THE AFFORDANCES OF MOBILE COMPUTING DEVICES IN COLLABORATIVE LEARNING.
THE EFFICIENCY OF THESE UBIQUITOUS DEVICES IN EDUCATION.
A LITERATURE REVIEW

ILIAS HOTZOGLOU

DEREE / The American College of Greece, Athens

ihotzoglou@acg.edu

Tablet PCs, tablets, and PDAs are currently used in traditional classrooms to improve the learning process, allowing collaboration to take place among the instructor and students. Can these technologies promote student engagement, enhance the delivery of electronic course materials, and provide an effective way to connect the instructor and student together in an integrated learning environment? A literature review is conducted to determine the efficiency of these technologies contributing to collaborative learning. Tablet PCs have been successfully used in multiple United States institutions with many positive outcomes. Poor findings were found for the new tablets and smartphone devices which require more research to be conducted in the future.

Key words: Tablet PC, Tablets, iPad, collaborative learning

1. Introduction

Mobile computing devices introduced in the last decade, have turned into powerful educational units used in the traditional classroom to support collaborative learning. They are also "providing motivation for increasing emphasis on effective use of technology and on communication as an essential tool for management and innovation on education". (Bonastre, Benavent, & Belmonte, 2006)

As a professor and the Head of Computer Information Systems (CIS) Department at the American College of Greece, DEREE, I am currently interested in new mobile devices to be used in the traditional classroom as well as in the computer laboratory sessions in order to allow collaborative learning. One of the CIS department's objectives is to make teaching more interesting to the student, not dull and at the same time more efficient. This may be achieved by introducing innovative information technology to enhance the teaching process, allow instant feedback and help students build new knowledge. DEREE is currently using the Blackboard[a] Learning Management System (LMS)[b] . The Blackboard's feature called "the discussion board" is currently the main tool to allow collaboration among students and faculty at Deree.

Possible portable devices to be used include the Tablet PC, tablets such as the apple's iPad, Personal Digital Assistant devices (PDA)'s and smartphones. Tablet PC's are extensively used in United States higher educational institutions whereas newer technologies, inclusive of mobile phones

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[a] Blackboard is one of the leading commercial CMS products used in North America and Europe.
[b] Learning management system (LMS) is a software tool that enables the management and delivery of learning content and resources to students.

and electronic tablets such as the iPad, iPod and smartphones are now available and evident in the daily life of technological societies, representing new multiple classroom possibilities. (Preciado-Babb, 2012; Raja & JosephRaj, 2012)

There was a need of instructional methods that encourage student engagement during class. (Theys, Lawless, & George, 2005) The above mentioned interactive technologies are used to create environments where students "learn by doing, receive feedback, and continually refine their understanding and build new knowledge". (Theys et al., 2005)

In my research, I focus on the contribution of these mobile devices in collaborative learning as well as on how they can enable students' learning. The current situation shows that Tablet PCs and no other devices were mostly used in the studies. This was expected up to a point due to the introduction of these devices in 2002. The rest of the mobile devices such as the Apple's iPad and the Android based tablets which were introduced in 2009 appear in fewer cases.

The structure of the paper includes: i) definitions on collaborative learning and mobile devices including software, ii) a literature review on studies that took place in the last decade, iii) the advantages and disadvantages of these technologies in the learning process, iv) the gap I detected in my review and finally v) some conclusions derived from the research.

2   Definitions and literature review

Dillenbourg, (1999) mentions the broadest but at the same time "unsatisfactory" definition for collaborative learning; "it is a situation in which two or more people learn or attempt to learn something together". The possible interpretations of the elements can be:

- "two or more" may be interpreted as a pair, a small group (3-5 subjects), a class (20-30 subjects), a community (a few hundreds or thousands of people), a society (several thousands or millions of people)... and all intermediate levels.

- "learn something" may be interpreted as "follow a course", "study course material", "perform learning activities such as problem solving", "learn from lifelong work practice", ...

- "together" may be interpreted as different forms of interaction: face-to-face or computer-mediated, synchronous or not, frequent in time or not, whether it is a truly joint effort or whether the labour is divided in a systematic way.

Collaborative learning (CL) also "refers to the potential of motivating and enhancing learning activities through the collaboration among students: it is learning by and learning about collaboration". (Breuer, Sousa, Baloian, & Matsumoto, 2007) "Collaborative Learning Environment (CLE) works co-ordinately with the wireless network technology. This has supported mobility of computer devices to improve the difficulties in using desktop PCs". (Chang, Lin, & Lin, 2008) In addition, CL "emphasizes learner-centric grouping discussion methodology that empowers students to build up their own knowledge system by interactively communicating and discussing in group-based collaboration". (Lin, Liu, & Niramitranon, 2008) Moreover, collaboration in education helps students "to develop general strategies and abilities for problem solving through the implicit cognitive processes contained in interaction and communication". (Ambrósio & Costa, 2010)

But how can mobile devices contribute in collaborative learning?

The questions most researchers make in their studies are the following:

- Can these new ubiquitous technologies enable students' learning?

- How can they contribute in collaborative learning?

In this literature review, I will try to answer these questions by discussing mobile technologies, their implementation in the classroom and their contribution in collaborative learning and by providing the results of research in this field.

Mobile ubiquitous devices are actually used in a learning environment with a mix of pedagogy and technology. (Sneller, 2007) Learning systems using these technologies support note taking and sharing and real-time active collaboration through classroom presentation (Bonastre et al., 2006)

Tablet PC is a portable computer which users can write or draw using a digital pen. Tablet PCs can be found in two models: "(a) the "convertible" which looks like a notebook, has a keyboard and a screen, but whose screen can swivel to a flat position over the keyboard when used for writing/"digital inking," and (b) the "slate," which has only a pen and screen and no keyboard". (Sneller, 2007)

"The Tablet PC can be used solely by the instructor, solely by the student, or by both". (French, 2007) Tablet PCs "become one of the important roles in computer supported collaborative learning (CSCL) contexts". (Lin et al., 2008)

By using a platform involving Tablet PCs the instructor may (1) present course material during the lecture period; (2) administer summative assessment during the lecture period; (3) grade assessments with "digital ink;" and 4) provide timely feedback of student projects. (Theys et al., 2005)

On the other hand, tablets such as the apple's iPad "might be conceived only as a media reproduction and communication device for one student before using it in the classroom". (Preciado-Babb, 2012) In addition, there are two properties found in tablets to support interactive collaborative learning: "Direct Input which means that an end user can directly manipulate the user interface and applications using touch, pen and/or tangible objects. Multiple Access Points means that multiple concurrent interaction points are sensed by the hardware and utilized by the software. This enables pinching with two fingers to zoom out, and switching which hand to use". (Rick, 2012)

Raja & JosephRaj, (2012) define e-classroom including the devices and the media required for its setup. It involves the use of multimedia as video, audio, images and YouTube which is proven to support teaching and learning. More specifically they mention the following: "Tablet devices afford teachers and students opportunities to access these resources digitally, individually, and in a "just in time" fashion… tablet devices typically features a variety of applications that move beyond media distribution providing a mobile "digital toolkit." Software applications like Notes provide users with a quick way to enter text for future review".

Software technologies to support Tablet PC collaborative functions are called Classroom Communication Systems (CCSs). Three of the most famous CSS's are:

Classroom presenter

This invaluable pedagogical tool allows the instructor to incorporate a diversity of ideas, show novel solutions, and discuss misconceptions illustrated by student answers. (Bonastre et al., 2006)

The features of the classroom presenter include "support of real-time natural handwriting in addition to prepared lecture slides, use of a pen based computer as the instructor's input device and support of the writing on top of slides as well as of the writing on a separate whiteboard space". Students' computers are updated from the system at real time displaying the lecture presentation. Students are also able to send an instant feedback to the instructor's device. (Bonastre et al., 2006)

Classroom Presenter allows the instructor to send slides to students. Moreover, the software allows him to sketch over the slides, using annotations including open questions for the students to answer.

Simon, Anderson, Hoyer, & Su (2004) implemented an extension to Classroom Presenter called Student Submissions. This tool "enables students equipped with Tablet PCs to contribute to and participate in the lecture at points determined by the instructor".

DyKnow Vision Suite

The most important feature of this CCS is the creation of session notebooks. By using these notebooks instructors can present electronically the content discussed every day. "Before class, instructors create notebook with imported PowerPoint slides or images, embedded web sites, panels listing major points of the day, blank slides upon which s/he can extemporaneously use "ink" to highlight main points, write out solutions, draw schematics, or any combination of the above". (Sneller, 2007)

Session notebooks allow interactive communication among students and the instructor. The panels of the notebooks can be revisited as many times as the students wishes.

DyKnow is preferred for its "participant status, polling, and student submissions features allowing easy gathering of real time feedback". (Sneller, 2007) Students are able to indicate their status if they understand the material, participate in a poll including multiple choice or true/false questions; "polling results can be used to prompt discussion or to adjust the day's material" (Sneller, 2007) and submit their panels to share their thoughts with the instructor or other students.

Microsoft OneNote

Microsoft OneNote is used both by Tablet PCs, the new tablets and smartphones to keep notes and share them for collaboration. Dorothy (2008) mentions in his paper on tablet notes that MS-OneNote "employs handwriting recognition and OCR to aid in searching". The software's capturing abilities have been found very convenient for classroom and personal study. "MS-OneNote allows you to think of your notes as being organized in notebooks and sections is a very natural way of thinking for most individuals. It maps very clearly to a physical notebook that can be purchased at most office supply stores".

Different research studies have been conducted and methodologies have been proposed to determine the efficiency of mobile ubiquitous devices and software in learning. In the next paragraphs I present some of the most important ones in the field.

Ambrósio & Costa (2010) in their study proposed a methodology for students to use tablets in a collaborative environment in order "to solve problems by applying abstract thinking". Students "must first focus on building an algorithm that provides a solution to the problem before implementing the

algorithm in a programming language; They also mention the following "…we use the Problem Based Learning (PBL) method to introduce the concepts in the course syllabus as a series of open-ended problems". Students split in groups to answer these problems through a series of steps, collaborate and exchange their solutions. "The instructors act as tutors, inducing the discussions in the groups and preventing students from drifting from the learning goals". As far as the method's evaluation is concerned students "criticized PBL due to the workload it imposed, but believed by the great majority as a positive contribution to their learning process". On the other hand the authors believe that it had a positive influence on students, both in academic/learning and personal perspective, "making them more independent, proactive, and responsible preparing them to work with peers".

Stickel (2009) conducted a study of how Tablet PCs impact students with different learning styles. He executed a survey on four different courses during the period of three terms (280 participants). In all courses the instructor was the only one to use a Tablet PC in order to replace the Blackboard CSM. The questions related with learning (in this study not collaborative due to the limitation of the number of tablets) were the following: "Does the use of the tablet make the lectures a more enjoyable experience?", "Do you learn more from the lectures?", "The pace of the tablet-based lectures is:" "Do the additional visual aids enable you to understand the material more clearly?" "Students were overwhelmingly supportive of the additional visual aids and many of them felt that they learnt better in the Tablet PC-based lectures. They also felt that the usual pace of the lectures was reasonable, which was likely due to the fact that skeleton notes were provided and the instructor annotated over these notes". Students found Tablet PC lectures more enjoyable than the blackboard-based ones.

Avery et al., (2010) mention in their study on the impact of Tablet PC in student learning that "according to the classroom observation results and student performance comparison, all faculty members agreed that the Tablet PC based teaching strategy helped to make students more engaged in learning and develop a better understanding of the lecture. They also agreed that the friendly and interactive learning environment helped students to achieve their learning outcomes".

Preciado-Babb, (2012) mentions in his paper, his experience as a team of educators from the Galileo Educational Network Association (GENA) and two teachers, to plan a unit together for a mathematics high school course using the iPad tablet to solve arithmetic problems. The author's experience focused in the collaborative "design of mathematical tasks with teachers and other educators". High school teachers allowed students to use iPad with the 'Numbers' application or a standard calculator to solve the formulas of the problem. Most of the students preferred the iPad tablet, explaining the features they have used. The drawback was that students who were not familiar with the application they did not even try to use it. "The teacher generated, from students' suggestions, an assessment rubric for both the problem solving process" and the explanations of the solution of the problem results were presented using the 'Pages', an iPad word processor. "Edited photographs were added to the presentations as a means to explain how they demonstrated the correct use of the formulas. Other students used the video camera of the iPad to present their solutions to the problem. No instruction to the use of these applications was given to the students. They explored and used them by their own. The interaction between the students and the mathematics task, as well as the student and the iPad, evolved during this activity". The author concludes his paper indicating that "students created knowledge in the classroom and in addition to the mathematical knowledge developed in class, students know that they can also contribute to collective learning".

Buendía & Cano, (2010) proposed a novel approach to design interactive classroom environments supported by Tablet PCs. The scope of the project was to integrate formative assessment into classroom practices and provide instant feedback to students. The approach included six steps and was

implemented in the first year freshmen students of a computer engineering course. The following are the steps used in this approach: "Step #1: To reduce slides content to the essentials in order to permit a dynamic adjustment of delivery and concepts, Step #2: To design and develop specific add-value multimedia resources allowing students to gain a good level of understanding, Step #3: To design and develop in-class individual and group activities in order to directly engage learners with the subject matter, Step #4: To introduce the use of discipline specific software and resources to tackle problems and/or projects in more realistic scenarios, Step #5: To design and develop one-minute papers that help instructors to gain knowledge about students understanding and Step #6: To design and develop assessment items in such a way that the overall content of the course be covered". In the findings the author mentions the following: initial results showed that the drop rate has been decreased more than 50%, by double increasing the number of students passing the course. "Our approach has also promoted the students' autonomy and motivation, thereby improving their academic performance and enhancing their self-confidence in the learning process".

Ii et al. (2008) conducted a preliminary research study at the Georgia Tech Savannah campus on how Tablet PCs enhance distributed learning environments. Distributed learning environment may involve synchronous or asynchronous collaborative learning. This is exactly the opposite with all the previous mentioned. The research questions addressed were: "1) "What impact does the Tablet PC have on student perceptions of their engagement in a distributed learning environment?" and 2) "Can the Tablet PC be used to improve student learning in a distributed learning environment?"". The results indicated that the combination of Tablet PC with any interactive software as the Classroom Communication Systems (CCS) can a) improve student satisfaction in a synchronous distributed learning environment, b) there is evidence to suggest that student performance is positively affected compared with other environments that do not use tablets. The author mentions that more data analysis is required to determine the effect on student learning and his study may serve as a case that reports on the usefulness of Tablet PCs.

The studies' findings on mobile devices contribution in collaborative learning can be summarized as follows:

- Develop a better understanding of the lectures

- Provide instant feedback

- Create knowledge in the classroom

- Affect positively students' academic performance

- Enhance students' self confidence in the learning process

- Help students to better achieve the lesson's learning outcomes

Although the amount of the referenced studies is not sufficient enough to draw generic conclusions, the findings show that there is a good reason to believe that these ubiquitous devices may positively improve teaching and learning. Collaborative learning becomes more flexible allowing students to enhance self-confidence by creating knowledge and improving their academic performance.

3   Advantages /Disadvantages of using mobile devices to support Collaborative Learning

Some of the most important advantages of using Tablet PCs mentioned by Sneller (2007) are the following: tablets improve communication, facilitate active learning and improve the delivery of material in class. In addition, Cromack, (2008) and Chidanandan & Sexton, (2008) indicate that Tablet PCs promote student engagement, enhance the delivery of electronic course materials, and provide an effective way to connect the instructor and student together in an integrated learning environment.

Colwell (2003) mentions two main advantages of using "digital ink" – a feature of Tablet PCs - to add notes, highlights and student comments using Tablet PCs: "permanence (the ability to save in-class notations for future use) and interactivity/immediacy". (Colwell, 2003; Sneller, 2007) In addition, digital ink affords participants ability to take handwritten notes directly on the tablet and store a digital version of these notes for later retrieval. (Theys et al., 2005); Ambrósio & Costa (2010) mention in their evaluation of Problem-Based Learning and Tablet PCs in a programming course that "ink-based computing presents students with a powerful tool for note taking and for expressing their creativity when working in the abstract reasoning associated with algorithmic thinking; …the use of digital ink in the classroom not only stimulates interest because it represents state-of-the-art technology, but also because it allows for different types of expression that include, but are not limited to, diagrams, sketches, free-hand drawings, and mathematical formulas. This freedom of expression allows students to bring forth their creativity and communicate in a more natural way".

Instant informational feedback to students is another advantage. Students are able to view the instructor's feedback on the spot. This may include comments, assignment of grades and answers to any questions posed. In a traditional classroom as in the case of my college, students may have to wait their instructors to receive feedback. The Blackboard Learning Management System Platform is used to provide this feedback on students' assessments using the grade sheet and discussion board to comment the discussion with a thread; but mobile technology does not exist to allow instant feedback.c Moreover, the use of a Tablet PC in a collaborative learning environment "arouses students' motivations and improves students' mutual interactions"(Lin et al., 2008)and academic performance (Buendía & Cano, 2010); it also attracts attention to the course and contributes to engage students. (Ambrósio & Costa, 2010)

As far as the new tablets are concerned, anecdotal evidence from early adopters suggests that the iPad's shape and portability makes it feel more natural to pass around a group, and several of these devices could be used comfortably by groups of students working at tables. (Melhuish & Falloon, 2010)

Classroom learning improves significantly when students participate socially, interacting in face-to-face collaborative learning activities with small groups of members. (Lin et al., 2008) The use of tablets allows students to collaborate each other by "exchanging, evaluating and complementing each other's solutions to problems". (Ambrósio & Costa, 2010) Instructors are able "to achieve a wide range of educational goals and promote a more dynamic classroom environment". (Benlloch-Dualde, Buendía, & Cano, 2010)

Mobile devices enable a flexible environment where the instructor and students are able to move around carrying their devices connected to a Wireless Local Area Network (WLAN). This is the "key to facilitate classroom rearrangement, interaction, experimentation, and access to external resources". (Ambrósio & Costa, 2010)

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c Blackboard is currently offering a new licence to allow access to students and instructors from mobile devices such as tablets and smartphones.

However, there are a few disadvantages mentioned in bibliography related to the use of mobile devices in collaborative learning.

The most important ones were related with the devices themselves. These include high purchasing cost, the chance of introducing distraction in the classroom and lack of battery life provided by some devices.

Stickel (2009) mentions his experience as an instructor the following drawback using Tablet PCs. He complained that the operating system used in his Tablet PC crashed all the time.
Edwards & Barnette (2004) in their paper recording experiences mention that "Tablet PCs are poorly matched to typical CS laboratory tasks: writing, compiling, and testing programs. Pen-based input is inadequate for typical program editing tasks, and a pen is less effective than a mouse when typing at a keyboard. Students show a clear preference for desktop computers in this environment".

Mobile technologies can contribute positively in the traditional learning and more particular in the collaborative learning process. In traditional learning, there are other information technologies to use such as the Learning Management Systems (Blackboard, Moodle, etc,) using traditional PCs, which can equally contribute in the process, but they are inflexible to collaborate; especially if students are participating in a class and not in a laboratory. At the same time, they have to be static in the room and they cannot move around to form groups. On the other hand, mobile devices provide the flexibility to be portable using most of the LMSs features and at the same allowing instant collaboration!

4 Gap in the literature

There is limited research in the implementation of new tablet mobile devices as the new Apple iPad and the new smartphones in collaborative learning. Most of the research was conducted on Tablet PC introduced by Microsoft in 2002. The reason may be the Microsoft's donations of Tablet PCs to US institutions (secondary and tertiary education). The Apple's iPad and other tablet devices which appeared in 2009, are more flexible devices, handy and cheaper compared with the Tablet PC and sometimes more efficient. High schools and universities at the United States have started building interactive classrooms based on these technologies. Applications have been developed for the tablet platforms (iOS and Android) to support collaborative learning. As an iPad and iPhone holder, I am currently using Microsoft OneNote to record student comments sharing them at Microsoft SkyDrive. All students have access to their Microsoft Hotmail Accounts (e-mail college accounts in collaboration with Microsoft) and access to Microsoft SkyDrive to view and store their shared documents. Research should be conducted to measure the effectiveness of these new devices in collaborative learning environments as well as to compare and contrast them with the Tablet PCs.

5   Conclusions

Students who engage and interact in a collaborative environment are more likely to build the personal knowledge structures necessary for their learning. Mobile computing systems and software tools contribute to allow students and instructors to easily communicate, receive instant feedback responses and have all the material of the lectures including student to student and instructor to student discussions stored for future reference. This makes collaboration more efficient resulting in building new knowledge for the student.

The advantages of the ubiquitous mobile devices in a collaborative environment are more than their disadvantages which are mostly device oriented.

Mobile devices can positively contribute in collaborative learning by allowing portability and the flexibility to build knowledge providing an instant feedback. In addition, findings of the studies show that the use of these technologies in collaborative learning enables students to improve their academic performance.

Studies have also shown that the use of tablets in teaching can be more efficient than course management systems as the Blackboard platform.

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