Available online at www.sciencedirect.com
ScienceDirect
Computers & Education xxx (2007) xxx–xxx
COMPUTERS & EDUCATION
www.elsevier.com/locate/compedu

Educational affordances of PDAs: A study of a teacher's exploration of this technology

Daniel Churchill [a,*], Natalia Churchill [b,*]

[a] *Faculty of Education, The University of Hong Kong, Pokfulam Road, Hong Kong*
[b] *TWGHs Lee Chi Hung Memorial Primary School, Chai Wan, Hong Kong*

Received 13 October 2006; received in revised form 21 December 2006; accepted 14 January 2007

Abstract

This paper reports on a case study of a teacher from a technical education institution who explored the educational affordances of PDA technology over a period of six months. Based on this teacher's perspectives, the study was designed to inform our own understanding of educational affordances of this new and emerging technology. Understanding of educational affordances is important in the context of planning a suitable intervention to support pedagogically effective integration of PDA technology. The study explicated a set of five affordances of PDA technology: as a multimedia-access tool, connectivity tool, capture tool, representational tool and analytical tool. We call on further research to expand this set into a more comprehensive collage of educational affordances of PDA technology.

Keywords: PDA; Mobile learning; Affordances; Teacher technology use

1. PDA technology and its educational affordances

A Portable Digital Assistant, or PDA, is a hand-held device equipped with computer capabilities. Nowadays, PDAs include wireless network connectivity, mobile phones, cameras and a variety of add-on hardware extensions. This set of tools potentially creates a spectrum of educational affordances. Csete, Wong, and Vogel (2004) refer to this convergence as "the newest technological revolution", while Attewell (2005) suggests that as the number of devices globally available increases, this technology will become "digital life" for many people.

PDA technology will potentially assist individuals to learn any time, anywhere, by empowering them "to access internet resources and run experiments in the field, capture, store and manage everyday events as images and sounds, and communicate and share the material with colleagues and experts throughout the world" (Sharples, Corlett, & Westmancott, 2002, p. 222). For Luchini, Quintana, and Soloway (2004), the key benefit of PDAs is that they can be powerful personal devices that "provide access to tools and information within the

* Tel.: +852 2859 1142; fax: +852 2517 7195 (D. Churchill).
E-mail address: dchurch@hku.hk (D. Churchill).

0360-1315/$ - see front matter © 2007 Elsevier Ltd. All rights reserved.
doi:10.1016/j.compedu.2007.01.002

context of learning activities'' (p. 135). Studies reported a variety of contexts for the use of PDAs: during classes, enabling teachers and students to share files (Ray, 2002) and allowing students to ask anonymous questions, answer polls, and give teachers feedback (Ratto, Shapiro, Truong, & Griswold, 2003); for delivery of courseware and quizzes and as an intelligent tutoring system (Kazi, 2005); for dissemination of information and collection of data during field trips (So, 2004); as a tool that supports students' inquiries (Clyde, 2004; Sharples et al., 2002); in computer-supported collaborative learning (Roschelle & Pea, 2002; Zurita & Nussbaum, 2004); as personal technology for lifelong learning (Sharples, 2000); and for disadvantaged young adults to improve literacy and numeracy skills (Attewell, 2005).

How PDAs will be used in teaching and learning depends largely on teacher understanding of the educational affordances of this technology (Klopfer & Squire, 2005). Norman (1988) defines affordances as ''the perceived and actual properties of the thing, primarily those fundamental properties that determine just how the thing could possibly be used'' (p. 9). For Barnes (2000), a teacher's use of new technology in teaching and learning is carried out with a belief that this technology will afford learning in some way. Klopfer and Squire (2005) write that affordances of handheld technologies for education have rarely been explored. They describe five potential educational affordances: (a) *portability*, as handhelds can be taken to different locations; (b) *social interactivity*, as handhelds can be used to collaborate with other people; (c) *context sensitivity*, as handhelds can be used to gather real or simulated data; (d) *connectivity*, as handhelds enable connection to data collection devices, other handhelds, and to a network, and (e) *individuality*, as handhelds can provide scaffolding to the learners' approaches to investigation. Patten, Sánches, and Tangney (2006) use the term *functionality* to describe what might be understood as educational affordances of PDA technology. They present a framework that consists of the following functionalities of PDA technology: (a) *administration* (e.g., calendars, contacts and grading books); (b) *referential* (e.g., e-books and dictionaries); (c) *interactive* (e.g., drill & practice, and interactive representations); (d) *microworld* (e.g.,: tools that allow students to build models); (e) *data collection* (e.g., note taking and data logging); (f) *location awareness* (e.g., augmented reality and museum guides) and (g) *collaboration* (e.g., communication and collaborative games).

Even though these studies provide useful overviews of different applications of PDA technology in education, there is an emerging need for a more applicable framework to provide teachers, educational policy-makers and researchers with a better representation of educational affordances of this technology. The studies must attempt to explore affordances as they emerge from classroom practitioners' efforts to understand and use this technology.

2. The study

In this single case study, we investigated educational affordances of PDA, based upon a technical education teacher's explorative use of this technology. An exemplary teacher (with a good record of technology use and classroom teaching) was selected, based on the assumption that such a teacher would generate and provide more ideas about PDA technology than the average teacher.

Critics might question value of a single case study such as the one we report in this paper. However, common criticisms of a single case study are addressed by Flyvbjerg (2006) who wrote that there are many misconceptions about this type of research. Key to successful single case study for Flyvbjerg is the strategic choice of the case. The participant in our study was selected based on Flyvbjerg's ''Critical Case'' criteria whose purpose is to achieve information that permits logical deduction of the type ''if this is (not) valid for this case, then it applies to all (no) cases'' (p. 230). For example, if an affordance has been explicated in this study, then this affordance is one possible affordances of PDA technology whether other cases hold it or not. The case in our study is used as an instrument to explicate affordances of PDA technology. Involving more cases would result in more affordances rather than rejection of the affordances explicated in our single case study (even though other cases might understand these affordances differently or completely disregard them). We acknowledge that a single case study, such as that reported in this paper, is not able to generate a complete collection of educational affordances of PDA technology, but this was not our intention. We intended to explicate an initial set of educational affordances of PDA technology (based on our involvement with an exemplary teacher) and to call on further research to expand this set into a more comprehensive collection.

Please cite this article in press as: Churchill, D., & Churchill, N, Educational affordances of PDAs: A study of a ..., *Computers & Education* (2007), doi:10.1016/j.compedu.2007.01.002

2.1. The participant

In this paper, we use the name "Jack" for this participant to protect his identity. Jack is a 50-year-old technical education teacher with 25 years of teaching experience in the precision engineering field. Most of Jack's full-time students were 16–19 years old. Some of his students were adults seeking to upgrade their qualifications by studying part-time. His institute includes ten geographically dispersed campuses, with about 1500 teaching staff (the institute calls them lecturers), over 50 programs in the areas of applied health and sciences, engineering, business and services, and info-communications technology, and over 16,000 full-time and 40,000 part-time students. The institute was established as a post-secondary institution under the charge of the Ministry of Education and its key role was to provide pre-employment technical education and training to post-secondary students. Students graduate with NTC (National Trade Certification) or ITC (Industrial Trade Certification) certificates that qualified them to enter employment or to continue their education at one of the local polytechnics. The majority of the teachers at the institute held trade certificates and polytechnic diplomas, and were frequently recruited from the industry. Only about 20% of the teachers were university graduates. Upon employment, all new teachers were required to complete the "Certificate in Teaching" program conducted by the institute.

Jack's institute is the key technical training institution in his country's knowledge-based economy. Traditionally a powerful manufacturing sector in the country, or what Jack calls "the backbone of the economy", in recent times it has been challenged by the emergence of more economical labor forces and cheaper technologies from countries such as China and Indonesia. The Government recognizes these challenges and provides significant attention to the uplift of technical education in order to maintain its competitive advantage. Over the last several years, the institute has received significant external funding to modernize educational processes, and in particular, to integrate technology into teaching and learning to support more student-centred pedagogical practices. This is very evident across the institution, where new computer classrooms have emerged over the last few years, the majority of teachers have been provided with notebook computers, new networked infrastructure has been put in place, and new training and professional development initiatives undertaken. According to Jack, however, effective integration of technology has been slowed down by unfavorable thinking on the part of teachers and a lack of readiness by management to support reforms initiated by external demands.

One course taught by Jack is Precision Engineering (Machining). The overall objective of his course is to equip students with the knowledge and skills to effectively configure and operate certain machines in the production of precision engineering parts. His curriculum is divided into theoretical (classroom-based) and workshop-based parts. The theory addresses key concepts (e.g., machine cutting speed) and procedures (e.g., tool selection) required for configuration of specific machining processes (e.g., turning, milling or grinding). Students learn theory that they are required to apply in subsequent workshop-based classes. The wide practice across the institute is that theory is taught and examined independently from the workshop-based parts of courses. Contrary to these practices, Jack believes that theory and practice should be better connected. He expressed concerns that his students have difficulties applying theory in workshops or developing knowledge of theoretical concepts from the practical workshop. He saw PDA technology as one effective tool that might support this integration because of the portability that allows students to take information between the two contexts.

Jack is known in his institution as an "education technology champion". Education technology champions comprise only a small minority of teachers (about two or three per campus for each of the ten campuses). These teachers are carefully selected by their management as being willing to use technology and advance pedagogy, and attend an extensive, full-time, six-month professional development program organized by the Education Technology Division of the institution. Upon return from this program, these teachers are expected to demonstrate good practice in the use of technology in teaching and learning, mentor and advise their colleagues, and support various initiatives from the Education Technology Division. In addition to being an education technology champion, Jack was also recognized by the institution for his effective classroom teaching when he received a "Best Teacher Award." Our engagement with an exemplary teacher such as Jack was intended to maximize the flow of useful information regarding educational affordances of PDA technology.

Please cite this article in press as: Churchill, D., & Churchill, N, Educational affordances of PDAs: A study of a ..., *Computers & Education* (2007), doi:10.1016/j.compedu.2007.01.002

Prior to this study, Jack lobbied unsuccessfully to acquire financial assistance to obtain a few PDA devices for his class in order to explore the educational uses of this technology. However, he was not discouraged. In one conversation before the study, he informed one of the researchers that he would be happy to have a PDA device and explore its uses. This was understood as an excellent opportunity to gain insight into the educational affordances of PDAs through this teacher's explorative uses of this technology.

2.2. Procedure

In order to obtain informed consent from Jack, one of the researchers briefed him during their initial meeting. The researcher provided Jack with a plain language statement containing information about the study, his right to withdraw, and an assurance that a pseudonym for his name and an acronym for the name of the institution would be used in any reports. He was told that he would be provided with a PDA device of his choice (to be returned at the end of the study). A few days later, Jack decided to take part in the study and signed the consent form. After this, data collection and analysis occurred over six months, as follows:

1. Interview to explore the participant's initial ideas about educational affordances of PDA technology
   Through this interview our primary aim was to gain insight into Jack's initial understanding of the educational affordances of PDA technology. The following two key questions guided this semi-structured interview: "What are effective learning activities in your classes and how might PDA technology help there?"; "Describe your students and how they might use PDA technology?" We also brought one PDA device to the interview and gave it to Jack while he considered our questions. This was an attempt to prompt Jack to think aloud about this technology while accessing the device at hand. The interview was transcribed and the transcript checked by the participant.
2. The participant's prolonged exploration of educational affordances of PDA
   We obtained one O2 model XDAIIs PDA device based on a recommendation by the participant. This device was equipped with a mobile phone, Bluetooth and wireless network connectivity, and a digital camera. The device also integrated a small keyboard which was favored by the participant but latter was disregarded. The device was preinstalled with the Windows based Pocket PC system and software such as calendar, contacts management, world processor, spreadsheet, Internet Explorer, PowerPoint viewer, Adobe Acrobat viewer, camera-related tools, and some games. The device was connectable to a computer via USB port so that files between the two could be transferred. Once Jack was provided with the device and began to explore its uses, he wrote regular reflective journal entries to document his observations, any new discoveries and any changes in his thinking. The reflective journal was recorded using the on-line 'blog' technology. The researchers set up the blog and briefed Jack on its use. Blogging was selected on the assumption that it would enable the researchers to have access to Jack's most recent reflections, while at the same time acting as an intervention tool encouraging him to reflect in a technology-mediated environment. Almost four months were allotted to this phase of the study to allow substantial time for Jack to explore the device, search for useful resources, examine software, design some files for testing, take the device to the class and otherwise explore affordances. The reflections were monitored on a regular basis in search of emerging affordances; any such observations by Jack that we considered significant we subsequently discussed with him in casual conversation. On a number of occasions, we met with Jack to collect artifacts of his engagement with the PDA technology (e.g., resources that he designed, or software that he found useful). These artifacts were used to further validate affordances noted from the interview and reflections.
3. Final interview with Jack to discuss the educational affordances that emerged through the study
   The final interview with the participant focused on the affordances that emerged through the study. The participant was asked to (a) comment on these emerging affordances, and (b) describe any further changes in his thinking about the uses of PDA technology. The interview was transcribed, the transcript checked by the participant.

Interviews and reflection records were subjected to content analysis in search of heterogeneous categories representing affordances of PDA technology. Statements made by the participant representing units of data

Please cite this article in press as: Churchill, D., & Churchill, N, Educational affordances of PDAs: A study of a ..., *Computers & Education* (2007), doi:10.1016/j.compedu.2007.01.002

(for example "I can download a PowerPoint presentation to a PDA") were highlighted in the texts of interviews and reflection records. These statements were then sorted into categories representing affordances. Emerging affordances were then validated by matching them with the artifacts collected through the study and by discussing them with the participant. As an addition to the main focus of the study, the data was then analyzed to explore changes in the participant's thinking about PDA technology use.

The study ensured validity through triangulation (Merriam, 1988) including: (a) member checking – the researchers allowed Jack to scan interview transcripts, and the preliminary analysis and report; (b) use of multiple sources of data–interviews, reflection records and artifacts, and (c) study of literature for theoretical validation purposes.

3. Results – a set of five educational affordances of PDAs from the participant's perspective

Two educational affordances of PDA technology emerged from the interview at the beginning of the study: *multimedia-access tools* and *connectivity tool*. An additional three educational affordances emerged as Jack explored the PDA device, reflected in his blog and provided various artifacts: namely, the PDA as a *capture tool*, *representational tool* and *analytical tool*.

3.1. Multimedia-access tool

Early in the study during the initial interview, Jack indicated that he perceived PDAs as a potentially useful tool for delivery of multimedia resources, courseware and other kinds of subject matter materials. As he begun exploring the PDA device, Jack learnt that, for him, the multimedia presentation capabilities of this technology are almost equivalent to that of a computer. He realized that the same kind of files – e.g., Adobe PDF, Microsoft PowerPoint, Macromedia Flash – can be presented on both a computer and PDA. He also understood that the kind of material accessible via PDAs could be available through the Internet. However, he also realized that the design of the material presented must be modified due to the screen size constraint. He became concerned with the size of the display area and the potential limitation of this constraint and began to explore ways of working around this limitation. One strategy for him was to switch the display area to landscape mode. He wrote in his reflections:

> I was looking at a kind of content that can be accessed with the device. I realized that I can have the following kinds of resources: video, audio, Adobe Acrobat PDF, Microsoft Word, Microsoft Excel, PowerPoint and Macromedia Flash... I connected the PDA to my notebook computer and sent some PowerPoint files to test how they might appear on the PDA. I also realized that I can change the screen on the PDA into a landscape kind, or whatever it is called. This allows a relatively nice preview of PowerPoint files. However, the presentation must be designed in a way that it is suitable for this kind of screen... I was excited to see that Flash content also can work well on the PDA. Getting it to run gave me a bit of trouble. I had to do some investigation on the Internet and then I found that I needed to download a special plug-in from Macromedia and install it to my PDA from my notebook. Somehow I worked it out and now I can see Flash files!

In further reflections at a later stage of the study, Jack arrived at the understanding that effective material for PDA technology should be something interactive and visual illustrating important concepts from his field, rather than documents that require lengthy reading time on a small screen. Such effective material could be the kind of learning objects that he had previously developed for computer-based delivery and had utilized in his teaching. He saw that PDA technology offers an important advantage here, as it enables students to move away from a theoretical class location to a practical workshop. Jack wrote:

> [Previously] I used one learning object on several occasions with my students. I set a real-life task for them where a virtual client is inviting them to propose suitable parameters and the cost of producing certain metal components. Then the students used the learning object to explore parameters and discover relationships which guided their final decisions on providing the client with a proposal. Then they had to have a discussion about their approaches towards optimization of the cost... I think that

Please cite this article in press as: Churchill, D., & Churchill, N, Educational affordances of PDAs: A study of a ..., *Computers & Education* (2007), doi:10.1016/j.compedu.2007.01.002

> a PDA might take this kind of activity to an altogether different level. Students, rather than being isolated from machines and workshops and conducting this kind of activity in a classroom environment can actually be in the workshop or even at a client's location and exploring the learning object on a PDA. They might try optimizing some parameters on a PDA-based learning object and then immediately examine a machine in front of them.

The interface of this learning object mentioned by Jack is shown below in Fig. 1.

This learning object presents a variety of milling machining parameters and their relationships, which are of key importance in Jack's curriculum. Previously, these parameters were taught and explored one-by-one during the theoretical classes; it was only during workshop sessions that the students were able to actually examine how these parameters interact together and influence overall performance of the machine. With the learning object, students are enabled to interact with virtual parameters and explore relationships before actually moving to the workshop. PDA technology would facilitate better integration of theory and practice in Jack's teaching by enabling his students to take this learning object between the theoretical and workshop sessions.

3.2. Connectivity tool

In the initial interview, Jack informed us that he understood PDA technology as an effective tool through which students could connect and exchange ideas, ask questions, get in touch with potential clients, engage in discussions, etc. For example, he reflected:

> Students, rather than being isolated from machines and workshops and conducting this kind of activity in a classroom environment, can actually be in the workshop or even at a client's location and exploring the learning object on a PDA. They might try optimizing some parameters on a PDA-based learning object and then immediately examine a machine in front of them. Then they can SMS their quotations to a client, or even MMS photos from a workshop with the quote.

In the initial stages of his exploration he become attracted to the capabilities of PDA technology emanating from its integration with mobile phones. These included mobile telephony, SMS messaging (Short Message Service) and MMS messaging (Multimedia Message Service). Jack observed that these capabilities allowed

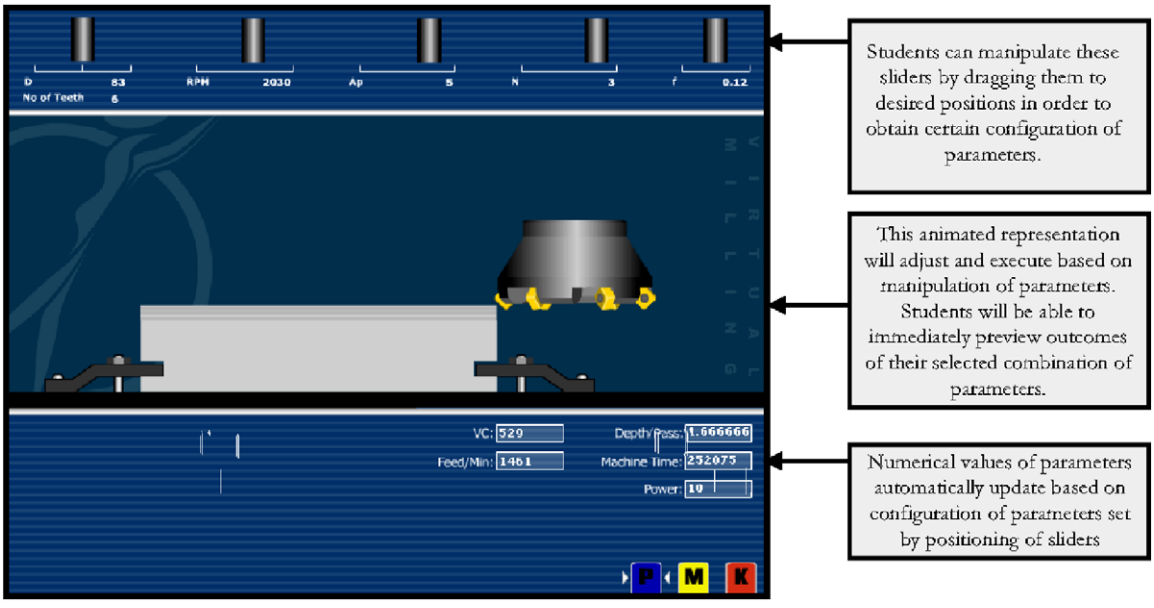

Fig. 1. "Milling" learning object developed by Jack in collaboration with his colleague.

Please cite this article in press as: Churchill, D., & Churchill, N, Educational affordances of PDAs: A study of a ..., *Computers & Education* (2007), doi:10.1016/j.compedu.2007.01.002

students to exchange information in multimodal formats. However, he appeared concerned to some extent about the cost of using a mobile service and began to explore an alternative: wireless network. He soon discovered an interesting collaboration technology for PDAs–Skype–that allows individuals to converse globally using a wireless network at no cost:

> I found an excellent free communication tool called Skype. It allows people to connect over the Internet from anywhere as long as they are connected to the network. This service is for free and potentially students might connect globally to exchange ideas and maybe get and provide advice when attending to learning tasks. Communication and connectivity are very important today and I must ensure that my students are able to do this. PDAs appear great for this; in particular, I can send and receive MMS, SMS, talk over the mobile network and now connect all over the Internet for free!

From Jack's reflections, it appears that he saw this affordance of technology in two contexts: (a) as an important enabler of learning activity by allowing students to connect and exchange ideas, and (b) as a tool that leads to the development of contemporary relevant skills for his students: that is, communication skills.

3.3. Capture tool

Jack considered the capture capabilities of PDA technology important for learning. He pondered these capabilities very early in the study during the process of deciding on an appropriate PDA device to acquire:

> Is the camera needed? What can my students do with it? PDA also has a camera, but is this camera sufficient? Well, I believe that camera is needed but its quality is not so critical. It would be great for my students to capture examples of their work from a workshop or to capture some scenes from their industry visits. They can send these pictures over the Internet or as multimedia messages and share them with me and the rest of their class. Is this possible? I think, theoretically speaking, it is; however, I will have to explore. Students might also be able to capture small video clips and present them to the rest of the class. I have to think a bit more about what kinds of tasks I can set for my students to get them to use effectively this image-capture technology. Maybe I can set a task for them to explore some manufacturing situation, workplace safety issues or a faulty machine, capture evidence and present it to a class.

Jack noted that capture enables students to take photos of places, mechanical equipment and parts, and pictures of interesting documents. It also allows students to capture videos of some processes or interesting learning moments, such as partners' presentations in class. In addition, Jack observed that capture allows students to record audio clips. These might be recordings of their own voice reminders or sounds in a workshop. Notes can also be attached to all of these captured materials. A PDA might also be used to capture various data and media for later download to a computer: e.g., students might capture some observations while in a workshop, download this data to their computers and use it when creating a presentation.

3.4. Representational tool

Another important affordance perceived by Jack was that PDAs allow students to create representations of their knowledge and ideas: One way of achieving this is through the use of mind-mapping tools such as Inspiration or MindManager. Jack wrote in his reflections:

> An interesting tool I found is the mind-mapping tool. It can possibly become a very valuable tool for students: they might collect information and ideas and represent them in mind maps on a PDA. They can send these maps to each other or to me so that I can see how their thinking emerges in some contexts such as when performing some job in a workshop. There are tools for students to make maps on desktop computers, but a PDA really allows students to go somewhere else beyond the wall of the classroom and explore the world as it is out there. For me this is important, in particular because traditionally we

Please cite this article in press as: Churchill, D., & Churchill, N, Educational affordances of PDAs: A study of a ..., *Computers & Education* (2007), doi:10.1016/j.compedu.2007.01.002

> divided our courses into classroom-based (theory) and workshop-based (practice) and in my opinion this is not effective and technology allows us to bring these two together as they are in real-life.

Fig. 2 shows a "Tool selection" mind map created by Jack to illustrate the usefulness of Inspiration for creating representations. For example, students might be tasked to collect information about tools available in the workshop, examine catalogues and web sites of manufacturers who produce actual tools, and create such mind maps to illustrate the process of selecting appropriate tools within given machining parameters.

These representational affordances are further enhanced when combined with capture affordance, for as Jack noted, this allows students to capture image, for example, then to sketch on it or add some text.

3.5. Analytical tool

The final educational affordance of PDA technology noted by Jack in the study was the ability of this technology to provide a variety of analytical tools such as standard and more advanced graphic calculators, or special-purpose analytical tools that he could develop (e.g., using a Microsoft Excel). Fig. 3 shows an analytical tool created by Jack: "Speed of grinding wheel". This tool allows students to input values of the diameter of a grinding wheel (D) and number of rotations of a wheel (N), which they obtain from actual machine in the workshop; the tool will calculate and return value of the speed of a grinding wheel (GW).

4. Changes in Jack's thinking about PDA

Through the study, Jack demonstrated increased enthusiasm and commitment to explore educational uses of PDA technology in his teaching. He observed that students appear very keen to make use of PDAs and this was special motive for him to keep exploring this technology:

> I took the device home last night and my children were "fighting" for a chance to hold it longer. My youngest daughter figured out how to take photos in some frames provided by internal application. She also worked out how to write in Pocket Word, draw some things, etc. She was very excited and when I invited her to go with me to the swimming pool (her favorite activity) she rejected the idea and kept "playing" with the PDA... I also took the device into my classroom several times and students were excited and they all wanted to try out and look into it. They were asking me a lot questions like: Sir, can it play MP3s? Can we see videos? Are there any games on it? Can I hold it? Their voices are still echoing in my ear. Wait until they see what I plan for them later on!

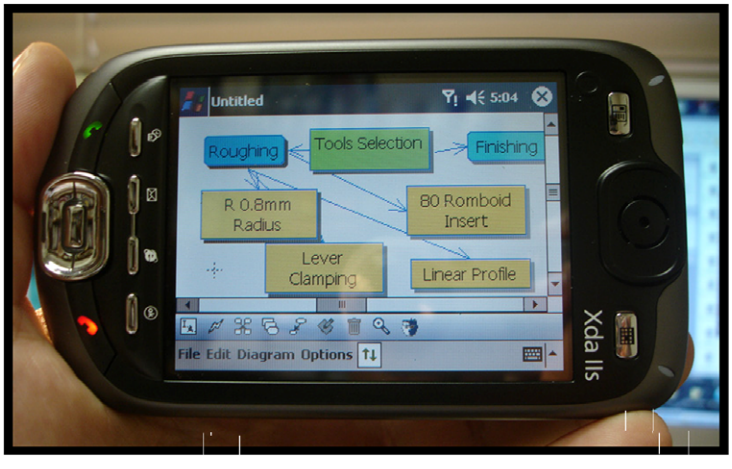

Fig. 2. "Tool selection" mind map created by Jack to illustrate usefulness of inspiration.

Please cite this article in press as: Churchill, D., & Churchill, N, Educational affordances of PDAs: A study of a ..., *Computers & Education* (2007), doi:10.1016/j.compedu.2007.01.002

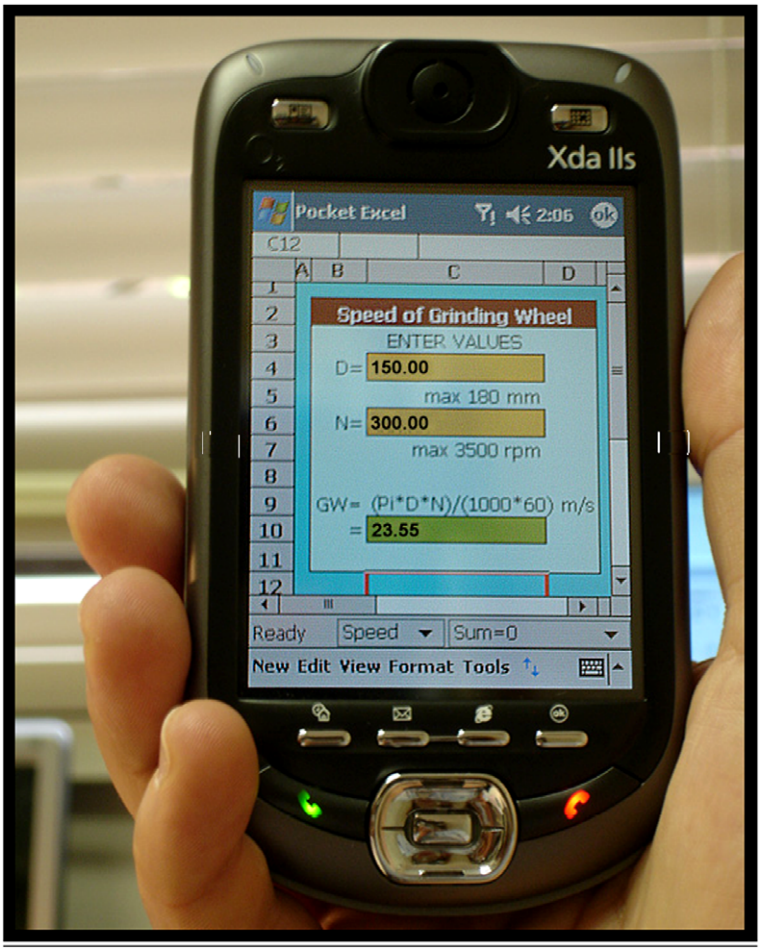

Fig. 3. "Speed of grinding wheel" analytical tool created by Jack with MS Excel.

Three areas of change in Jack's thinking about the educational affordances of PDA technology were observed through the study: (a) a shift in perception of the PDA as a tool for assisting a group of students to a tool for the individual; (b) a shift from traditional resources supporting more direct instruction approaches towards types of learning objects that support more student-centered pedagogy, and (c) a shift from subject matter resources to consideration of software tools that, for example, allow students to create representations, capture data and connect.

Initially, Jack appeared influenced by the idea that learning is collaborative, and in this context there is no clear need to have one computer per student. One computer is usually useful for supporting collaboration between members of a group of students. For Jack, a group of students presented with a learning task might utilize one PDA device, gathering around it and passing it to each other during a learning process. As he continued to use the PDA and reflect upon the affordances of this technology, he began to realize that the device is, rather, a personal tool and that he would like to see one provided for each of his students. He wrote:

> Somehow I am beginning to realize how powerful is the fact that my PDA can be taken anywhere you want. I start feeling some attachment to this thing. The first thing in the morning when I get up, I look for it and check if it has enough battery to let me work with it throughout the day. I feel that it has become a very personal tool for me. But, what about my students? Before, I thought that a PDA device might be used with a small group of students when working together on some learning tasks. Now I

Please cite this article in press as: Churchill, D., & Churchill, N, Educational affordances of PDAs: A study of a ..., *Computers & Education* (2007), doi:10.1016/j.compedu.2007.01.002

> think that this technology is rather personal, and that it would be much more effective if a student had their own PDA. A student could use it to organize activities, timetables and even plan learning tasks. At the same time, the student could document reflections, keep notes as a text file or as audio notes, capture interesting learning moments and photograph images from books, take short videos and so on.

Initially, it appeared that Jack was paying attention to the delivery of resources and use of a PDA in a manner that resembled the use of computers. He was moving various kinds of resources over to the PDA, such as PDF documents, web sites, PowerPoint presentations, MS Word documents, e-books, video files and some interactive tutorial files created with Flash. However, during the study, he began to question the usefulness of these resources given the size of the presentation area and other factors, such as students' ability to focus on the small screen for extended periods. He began to think that perhaps PDA technology is more promising for learning when it offers students some tools to capture, save and process data and create representations. His focus appeared to be shifting away from resources and towards tools that could be used by students to demonstrate their engagements in a learning activity, and their thinking and knowledge.

Influenced by his previous experience in developing useful educational material, Jack began once again to examine the kinds of material that could be effectively deployed over PDA devices. He wrote:

> Certainly, having a variety of useful learning objects would be very effective for learning. I searched the Internet for useful learning objects and found a lot of stuff out there, but they are not really what I mean by learning objects. A lot of stuff out there is just like web pages and those things that I call teaching machines. What I want is some powerful illustrations concepts from my teaching subjects, so that I can provide them to my students when setting learning tasks for them. In this way, students could attend to a variety of learning situations in the classroom, workshop and elsewhere, and pull out these learning objects when needed to help them to complete tasks. More stuff like my machining parameters would be excellent.

For Jack, these kinds of educational materials should not require students to spend a long time reading; such material should be effectively designed for a small screen, should be visual in order to reduce the words needed to deliver ideas, and should be interactive to allow students to develop their own conceptual knowledge.

5. Discussion of results

5.1. Areas of perceived affordances

The following five perceived affordances of PDA technology were explicated in this study:

1. *Multimedia-access tool* – a variety of multimedia resources can be delivered using this technology, such as e-books, web pages, presentations, interactive resources, audio files and video segments. These resources can be accessed any time, anywhere, by connecting to the Internet using GPRS or wireless network connections, from the memory of the device or storage card if the resources were previously downloaded, or through synchronization of the device with a computer. However, the participant noted that merely moving resources from a computer to a PDA might not lead to effective learning. Resources for PDA use must be designed with certain principles in mind. A learning object consisting of a single interface, containing multimodal information that focuses on an important concept from a discipline, and which does not require long usage time, might be an effective resource for PDA technology. Such learning objects are best described as *conceptual models* (Churchill, 2006). Conceptual models are designed to represent one or more related concepts in primarily interactive and visual ways.
2. *Connectivity tool* – PDA technology empowers students to connect to each other, facilitators and experts in the field, exchange ideas and files, collaboratively build understanding, manage activities and negotiate roles in their projects, etc. Connection might be established synchronously and asynchronously over mobile telephony and wireless networks that support voice and multimedia data transmission.

Please cite this article in press as: Churchill, D., & Churchill, N, Educational affordances of PDAs: A study of a ..., *Computers & Education* (2007), doi:10.1016/j.compedu.2007.01.002

3. *Capture tool* – PDA technology is equipped with capture capabilities that include capture of video and still photographs. Students might, for example, photograph and videotape machines and people during their industry visits, or photograph diagrams from a book or catalogue. The capture affordance also includes audio capture. For example, students might interview experts and capture their own audio notes, or capture characteristic sounds of a faulty engine. There is a possibility for specially designed extensions and consoles to be attached to a PDA and used to capture, store and process other kinds of data such as, for example, recording global positioning of certain air pollution sources.
4. *Representational tool* – PDA technology might be used by students to create representations which demonstrate their thinking and knowledge. These might be, for example, mind maps or captured and edited images.
5. *Analytical tool* – a mobile-enabled PDA might be used as an analytical tool to aid students' tasks. For example, these might include standard, scientific and graphic calculators or specially designed analytical tools created by teachers to allow students to process certain data.

Three of the affordances explicated in the study were previously discussed in the literature: multimedia-access tools (e.g., Kazi, 2005; Luchini et al., 2004; Patten et al., 2006; Sharples et al., 2002; So, 2004), connectivity tools (e.g., Barnes, 2000; Klopfer & Squire, 2005; Patten et al., 2006; Ratto et al., 2003; Ray, 2002; Roschelle & Pea, 2002; Sharples et al., 2002; Zurita & Nussbaum, 2004), and capture tools (e.g., Klopfer & Squire, 2005; Patten et al., 2006; Sharples et al., 2002; So, 2004). Use of technology as a tool that enables students to create representations of their thinking and knowledge is well documented in the literature dealing with learning with computers. The literature often refers to these representation tools as "mind tools" or "cognitive tools" (Jonassen & Reeves, 1996; Jonassen & Carr, 2000). Patten et al. (2006) noted that such tools exist for PDA applications when they discussed microworld functionality that allows students to build models. Lately, there has been an emergence of a number of representational tools for PDA delivery (e.g., Mind Manager, Inspiration); these tools should be given due attention, as potentially they may be very useful for student-centered learning in and out of a classroom. Analytical tool affordance was not found in the reviewed literature, possibly because authors and researchers appear to consider analytical tools as just another kind of resource or learning object, or as the sub-functionality of a capture tool.

Some affordances previously addressed in the literature have not been reiterated by our study. Literature suggests that another area of affordances of PDA technology is portability and individual assistance (see Clyde, 2004; Kazi, 2005; Klopfer & Squire, 2005; Sharples et al., 2002). All the affordances explicated in our study involve portability and enable individual activity; hence, it is difficult to justify singling out these as perceived affordances. The very label of this kind of technology–PDA–incorporates the idea of portability and assistance. One more affordance of PDA technology in literature is its use by teachers as an administrative tool (Ray, 2002). Equally, students might also find PDAs to be effective administration tools to help them manage their day-to-day activities (e.g., incorporating calendars, task managers, or contacts). This administration tool idea briefly surfaced in our study and was later also noted in reviewing the literature (see Patten et al., 2006).

Three areas of changes in the participating teacher's perception of PDA technology were observed in the study: (a) a shift in perception of the PDA as a tool for assisting a group of students to a tool for the individual; (b) a shift from traditional resources supporting more direct instruction approaches towards types of learning objects that support more student-centered pedagogy, and (c) a shift from subject matter resources to consideration of tools that, for example, allow students to create representations, capture data and connect. This is an indicator that for the particular case in our study, experience of exploring educational affordances of PDA promoted shifts in practice to more student-centered pedagogy. Further studies should attempt to explore this phenomenon using a large group of teachers and to establish whether the possibility exists for this kind of technology to be used as an intervention strategy supporting transformation of teachers' pedagogical practices.

6. Summary

This study explicated five educational affordances of PDAs based on the participating teacher's explorative uses of this technology, described as follows: multimedia-access tool, connectivity tool, capture tool,

Please cite this article in press as: Churchill, D., & Churchill, N, Educational affordances of PDAs: A study of a ..., *Computers & Education* (2007), doi:10.1016/j.compedu.2007.01.002

representational tool and analytical tool. The study also shows that there were certain developments in the participant's thinking as he explored educational affordances. These developments suggest a possible shift in the participating teacher's thinking towards more student-centered pedagogical applications of PDAs. The set of educational affordances explicated in this study should be useful to other teachers, as these provide potentially useful strategies for applications of PDA technology in their pedagogical practice. Further, for educational administrators, the understanding of the affordances detailed herein may help in more successful implementation of PDA technologies, as these affordances can be planned for as part of an implementation and intervention strategy.

This study is a relatively small inquiry, focusing on a single participant in a particular context and a single content area. Further studies should attempt to engage more teachers in similar inquiries to expand this initial set into a more comprehensive collage of educational affordances of PDA technology. Further studies should explore contexts other than a technical education institution and should also provide more detailed accounts of teachers' actual applications of PDA technology with students over an extended period of time. The PDA, especially combined with a mobile phone, is a new technology that is yet to make its way into teaching and learning. This technology potentially opens a spectrum of opportunities for interesting educational research in relation to teachers and students.

References

Attewell, J. (2005). *Mobile technologies for learning*. London, UK: Learning and Skills Development Agency.

Barnes, S. (2000). What does electronic conferencing afford distance education? *Distance Education, 21*(2), 236–247.

Churchill, D. (2006). *Towards a useful classification of learning objects*. ETR&D.

Clyde, L. A. (2004). M-learning. *Teacher Librarian, 32*(1), 45–46.

Csete, J., Wong, Y., & Vogel, D. 2004. Mobile devices in and out of the classroom. In *World conference on educational multimedia, hypermedia and telecommunications 2004*, *Vol. 1* (pp. 4729–4736). Retrieved March 15, 2005 from <http://dl.aace.org/16147>.

Flyvbjerg, B. (2006). Five Misunderstandings about case-study research. *Qualitative Inquiry, 12*(2), 219–245.

Jonassen, D. A., & Reeves, T. C. (1996). Learning with technology: using computers as cognitive tools. In D. H. Jonassen (Ed.), *Handbook of research for educational communication and technology* (pp. 693–719). New York, NY: Simon & Schuster Macmillan.

Jonassen, D. H., & Carr, C. (2000). Mindtools: affording multiple knowledge representations in learning. In S. P. Lajoie (Ed.), *Computers as cognitive tools* (pp. 165–196). Mahwah, NJ: Lawrence Erlbaum Associates.

Kazi, S. A. (2005). Vocatest: an intelligent tutoring systems for vocabulary using mlearning approach. Paper to be presented at the redesigning pedagogy: research, policy, practice conference, 30 May–1 June 2005, Singapore.

Klopfer, E., & Squire, K. (2005). *Environmental detectives: the development of an augmented reality platform for environmental simulations*. Retrieved March 15, 2005 from <http://website.education.wisc.edu/kdsquire/manuscripts/ETRD-handheld-Draft.doc>.

Luchini, K., Quintana, C., & Soloway, E. (2004). Design guidelines for learner-centered handheld tools. *CHI, 6*(1), 135–141.

Merriam, B. S. (1988). *Case study research in education*. San Francisco: Jossey-Bass.

Norman, D. A. (1988). *The psychology of everyday things*. New York: Basic Books.

Patten, B., Sánches, I. A., & Tangney, B. (2006). Designing collaborative, constructivist and contextual applications for handheld devices. *Computers and Education, 46*, 294–308.

Ratto, M., Shapiro, R. B., Truong, T. M., & Griswold, W. G. (2003). *The active class project: experiments in encouraging classroom participation*. Retrieved February 22, 2005 from <http://www-cse.ucsd.edu/~wgg/Abstracts/activeclass-cscl03.pdf>.

Ray, B. (2002). PDAs in the classroom: integration strategies fro K-12 educators. *International Journal of Educational Technology, 3*(1), Retrieved November 3, 2004 from<http://www.ao.uiuc.edu/ijet/v3n1/ray/index.html>.

Roschelle, J., & Pea, R. (2002). A walk on the WILD side: how wireless handhelds may change CSCL. *International Journal of Cognition and Technology, 1*(1), 145–168.

Sharples, M. (2000). The design of personal mobile technologies for lifelong learning. *Computers and Education, 34*, 177–193.

Sharples, M., Corlett, D., & Westmancott, O. (2002). The design and implementation of a mobile learning resource. *Personal and Ubiquitous Computing, 6*, 220–234.

So, K. K. T. (2004). Applying wireless technology in field trips: a Hong Kong experience. *Australian Educational Computing, 19*(2), Retrieved January 20, 2005 from<http://www.cite.hku.hk/people/tkkso/Publications/2004/Applying%20Wireless%>.

Zurita, G., & Nussbaum, M. (2004). Computer supported collaborative learning using wirelessly interconnected handheld computers. *Computers and Education, 42*, 289–314.

Please cite this article in press as: Churchill, D., & Churchill, N, Educational affordances of PDAs: A study of a ..., *Computers & Education* (2007), doi:10.1016/j.compedu.2007.01.002