheld technologies; elementary school students; English word spelling; testing skills

Introduction

More and more schools have used handheld computers as integral and regularly used educational technology devices (Roschelle, 2003), as they are small, ease to move, inexpensive, and enable information to be shared quickly through wireless connections. These handheld devices, which can include mobile devices, personal digital assistants (PDA), and handheld computers (handheld PCs) have been introduced into classrooms in recent years. These devices are referred to as "mobile technologies." Within this field, a term "mobile learning" is used to describe any learning activities utilizing these mobile technologies. The low cost, availability of software, and convenience of handheld computers have encouraged educators to develop and use handhelds for teaching, learning, and assessment (Gladhart, Topp, Elder, Pownell, & Brahier, 2003). The number of handheld computers is projected to grow exponentially in the next three years, and handheld computers will mostly be available to every schoolchild in America as computing technology (Soloway, 2007). As of 2007, there were approximate 200 education-specific applications for the Palm operating system alone. In the near future, handheld computers will be designed toward more individualized education (Soloway, 2007). The study of mobile devices in a learning environment, such as a handheld PC, palmtop PC, and Personal Digital Assistant, referred to as m-learning, is an emerging research area. Even though the wireless local area network has become increasingly important in the learning milieu, educational

research has not been fully addressed (Goh & Kinshuk, 2006). The purpose of this study was to examine whether or not handheld computers can be credited with increasing student achievement in spelling and in developing testing skill in mathematics.

Literature review

Demands for research on handheld computers

Learning and teaching with mobile technologies has been evolving from small-scale to institution-wide implementations, as the availability of mobile devices has challenged educators as to how to use these emerging technologies to support learning (Naismith, Lonsdale, Vavoula, & Sharples, 2006). According to Goh and Kinshuk's (2006) extensive literature review of handheld PC research, most papers evaluated end learners' experiences with limited qualitative and quantitative first-hand data. It was imperative to understand the patterns and demands of mobile devices since they have become an indispensable part of everyday life (Corlett, Sharples, Bull, & Chan, 2005). Close attention should be paid to the pedagogical arrangements due to the introduction of handheld computers in the classroom (Roschelle & Pea, 2002). More precisely, an understanding of the attributes of handheld computer applications in pedagogical requirements was needed (Roschelle, 2003).

Due to the inexpensive cost, portability, and convenient size, handheld computers were an ideal, alternative platform for computer-based testing. However, there was little research on handheld computers and their applications in administering exams. Most research focused on handheld technology development and implementation issues; however, measuring and analyzing handheld computers for testing purpose has yet to be evaluated (Segall, Doolen, & Porter, 2005). There was a minimal amount of evidence that handheld computers could be effectively used in students' assessment in the classroom and utilization of handheld computers actually improved students' academic achievements. Therefore, systematic research on handheld computers' application in a variety of areas was needed (Hooft, Diaz, & Swan, 2004). While mobile technology was expanding to schools and colleges, what was lacking was an innovative educational framework to meet this new wave of technologies (Sharples, 2007).

Benefits of using handheld computers in education

The literature review shows that there is a growing interest in the relationship between learning/teaching and handheld computers. In the SRI International Center for Technology in Learning's first study of handhelds in the K-12 classroom survey, 93% of the teachers believed handhelds had a positive impact on students' learning (Joyner, 2003).

Mobile technologies with increased capabilities of networking, social interactions, and context awareness had an obvious impact on learning (Naismith, Lonsdale, Vavoula, & Sharples, 2006). Handheld PCs could broaden the range of assessment tasks and could be better aligned with inquiry-oriented instruction. These devices created new ways for students to express themselves and expanded the range of assessment methods in lieu of a new communication medium (Roschelle, Penuel, Yarnall, Shechtman, & Tatar, 2005).

Handheld computers were used in schools as assessment tools. For instance, a social studies teacher used handheld computers to pretest before units to assess what students knew, comprehension during a unit, and content knowledge after units. The results showed that computer-based testing possessed the characteristics of accurate grading, prompt feedback, real-time scoring, and security (Segall, Doolen, & Porter, 2005). The mClass program allowed teachers to assess early reading skills (*Instant feedback*, 2007). Handheld computers could be used for special education students to conduct spelling exercises, and had an impact on these students' penmanship (Hooft, Diaz, & Swan, 2004). Handheld PCs were also used by foreign language teachers in their learning/training (Wishart, 2008), while elementary school students used handheld computers to concurrently collect, report, and organize the data for their inquiry-based science water quality project (Avraamidou, Evagorou, Demetriou, & Vrasidas, 2008).

Portable assessment technology could shift from drill-and-practice to more student-directed learning (Yarnall et al., 2003). Mobile technology allowed young people to explore new knowledge through continual communications (Sharples, 2007). Inexpensive and portable handhelds required less difficult pedagogical adjustments and could facilitate formative assessment solutions (Penuel, Tatar, & Roschelle, 2004). Mobile technologies were not passively used. On the contrary, they were utilized actively at all stages of students' learning. Therefore, it was imperative to address the empirical and theoretical realities of mobile technologies in schools (Selwyn, 2003). Students used handheld devices as individual workplaces and interacted with peers through shared display, supporting one-to-one collaborative learning activities (Liu & Kao, 2007).

A recent report from Wang, Shen, Novak, and Pan (2009) described how students in a large blended class used mobile devices in language acquisition. They found that course content revealed itself to be well-suited for text based interactions. Their project re-confirmed previous research that mobile devices in the language learning/teaching process promoted students' learning in three aspects – cognitive, social, and emotive.

Previous research on handheld computers in education

Chen, Myers, and Yaron (2000) surveyed chemistry students about their preferences of handheld computer functions versus flash cards or showing of hands. Over half of the respondents were in favor of using handheld computers.

Chen, Kao, Yu, and Shen (2004) conducted an experimental study to determine the effectiveness of a mobile device in field studies to identify different kinds of butterflies in the region. The control group used a text-based butterfly guidebook, while the experimental group used handheld PCs to take photos and match the databases through wireless telecommunication. As a result, the experimental group was able to more correctly identify butterfly features than the control group.

Ng and Nicholas (2009) conducted a study to examine the realities of integrating handheld computers in five Victorian schools in Australia. Their findings indicated that primary and secondary teachers shared similar beliefs in the handheld computers' capacity to students and the motivational aspect of the technology on student engagement.

Chen (2008) investigated whether or not using handheld computers for instantaneous feedback in quizzes could enhance learning in an engineering mechanics

course. The results showed that there was no statistically significant difference in knowledge gained between feedback through handheld computers and color-coded flashcards. However, the students using handheld computers showed a good retention of statistical concepts and skills in follow-on courses. Segall, Doolen, and Porter (2005) compared the usability of the handheld computer quiz application to that of the paper-and-pencil quiz among college engineering students. The results showed that the handheld computer might facilitate test taking, as students used less time to complete the test than those who took a paper-and-pencil test. The study did not detect any significant differences in handheld computer satisfaction, and no significant relationship was found between computer anxiety and quiz type. The researchers suggested that further study was needed, to randomly select half of the students in the class to take a paper-and-pencil quiz and the other half to take a handheld computer-based test to improve internal validity in this type study. They further recommended using different populations instead of exclusively university students.

The current study involved two experiments to examine the potentials of handheld technology in elementary school students' learning activities. The first one compared students' learning activities of English spelling for fourth grade students, while the second one compared students' testing skills of mathematics – dividing fractions for fifth grade students. Two research questions were formulated for this study:

(1) Is there a positive effect of using handheld computers on the fourth grade students' learning English spelling?
(2) Is there a positive effect of using handheld computers on the fifth grade students' acquisition of test skills of dividing fractions?

Experiment 1

The first study was to examine the acquisition of English vocabulary by a group of students who used handheld computers and a group of students who learned English vocabulary in a traditional way. The null hypothesis was that there is no statistically significant difference in the test scores of English vocabulary spelling by a group of students who learned English vocabulary using handheld computers and a group of students who learned English vocabulary in a traditional way.

Method

Subjects

A total of 47 fourth grade students participated in this study from a public school located in the mid-southwest in the USA. All students were English native speakers. Twenty-two students learned English vocabulary utilizing a handheld computer, the palmOne Zire 72s. Twenty-five students learned English vocabulary without handheld computers. The same teacher taught this lesson for both groups of students.

Measurements

The same fourth grade teacher designed and produced the test for both control and experiment groups. There were 20 words on the test, with each word worth five points. The test scores were used as the experimental research dependent variable, and the highest possible score was 100.

Procedure

To avoiding confounding variables, the same teachers taught the same vocabulary, spent the same amount of time teaching and used the same instruction. The only difference in this experiment was the pedagogy. That was the purpose of the study, in which the students in the control group did not use handheld computers, and the students in the experimental group used handheld computers. The students used NotePad on the handhelds to learn the spelling of the 20 words and worked in pairs. One student used the text to call out the spelling words to their partner. The partner would send the word to him/her and that student would check if he/she spelled the word correctly. Once they felt good about knowing how to spell the words, they would switch jobs. The student who had called out the words before would then be the one who had to write and beam the words rather than call them out.

The students did this lesson over a two-day period. They were focused on the task because they were having fun, as they expressed that they much preferred doing it this way with the handhelds than having to study in the traditional way. After the two lessons they did not have to study for the test: they had mastered the words without memorization. The students that did not use the handhelds had to study at home with drill and practice.

Data analysis and results

The researcher used a quasi-experimental method in this study (Sprinthall, 2007). The two samples were independent of each other and comparisons were made only between measures of the same traits. The dependent variable data collected were interval data. No outliers were detected before the analysis was carried out.

The hypothesis for this study states that there is no statistically significant difference in the test scores of English vocabulary spelling between a group of students who used handheld computers and a group of students who learned English vocabulary in a traditional way. The same test was used for both groups. The data collected were analyzed using *Independent-Samples T*. Table 1 shows the result in details.

The result of the *Independent-Samples T* test indicated that scores from students who used handheld computers were significantly higher than those from students who did not use handheld computers ($df = 45$, $t = 4.10$, $p < .001$). Therefore, the null hypothesis was rejected. The students who learned English spelling without handheld computers did not do as well as the students who used the handheld computers.

Table 1. Instruction of English vocabulary with and without handheld PC. Descriptive statistics and *t-test.*

	N	Mean	SD
Instruction with handheld PC	22	100.00	0.00
Instruction without handheld PC	25	90.60	2.15
t	*df*	*Mean Difference*	*Significant*
4.10	45	9.40	*S****

Note: Effect size $d = 1.20$. ***$p < .001$.

Experiment 2

The second experiment focused on the test skills. As in the first experiment, all other variables were maintained the same, in terms of the teacher, time spent on teaching, instruction, and the equal opportunities of using handheld computers in learning the unit. Two different groups of the fifth grade students' test results on dividing fractions were examined. One group of students used a paper-and-pencil to take the test. The other group of students took the same test using palmOne Zire 72s handheld computers. The null hypothesis was that there is no statistically significant difference in the final test scores between the two groups of students.

Methods

Subjects

A total of 97 fifth grade students participated in this study. The purpose of this study was to examine the results of the same test on a dividing fractions lesson. Thirty-nine students used the handheld computer Zire 72 to take the test, while the other 58 fifth grade students took the same test using paper-and-pencil.

Measurements

The same fifth grade mathematics teacher designed and produced the test for both control and experiment groups. There were eight dividing fractions problems on the test. The students were expected to divide the fractions and write the answers in the simplest form whenever possible. The test scores were used as the experimental research dependent variable, and the highest possible score was 100.

Procedures

The same teachers taught, designed, and administered this dividing fractions unit. Students in both control group and experimental group received the same instruction and spent the same amount of time in learning the unit. After completing the dividing fractions unit, the teacher gave 58 students a paper-and-pencil test with eight questions. Students were instructed to divide the fractions and write the answer in simplest form where possible. The same eight questions were loaded into palmOne Zire 72s handheld computers, and 39 students took the test using the handheld computers.

Data analysis and results

The researcher used a quasi-experimental method in this study. The two samples were independent of each other, and comparisons were made only between measures of the same traits. The dependent variable data collected were interval data. No outliers were detected before the analysis was carried out.

The final test scores were analyzed using the statistical technique *Independent-Samples T.* Table 2 shows the details of the result.

The result revealed that the test scores from the students who used the handheld computers were significantly higher than those from the students who used paper-and-pencil ($df = 95$, $t = 4.61$, $p < 001$). Therefore, the null hypothesis was rejected.

Table 2. Instruction of dividing fractions with and without handheld PC. Descriptive statistics and *t-test*.

	N	Mean	SD
Examination with handheld PC	39	87.03	17.29
Examination without handheld PC	58	60.98	32.30
t	*df*	*Mean Difference*	*Significant*
4.61	95	26.05	*S***

Note: Effect size $d = 0.95$. ***$p < .001$.

Highlights of qualitative data

The researchers also collected qualitative data from all of those fourth and fifth grade students. The qualitative data contain two folds: field notes from the researcher taken in the school settings and the results of an online survey. The online survey consisted of six questions (e.g. Every student at [School Name] should have a handheld PC) pertinent to elementary students' attitudes towards handheld PCs. The results of the qualitative data supported both experimental studies. The students expressed their optimistic learning experiences with handheld computers, and indicated the use of handheld computers made learning more enjoyable and easier. One student commented:

> The Palm made learning more fun to me. Especially when we used notepad, calculator, and when we beamed each other. It also made it easier to learn things with a Palm than paper and pencil. It would be very fun if we used Palms everyday that would make learning easier for us students. Even kids in the lower grades could use it.

The students also felt that using handheld computers made learning more interactive and collaborative. Because the handheld computers allowed the students to transfer data by beaming functionality, the students helped one another in learning groups. One student said,

> We got to use notepad then beam to each other and check their words. Since we got to use the Palms everyone got an A. Using the Palms is much better than using paper and pencil.

Discussion and conclusion

This research involved two experimental studies examining handheld computers' potentialities to facilitate elementary students' learning vocabulary spelling and dividing fractions. Methodology of this research utilized comparisons of experimental and control groups at the fourth and fifth grades in an elementary school to test null hypotheses.

Even though handheld computers are becoming popular as teaching/learning tools in schools, research on pedagogical arrangements has not been fully addressed (Roschelle & Pea, 2002). In the first study, the fourth grade students who used handheld computers to acquire correct spelling vocabulary learned better than those students who learned spelling without using handheld computers. In the second experiment, the students using handheld computers to take a dividing fractions test performed better than those students who used a paper-and-pencil test.

Furthermore, the researcher also collected the fourth and the fifth grade students' comments and perceptions with assistance from classroom teachers. Previous studies (e.g. Soloway, 2000; Liu & Kao, 2007) emphasized an important role that the handheld PCs played in collaborative learning activities. Qualitative data supported Soloway (2000) and Liu and Kao's research report that beaming files from one handheld to another provided collaborative learning opportunities among students. Students in this study overwhelmingly asserted that handheld computers provided interactive and collaborative learning opportunities. Students also stated that handheld computers made their learning easier and fun.

This study discovered a positive potential of utilizing handheld computers in elementary schools. The findings in this study provide confidence for both English language arts and mathematics teachers to utilize handheld computers in their classrooms. This study also shows that handheld computers have the potential to promote the students' motivation to learn and enhance their peer collaborations. This study finds that there is a positive effect of using handheld computers on both the fourth grade students' learning of English spelling, and on the fifth grade students' acquisition of test skills in dividing fractions.

Understanding students' learning conditions, experiences, and variety of attitudes has had a broad impact on schools' decisions to use mobile technologies (Penuel, Tatar, & Roschelle, 2004). Both experiments in this study illustrated that elementary students achieved better learning results in English vocabulary spelling and test skills in dividing fractions in mathematics. Generally, students' reflections on using handheld computers in their learning activities were positive. They particularly pointed out that (a) using handheld computers made learning fun and easier, and (b) using handheld computers made learning more interactive and collaborative. Both quantitative and qualitative data in this study show that handheld computers can enhance active learning in elementary school classrooms. Handheld computers were a potential solution for educators to promote digital equity, empower students, and seamlessly incorporate technology in every classroom (Staudt, 2005). This study concluded that handheld devices could be an addition to learning technologies in elementary classrooms.

Traylor (2009) interviewed two educational technology luminaries. Both interviewees agreed that handheld computers could address twenty-first century learning skills. Due to handheld computers' low cost, mobile capability, and interactive learning potentialities, they will become a realistic alternative for integrating technologies into the curriculum in K-12 settings. Handheld computers also facilitate collaborative learning because of network connectivity (Hooft, Diaz, & Swan, 2004). The finding of this study is consistent with Hooft, Diaz, and Swan's statement. This study concludes that handheld computers could impart positive potentialities in elementary school students' academic attainments.

This study was limited in the subject areas of English language arts and mathematics in elementary schools. Future research is recommended to explore handheld computer applications in other content areas and in different populations, such as students at secondary or college levels.

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