The Impact of Personal Digital Assistants on Academic Achievement

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Statement on Human Participants

This study was conducted under the supervision of the Millburn High School Institutional Review Board. Research involving human subjects was conducted under the supervision of an experienced teacher and followed state and federal regulatory guidance applicable to the appropriate ethical conduct of this research. All participants and their parents signed informed consent forms prior to their participation.

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Introduction

Research during the past decade suggests that integrating computing technology in general, and mobile computers in particular, into the educational environment has positive affects (National Research Council, 2002). Over the past decade, much money has been invested into the K-12 educational technology infrastructure. The United States Congress in 2001 recognized the potential for educational technology to enhance learning and set aside federal funds for schools that wish to purchase educational technology that has been proven through empirical based research (No Child Left Behind Act). To obtain higher academic achievement, a projected six billion dollars were spent on educational technology in the United States during the 2003-04 school year, adding to the approximately sixty billion dollars spent since 1991 (Johnson, 2004). Yet, much research remains in order to meet the scientific standards required by the No Child Left Behind Act and improve student academic achievement.

In 1998 three landmark studies found that laptop computers increased student achievement (Belanger, 2000). The Fisher *Study of Western Australian Schools* (1998) found that the correlation of laptops and a better attitude was stronger than the correlation of laptops and student achievement, though both were statistically significant. Rockman (1998), in a nationwide study of 144 teachers and more than 450 students, determined that students with laptops demonstrated a "sustained level of academic achievement." Stevenson (1998) found increased student motivation and achievement during the middle school years, as opposed to students not using laptops who tended to decline during this same period.

Fung (1998) wrote of a "paradigm shift" towards portable computing in education. Highly portable computers known as Personal Digital Assistants (PDAs) represent the next logical step in this progression of increasingly mobile computers. The current generation of PDAs (examples of which are Palm Pilots™ and Pocket PCs™) have the same raw computing power as the laptop computers of several years ago (Dieterle, 2004). PDAs generally have a 2.5 to 4 inch display size and use either a pen or miniature keyboard for input rather than a standard keyboard and mouse. The devices generally weigh 4 to 8 ounces and cost one hundred to four hundred dollars. PDAs can be used for a variety of functions, for example, to manage work or study schedules, to record and store data, and to access and disseminate information (Waycott, 2003). In addition, PDAs can run many of the same applications that laptops can. For example, Pocket versions of Microsoft Word® and Excel® and the Internet Explorer®

browser are all available for Pocket PCs and Palm Pilots.

As wireless handheld computers, PDAs have several advantages over laptops. PDAs cost about 10% of the cost of a laptop while providing about 60% of the performance (Dieterle, 2004). PDAs are far more portable than laptops as they weigh several ounces rather than pounds and can easily be stored in a pocket (Byrom, 2002). This enables ubiquitous access (Pfiefer, 2001). Students take care of their devices because of the feeling of ownership (Soloway, 2001). The devices encourage collaboration and sharing through "beaming" (the wireless transfer of information). Students are very comfortable with the handheld technology because of their experiences with GameBoys™ and other similar devices. This minimizes the amount of time teachers need to spend teaching how to use devices (Bornstein, 2004).

Analogies have been made between the function of laptops and the category of mobile computer devices known as Personal Digital Assistants (PDAs) (Soloway, 2001). Current research involving PDAs has focused on specific applications where PDAs can be used, for example with participatory simulations (Klopfer 2004) and distributed wireless simulations (Repenning, 2003a, 2003b). Other research has evaluated the effectiveness of PDAs for specific tasks. PDAs have been found to increase the efficiency of medical students in their primary clerkship (Kurth, 2002). Additionally, the effectiveness of PDAs has been demonstrated in the business environment (Devi, 2002). With all of this evidence, no long-term study has been reported in literature with the goal of determining the effects of using a PDA at the High School level.

Currently schools are spending thousands of dollars on mobile carts containing laptops for in-class use. For the same cost as a cart of 25 laptops at a total cost of $25,000, a school could potentially purchase a PDA for every student in a class of 250, increasing student access to technology and potentially saving money. Under the No Child Left Behind Act, schools can apply for federal grants for technology that is of proven value to increasing academic achievement. This research generates the "empirical data" based on "scientifically rigorous" study called for by the No Child Left Behind Act of 2001. This research is designed to provide necessary proof that will enables schools to apply for federal funds for Personal Digital Assistant purchases.

This study seeks to determine if there is a correlation between PDA usage and a standard measure of academic achievement i.e., Grade Point Average (GPA) (Hu 2002). The hypothesis is that if a student from the treatment group uses a PDA (referred to as a PDA-enabled student) then the relative change in their GPA during the study period of one semester will be positive when compared to the change in the GPA of the general student population (or control group) made up of all other students in the PDA-enabled student's grade.

Methods and Materials

The first step was to obtain necessary approval from Millburn High School and the Institutional Review Board. This group certified that the research would not harm the human participants in any way. A census of Millburn High School students was used to determine that the number of students currently possessing Pocket PCs in the High School was statistically insignificant. The entire population (referred to as a grade or a graduating class) not selected to receive PDAs was considered the control group. A simple random sample of second semester freshmen and first semester sophomores determined which students would be offered the fifteen Pocket PC devices donated by Microsoft Corporation. After all necessary parties signed consent forms, students were given Microsoft Pocket PCs (Specifically: Compaq iPaq 3850, HP Jornada 564 & Audiovox Thera) to use for a semester-long trial period. The Pocket PCs were loaded with a variety of productivity software (including Pocket Word, Pocket Excel, Pocket ClassPro and Graphit), custom usage tracking software (see Appendix A for further information about the tracking software) and survey software (see Appendix B for further information about the survey software). The students were given no training or specific instruction on how to use the devices but were provided with product manuals. The study was conducted at the 98% confidence level. This means that if the study of this sample size was repeated many times, two out of one hundred times the confidence intervals computed in this study will fail to contain the true population parameter because of random sampling variability. Participants were asked to upload usage data several times during the semester and occasionally asked to comment about their Pocket PC experience. At the end of the semester, the students returned the Pocket PCs. Anonymous information about the participant and control groups' academic performance were received from the school administration. The data was first analyzed to determine if the simple random sample of students was a representative sample. The students' performance was then compared to their previous performance to determine if relative to their prior performance if there was a change. The change in student performance was then compared to the change in performance of the rest of the grade. The relative change was then analyzed. For example if the sample students' achievement increased 13% and the population increased 3% the relative increase would be 10%. Finally a t-test was used to ensure that there was a statistically significant absolute difference between the sample and control group. Qualitative data collected through survey instruments were also analyzed.

Just as laptops have been shown to both have a positive effect on general achievement and as a subject specific teaching tool, PDAs were tested for this potential ability. In particular, PDAs, like laptops, were used in participatory simulations to test their effectiveness as a teaching tool. Participatory simulations are activities that teach by embedding learners in life-size role playing scenarios. This project sought to determine if a more economical platform could be employed for participatory simulations. Additionally, this project sought to determine if learning styles as measured by the Felder and Solomon (1988) Index of Learning Styles, affected the efficacy of the participatory simulation. To make this determination a 2,000-line C# software program was written which incorporates the MIT "Thinking Tags" participatory simulation protocols. This software was loaded on 20 Pocket PCs and used by 80 High School Biology students, ranging in age from 14 to 17, during five 45-minute sessions to enact the "Live Long and Prosper" genetics participatory simulation. Players in this game are told to live as long as possible and reproduce. Player's ability to survive and reproduce is influenced by their one to eight gene genome which is displayed. Each of the genes stands for a trait. The shading of the genes somehow stands for homozygous recessive, homozygous dominant and heterozygous at that position. The players choose which other participants to "mate" with (via the infrared port) and through selective mating gain the traits that allow them to "live long and prosper". Students learn genetics and the scientific method by embedding themselves in a inquiry based simulation of a fruit fly life cycle. Participants took pre-trial and post-trial assessments to evaluate their knowledge of the material presented by the Live Long and Prosper participatory simulation, using previously validated questionnaires. Participants' learning styles were also assessed using a version of the Index of Learning Styles assessment.

Results

Table 1: Study demographics

Trial Number	Students in Population: Class of 2006-7	Number of PDA Users	Trial Dates
1	301	9	January 2003- June 2003
2	303	8	September 2003-January 2004
3	295	9	January 2004-June 2004
4	295	11	September 2004- January 2005

Table 2: GPA change

Normalized[1] Average GPA change among PDA enabled students compared to the population

Trial	% change in PDA-enabled student GPA during trial	% change in Population's GPA during trial	% difference between change in PDA users and Population GPA
1	08.86	-04.65	13.51
2	00.57	06.80	-06.23
3	24.47	-09.41	33.89
4	12.22	01.82	10.40
Average	**11.53**	**-01.36**	**12.89**

Table 3: Most frequently used programs in order from most used to least used

Pocket Calendar
Pocket Tasks
Microsoft Word
Pocket Class Pro
Pocket Contacts
Windows Media Player
Games – (specifically Solitaire, Cubical Chaos, Pocket Chess)
Internet Explorer
Calculator
Microsoft Excel

Table 4: Participatory Simulation Demographics

# of Classes	Biology Level	Male	Female	Total
2	Standard	17	14	31
2	Honors	12	15	27
1	AP	11	9	20
Participants were all High School Students (Ages 14-16)			Total:	78

Table 5: Combined Results: Grade 10 Bio (AP, Honors, Standard)

Table 5a: Percent of correct Genetics questions

	Mean	Std Dev
Pretest	0.409	0.266
Posttest	0.735	0.272

Table 5b:
Two-sample T-test comparison of Pre-Test score vs. Post Test Score

	N	Mean	StDev	SE Mean
PostTest	78	0.735	0.272	0.039
PreTest	78	0.409	0.266	0.040

Difference = mu PostTest - mu PreTest
Estimate for difference: 0.3258
95% CI for difference: (0.2155, 0.4361)
T-Test of difference = 0 (vs not =): T-Value = 5.87 P-Value = 0.000

Table 6: Post test participatory simulation response questions by Class Level
1-strongly disagree 3-Neutral 5-strongly agree

1. This activity helped me understand the scientific content better
2. I feel that this activity is important in leaning and understanding scientific concepts
3. I feel that it is important to know how to work with my classmates
4. I feel that is activity helped me practice working with my peers
5. Class success in this activity depended on my participation
6. I felt that my contributions made the class activity successful
7. I thought the technology was fun
8. I thought the technology helped me learn
9. I feel like I learned something about genetics
10. I thought finding the patterns in the data was easy

Level		1	2	3	4	5	6	7	8	9	10
Standard	Mean	3.7	3.579	4.05	3.9	3.9	3.58	4.05	3.89	3.79	3.222
	Std Dev	0.9	1.017	0.91	0.9	0.7	0.84	0.97	0.94	1.08	1.166
Honors	Mean	3.4	3.174	3.39	3.5	2.9	3.13	3.63	3.13	3.26	2.783
	Std Dev	1.23	1.27	1.2	1.1	0.9	1.28	1.29	1.21	1.2	1.23
AP	Mean	3.4375	3.5	3.857	3.73	3.563	3.625	4.13	3.81	3.5	3.133
	Std Dev	0.62915	0.632	0.864	0.88	0.892	0.8062	0.74	0.98	0.63	0.99

Table 7: Information by Gender

Table 7a: percent of correct Genetics questions

	Pre Test		Post Test	
	Mean	Std Dev	Mean	Std Dev
Male	0.419	1.5134	0.6308	1.4632
Female	0.4154	1.1019	0.5714	1.5892

Table 7b: Post test Response questions
1-strongly disagree 3-Neutral 5-strongly agree

1. This activity helped me understand the scientific content better
2. I feel that this activity is important in leaning and understanding scientific concepts
3. I feel that it is important to know how to work with my classmates
4. I feel that is activity helped me practice working with my peers
5. Class success in this activity depended on my participation
6. I felt that my contributions made the class activity successful
7. I thought the technology was fun
8. I thought the technology helped me learn
9. I feel like I learned something about genetics
10. I thought finding the patterns in the data was easy

		1	2	3	4	5	6	7	8	9	10
Male	Mean	3.286	3.714	3.727	3.091	3.273	4.136	3.5	3.455	3.095	3.286
	Std Dev	1.24	1.119	1.008	1.083	0.862	1.013	1.27	1.233	1.191	1.24
Female	Mean	3.571	3.429	3.667	3.632	3.619	3.381	3.476	3.45	3.55	2.85
	Std Dev	0.92	1.035	1.207	1.184	1.051	0.959	1.213	1.098	1.106	1.195

Table 8: Information by Learning Style

Table 8a: Percent of correct Genetics questions

	Pre Test		Post Test		% difference in post-test scores	% difference in improvement (posttest-pretest)
	Mean	Std Dev	Mean	Std Dev		
Active	**0.40050**	**1.4142136**	**0.653846**	**1.326552**	**5.38%**	**12%**
Reflective	**0.4615385**	**1.1387288**	**0.60000**	**1.758098**		
Sensing	**0.35500**	**1.377733**	**0.582609**	**1.703287**	**16.48%**	**0%**
Intuitive	**0.5157895**	**1.1212983**	**0.747368**	**1.121224**		
Visual	**0.4235294**	**1.3431015**	**0.675862**	**1.612757**	**6.05%**	**4%**
Verbal	**0.40500**	**1.3540064**	**0.615385**	**1.38212**		
Sequential	**.4555556**	**1.3007934**	**0.682353**	**1.559286**	**13.24%**	**3%**
Global	**0.2909091**	**1.2933396**	**0.55000**	**1.38873**		

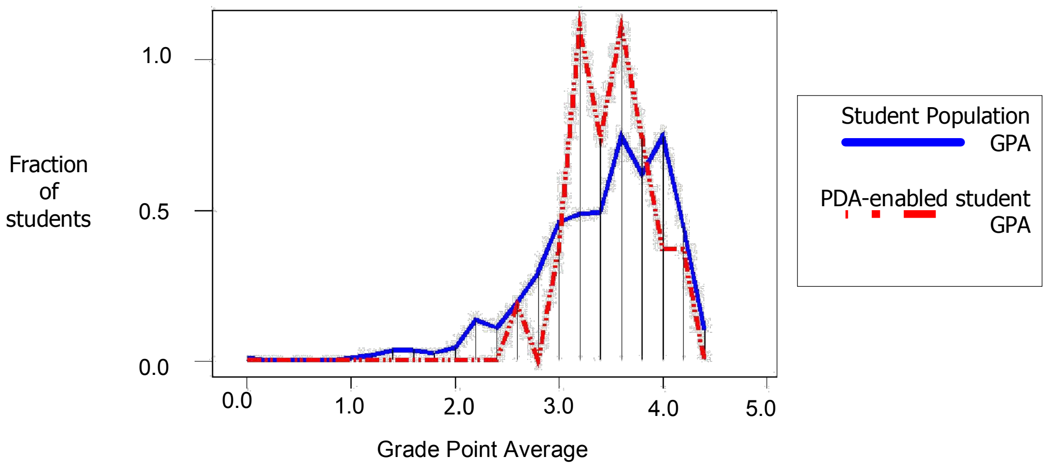
Table 8b: Post test Response questions

1-strongly disagree 3-Neutral 5-strongly agree

1. This activity helped me understand the scientific content better
2. I feel that this activity is important in leaning and understanding scientific concepts
3. I feel that it is important to know how to work with my classmates
4. I feel that is activity helped me practice working with my peers
5. Class success in this activity depended on my participation
6. I felt that my contributions made the class activity successful
7. I thought the technology was fun
8. I thought the technology helped me learn
9. I feel like I learned something about genetics
10. I thought finding the patterns in the data was easy

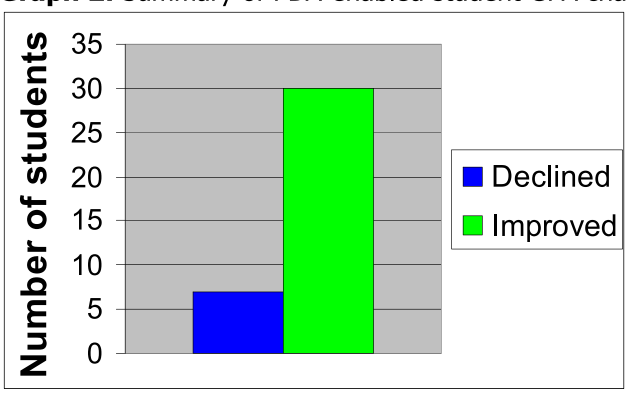
		1	2	3	4	5	6	7	8	9	10
Active	Mean	3.69	3.48	3.78	3.97	3.47	3.53	3.91	3.58	3.52	2.87
	Standard Deviation	**0.98**	**1.27**	**1.32**	**1.11**	**1.09**	**0.93**	**1.26**	**1.34**	**1.29**	**1.23**
Reflective	M	3.53	3.58	4.11	3.68	3.42	3.32	4.26	3.74	4.79	3.53
	SD	**0.77**	**0.90**	**1.02**	**1.11**	**1.02**	**0.82**	**1.05**	**1.05**	**0.71**	**1.12**
Sensing	M	3.67	3.50	3.74	3.84	3.26	3.52	4.00	3.65	3.46	2.89
	SD	**0.88**	**1.14**	**1.10**	**0.99**	**1.13**	**0.89**	**0.88**	**1.16**	**1.17**	**1.09**
Intuitive	M	3.25	3.21	3.74	3.54	3.33	3.04	3.75	3.29	3.46	3.05
	SD	**0.90**	**1.02**	**1.21**	**1.10**	**0.96**	**0.75**	**1.29**	**1.20**	**1.02**	**1.33**
Visual	M	3.45	3.42	3.73	3.69	3.48	3.24	3.79	3.58	3.55	2.81
	SD	**0.87**	**1.00**	**1.15**	**0.97**	**0.91**	**0.87**	**1.11**	**1.12**	**1.03**	**1.05**
Verbal	M	2.50	2.24	2.76	2.71	1.94	2.39	3.06	2.29	2.29	2.22
	SD	**0.99**	**1.25**	**1.15**	**1.21**	**1.21**	**0.85**	**1.06**	**1.31**	**1.21**	**1.40**
Sequential	M	3.45	3.26	3.73	3.76	3.23	3.28	3.83	3.38	3.33	2.82
	SD	**0.96**	**1.16**	**1.18**	**1.02**	**1.10**	**0.88**	**1.15**	**1.21**	**1.12**	**1.14**
Global	M	3.55	3.73	3.80	3.45	3.55	3.36	4.09	3.90	4.00	3.50
	SD	**0.69**	**0.65**	**1.03**	**1.13**	**0.82**	**0.81**	**0.83**	**0.99**	**0.82**	**1.27**

Graph 1: Density plot of all PDA users compared to all student populations before trial



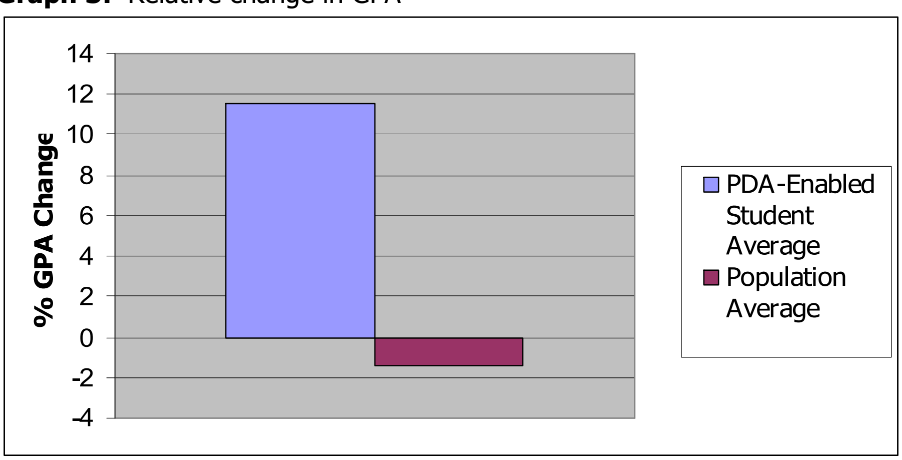
Graph 1 is a set of density distributions comparing the participants in each trial to the control group before the study occurred. This plot was used to ensure that the sample is representative of the population.

Graph 2: Summary of PDA-enabled student GPA change



Graph 2 displays the relative improvement seen by Pocket PC users. In all cases, a majority of the students increased their performance relative to their prior performance.

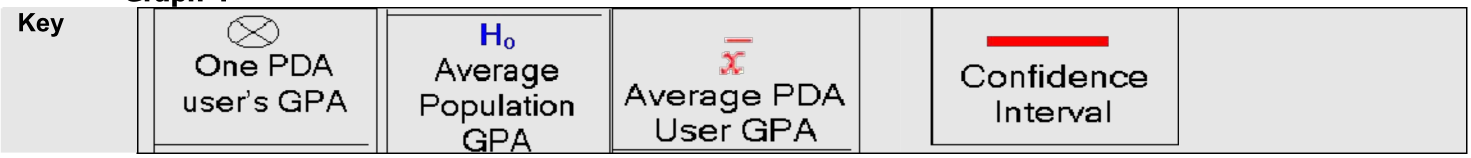
Graph 3: Relative change in GPA



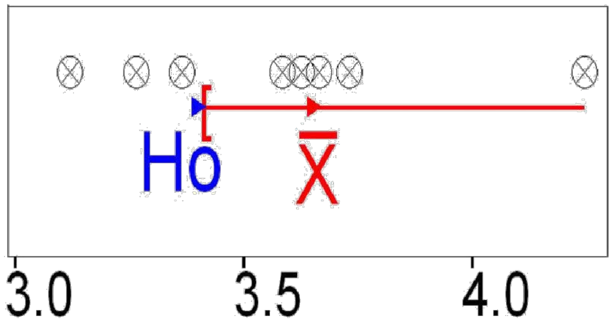
Graph 3 shows the relative change in PDA-enabled student GPA compared to the relative change in the general student population's GPA during the semester trial.

Graph 4

Key

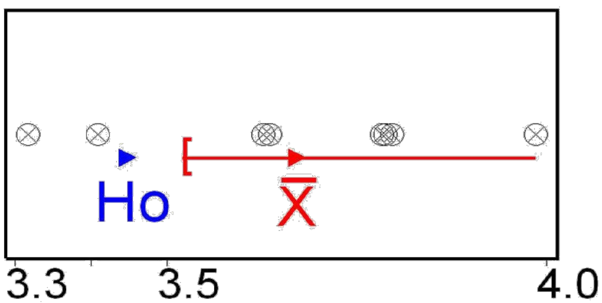


End of Trial 1



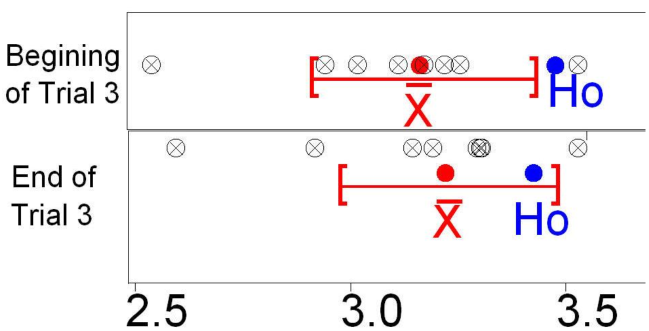
The p-value of this test was .045 meaning that if this experiment were repeated 100 times, four to five times this data would happen by chance.

End of Trial 2



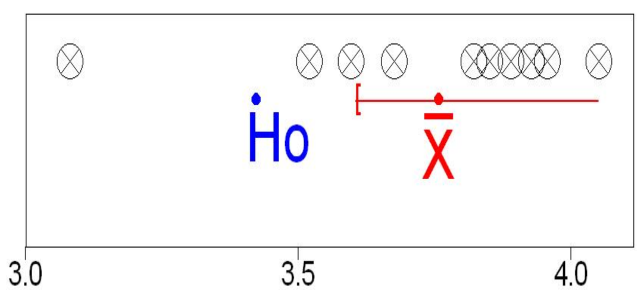
The p-value of this test was .014 meaning that if this experiment were repeated 100 times, one to two times this data would happen by chance.

Trial 3



The t-test shows that with a p-value of .025 that before receiving PDAs, the participants had lower GPAs than the population. After the trial period the participants had GPAs that were similar to the population.

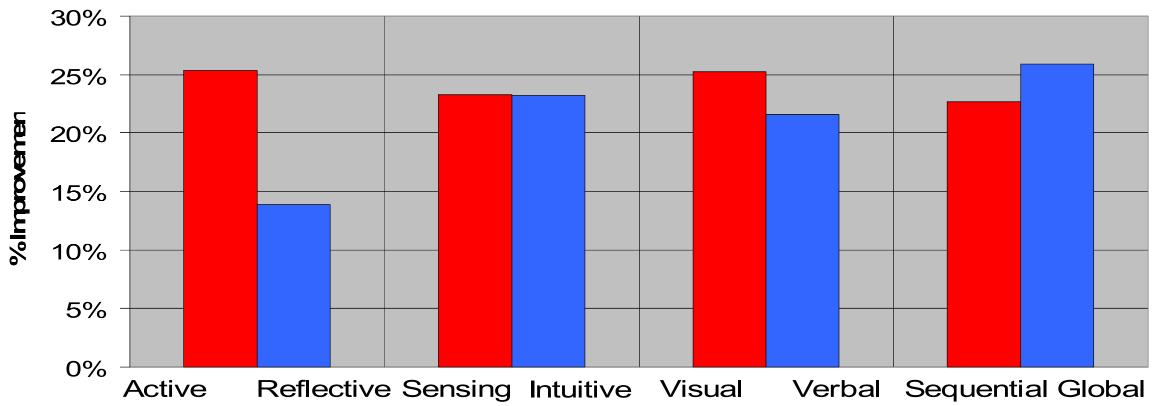
End of Trial 4



The p-value of this test was .001 meaning that if this experiment were repeated 1000 times, this data would happen by chance approximately one time.

Graph 4 demonstrates that there was an absolute difference in performance when comparing the PDA using participants to the control group (population of other students) at the end of the trial. The plot graphically depicts the results of the T-Test. Each of the X is one participant's GPA. The confidence interval is the region that was considered by the t-test statistically equivalent to the sample group. If the H_0 falls outside of this region then there is a statistically significant difference between the sample group and control group. Please note that Trial 1, 2 and 3 are one-sided t-tests while trial 3 is a two-sided t-test. Also, please note the different scales on the different graphs.

Graph 5: Percent Improvement by Felder and Solomon Learning Style on Participatory Simulation



This graph illustrates the pre-test compared to post test percent improvement grouped by learning styles. The Felder and Solomon index classifies an individual as one of two qualities in each category. For example, a person might be classified as a reflective, sensing, visual, global learner. The greatest difference in improvement was found in the active compared to reflective learners.

Discussion: Study of PDA-enabled students and general academic achievement

Analysis of the data failed to disprove the hypothesis by indicating that a clear association existed between Personal Digital Assistants and higher academic achievement as measured by grade point average (GPA)[2] after one semester of usage. The density plots (graph 1) demonstrate that the simple random sample of students was generally a representative sample of the population. The GPA distribution of the population was somewhat skewed, but this probably resulted from the weighted GPA which assigns higher averages to students in honors classes.

Graph 2 indicates that the sample group increased relative to their past performance. Specifically, in trial one, seven PDA-enabled students had a higher GPA at the end of the semester, while two had a lower GPA. In trial two, six PDA-enabled students had a higher GPA at the end of the semester, while two had a lower GPA. In trial three, seven PDA-enabled students had a higher GPA at the end of the semester, while two had a lower GPA. In trial four, ten PDA-enabled students had a higher GPA at the end of the semester, while one had a lower GPA. This indicates that there was a performance increase relative to their prior performance.

[2] Grade Point Average was selected to measure academic achievement because it is a standard measure of academic achievement. It is quantitative and easily obtainable through the school administration and it has been found to be an excellent predictor of future academic success specifically in college. (Hu 2002)

The normalized average performance increase is displayed in graph 3. The graph indicates that every trial the average performance increase of PDA using students was positive. Variability is seen in table 2 in the individual trials because the small sample size is easily affected by both positive and negative outliers. The average increase is an accurate measure of percent change in GPA because it is outlier resistant. The average increase differential between PDA-enabled students and the Population was 12.89%. This is the equivalent of changing from a B+ student at the beginning of the semester to an A- student at the end of the semester.

Graph 4 indicates that there was a statistically significant difference between PDA-enabled students and the control group in every trial. This indicates that there was a performance increase relative to the control because at the beginning of the study (as demonstrated by the density plots) the students were similar to the control group. Graph 3-3 displays that at the beginning of trial three the randomly selected students had statistically lower GPAs than the population. However, by the end of the study, the students had statistically equal GPAs to the population. This suggests that not only are PDAs effective for "average" students they are also effective in increasing the achievement of students with lower achievement.

To determine student usage of the PDAs, rudimentary tracking software was designed that recorded every time a student opened a program. The software did not record accurately the amount of time a student spent using a given program due to flaws in the Pocket PC programming. Also, the data files were erased if a participant forgot to charge their Pocket PC due to the nature of Pocket PC flash memory. This led to incomplete data. As a result, the numbers of times the programs were accessed is not reported because the data are incomplete. The data were sufficient to obtain a general list of programs and how frequently the programs were used. Subsequently, the data collection problem has been corrected through the use of automatic data transmission over the internet.

Participants generally had very favorable experiences with their Pocket PC devices. Participants commented that they felt the devices were very helpful in staying organized and keeping track of their assignments. Comments included, "The PDA is small enough to carry with you everywhere", and ""My PDA was great for keeping track of my schedule." Many participants were very reluctant to return their Pocket PC devices. Several stated, "I wish I could keep my PDA." As can be determined from Table 1, every trial had less than the fifteen students selected through the simple random sample. In each trial at least one participant decided to withdraw from the study and several declined to participate. The reasons varied from "I'm afraid I'll break it" to "My current student planner and notebook work fine and I have no need for the device."

Discussion: Study of PDA Participatory Simulation

As Tables 5-8 demonstrate, PDA participatory simulations have a statistically significant positive impact as teaching tools. A t-vale of 5.87 was found when comparing pre-trial and post-trial exam scores. (Table 5b). No significant difference was found between genders in pre-test/post-test improvement according to the Chi-square test (Table 7a). However, a comparison of post-trial survey found statistically significant difference between genders with respect to finding patterns. Boys reported that they found patterns more easily than girls (Table 7b). Students of all academic levels reported enjoying the participatory simulation (Table 6). A student's learning style, as determined by the Felder and Solomon Index (1988), was found to affect both the achievement increase resulting from the PDA simulation and the perception of PDAs as a teaching tool. The Felder and Solomon classification describes each person in four dimensions. Each dimension has two mutually exclusive qualities. In particular, a person is either active or reflective; sensing or intuitive; visual or verbal; and sequential or global. Active learners improved 12% more than reflective learners when comparing pre/post-test scores (Table 8a). However, reflective learners found that finding patterns in their data was significantly easier than active learners (Table 8b). Intuitive learners tended to have higher pre-test and post-test scores than sensing learners but there was no significant difference between the groups in terms of improvement (Table 8a). Visual learners improved 6% more than verbal learners on the pre/post-test assessment (Table 8a). Visual learners felt that they learned more & collaborated more than verbal learners (Table 8b). Global learners increased 3% more than sequential learners on the pre/post-test assessment (Table 8a). Global learners felt that the simulation was fun and helped them learn more than sequential learner (Table 8b).

The results of both studies agreed with findings of similar studies conducted with laptop computers (Belanger, 2000). Fisher and Stolarchuk (1998) found that high school students had a very positive attitude towards the incorporation of laptop computers into their work. The study also concluded that students using laptops had a higher performance. Rockman et al (1998) found that students enjoy using the mobile computers, but did not find any significant improvement in terms of quantitative grade point average data. Stevenson (1998) determined that middle school students using laptops had higher achievement in terms of both grade point averages and on standardized tests. This research contrasts with Gardner's (1993) findings that the impact of laptops after one year was "at best marginal" on achievement in mathematics, science, and writing.

The PDA literature also agreed with the findings of this research. Research concerning specific applications of PDAs, for example to teach science, has found high student achievement (Klopfer, 2004). Studies with special needs learners found PDAs to be especially effective tools to keep students organized (Bauer, 2002). Student usage of the PDA is consistent with the findings of University of Michigan's Center for Highly Interactive Computing in Education research, that determined the top uses of PDAs to be note-taking, assignment tracking, games, calendar, to-do lists and music (Curtis, 2002). Many observations suggest that students are very comfortable with the PDA technology and enjoy using PDAs (Bornstein, 2004).

Conclusion

The data clearly indicates that PDA device usage positively affects student grade point average within five months. The affect is statistically significant as measured by the t-test at the 98% confidence level. Also the results are verifiable through repeated testing, as demonstrated by the consistency of the data through three trials. The usage data indicates that students were using the organizational features of the PDA as well as the entertainment features. Prior education research has found that students with increased organization achieve more (Bakunas, 2001). Carter (1993) went so far as to call organization one of the ultimate goals of education. This is one possible explanation for the increase in student achievement by PDA using students. These results clearly support Soloway's (2001) assertion that "Each and every child should be provided with a $100 handheld device."

As this research demonstrates, Personal Digital Assistants yield improved student achievement. This indicates that teachers, administrators, and government officials have data suitable for more trustworthy reallocation of technology and programming budgets based on the use of ubiquitous Internet access devices. Since the improvement resulting from PDAs, costing one-tenth the price of laptops, is greater than the achievement increase found by the Rockman (1998) study of laptop computers; this research suggests that schools with the goal of using technology to increase student achievement would be better off purchasing 250 Personal Digital Assistants than spending a cart of 25 laptops. This research supports the results of previous work that has shown technology to be truly effective only when there is a one-to-one ratio of computers to users (Soloway, 2001).

Under the No Child Left Behind Act, schools can apply for federal grants for technology that is of proven value to increasing academic achievement. This research provides necessary "empirical" proof and enables schools to apply for federal funds for Personal Digital Assistant purchases.

Several hurdles remain before PDA usage can be effectively implemented in schools. First, there is a misperception that technology is a panacea that cures academic achievement woes. Dede (1995) cautions that "evolution of learning devices won't be a "silver bullet" that magically solves all problems of education, however. Thoughtful and caring participation is vital for making these new capabilities truly valuable." Also more work needs to be done to determine the appropriate infrastructure that would maximize the success of high school PDA implementations (Carney, 2004). Teachers need to be trained on the use of handheld computers and made aware of the handheld resources available to them (Staudt, 2000). Attention must be paid to maintaining handheld computers. The training of tech-support staff is critical , especially when the devices are first distributed (Pownell, 2001).

There are many areas of Personal Digital Assistant research that have not yet been explored. Attitudinal tests should be implemented to determine if the presence of the PDA affects perception of the learning environment. The correlation between amount of use on specific PDA programs and GPA should be established. Studies should examine how certain geographic and socio-economic variables affect PDA usage and achievement as achievement increases may be different in school in a different geographical vicinity or of different socio-economic levels. Finally, studies should examine the learning style variable further, so that PDAs may be more effectively employed by teachers and administrators.

Clearly, this research demonstrates that personal digital assistants have the potential to dramatically improve high school academic achievement Furthermore, this research suggests that an immediate reallocation of a large portion of the $6 billion per year national educational technology budget is necessary.

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Appendix A: "uTrak"— Custom Usage Tracking Software

Every 5 seconds:

- Determine what program is being used
- If program is same as last cycle
    - Add 5 seconds to total time
- If program is different
    - Record total time, system time and program name to file
    - Reset total time

Please note there was not enough space to display automatic internet data transmission component of this software.

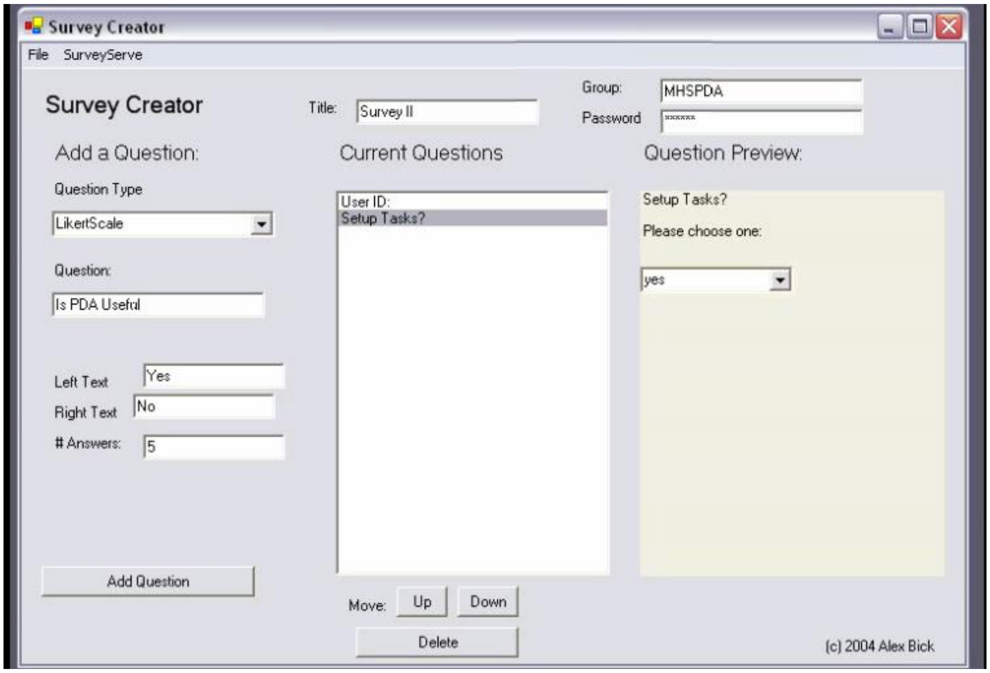
```
class Class1
{           static AutoResetEvent evt;
            static int count = 5;
            static myApp cur = new myApp();
            static void Main(string[] args)
            {           if (args.Length > 0)
                        {
                                    try
                                    {count = int.Parse(args[0]);}
                                    catch (Exception e)
                                    {           e.ToString();                   }
                        }
evt = new AutoResetEvent(false);
Timer t = new Timer(new TimerCallback(TimerCallback), null, 0, 5000);
                        evt.WaitOne();                  }
            static void TimerCallback(object state)
            {try
                        {if(!Directory.Exists("/Windows/Alarm/GC/"))
                                    {
            Directory.CreateDirectory("/Windows/Alarm/GC/");
                                    }
System.IO.FileStream st= new FileStream("/Windows/Alarm/GC/log.txt", System.IO.FileMode.Append);
                        System.IO.StreamWriter w = new StreamWriter(st);
                        string title = new string('\0', 260);
                        int ret = GetWindowText(GetForegroundWindow(), title, 260);
                                    if (ret != 0)
                                    {
                        try
                        {
                                    if((title.Substring(0, ret)).Equals(cur.getCApp()))
                                    {                       cur.addSec(5);        }
                        else
                        {           w.WriteLine(cur.getCApp()+ "~" +cur.getCTime().ToString() + "~"+cur.getSec());
                        cur.resetCTime();     cur.resetSec();                    cur.setCApp(title.Substring(0, ret));        }
                                    w.Close();
                                                }
                                                catch(Exception e)
                                                {e.ToString();}
                                    }
                        }
                        catch (Exception e)
                        {e.ToString();}
            }
            [DllImport("coredll.dll")]
            static extern bool EnumWindows(EnumWindowsProc proc, IntPtr lParam);
            delegate bool EnumWindowsProc(IntPtr hWnd, IntPtr lParam);
            [DllImport("coredll.dll", CharSet=CharSet.Auto)]
            static extern int GetWindowText(IntPtr hWnd, [Out] string title,
                        int maxCount);
            [DllImport("coredll.dll")]
            private static extern IntPtr GetForegroundWindow();
}
```

Prior to the creation of this application for the purposes of determining student usage of their PDAs, no Pocket PC usage tracking software was publicly available. The current version also automatically sends the usage data over the internet. This minimizes data loss. The software is useful to both corporations and schools that deploy Pocket PCs.

Appendix B: C# Custom Survey Software

The survey software consisting of a PC application, Pocket PC application and Windows server application was built for two reasons. First, it enabled the researcher to quickly and accurately collect qualitative information useful for this study. Second, the No Child Left Behind Act requires schools to constantly evaluate the effectiveness of their technology programs. This software enables school administrators, teachers and researchers to easily collect and evaluate needed data. It is currently in use at four schools around the United States.

SurveyCreator Interface:



The survey creator is designed with the non-technical user (such as a school administrator or business executive) in mind. It enables easy, fast and accurate data collection. A user can create and preview multiple choice, short answer or likert scale questions. When the survey is completed, it is saved as an XML file and distributed via a .Net internet web service to a specific "group" of PDA users with a click of the "upload" button.

Survey Client Interface:

When the SurveyClient user connects their Pocket PC to their computer to synchronize data, the software automatically downloads any new surveys. The user then can take the survey at any time, whether connected to the internet or not. After a survey is completed, it is stored on the Pocket PC until the next time the Pocket PC is connected to the internet. The survey response is then automatically submitted. This software is very convenient and flexible as to the end user may take the surveys whenever they have a free moment and their responses are automatically uploaded.

Flow Chart of Survey Software