Towards Blended Learning Environment based on Pervasive Computing Technologies*

Yue Suo[1], and Yuanchun Shi[1]

[1] Key Laboratory of Pervasive Computing, Ministry of Education
Department of Computer Science and Technology, Tsinghua University, Beijing 100084, China.
suoy@mails.thu.edu.cn, shiyc@tsinghua.edu.cn

Abstract. Nowadays Internet-based multimedia learning has been entered into our daily life over various end user devices including mobile phone. Whereas, participating in the classroom and book reading are still major modalities of learning. Pervasive computing technologies will accelerate the progress and help to build a more convenient learning environment for learners. Smart Space technologies can augment real classroom to help teachers and students having class with the support of natural tangible UIs and context aware aids where teaching is still in a similar fashion with what happens in traditional classroom. Books can also be fabricated with bits for browsing multimedia learning materials. Bits from cyberspace and atoms from real world will be more and more blended into each other. And learning will be pervasive and blended which is beyond today's e-learning.

Keywords: Blended Learning, Pervasive Computing

1   Introduction

Thanks to the booming development of the information technology in recent years, multimedia and internet has become common in our daily life. People are able to reach multimedia information via numerous various devices, including PC, Laptop, Smart Phone and PDA, as long as they connect to the internet. Learning has also been influenced by this trend: many e-learning [1] systems appear to enable the students to learn the knowledge shown in multimedia and attend the "class" at home with just a personal computer connected to the internet.

Whereas, traditional learning that students participate in the classroom and book reading are still major modalities of learning and has its unrivaled advantages. Researchers [2] [3] report that besides the aspect of the difference in knowledge transmitting methods, the traditional learning is more important for its cultural effect on the learners. Students learning at school or in the campus form tighter social relationship with each other. The teacher can interact with and convey enthusiasm to

the students through face-to-face interaction, which is exactly what the e-learning lacks of.

Therefore a new learning type called blended learning is born. Of the various definitions of blended learning, combining the e-learning and traditional learning is the key point. Blended learning tries to address the problems of traditional learning such as weak scalability and lack of fidelity while keeps the cultural effect as much as possible.

The emergence of Pervasive Computing [4] and Smart Space [5] provides new methods and accelerates the progress for the educators to build a more convenient blended learning environment. Several research projects in Smart Space [6] [7] [8] [9] [10] aiming at educational issues share the common idea that keeping the main learning place in the classroom while providing Smart Space technologies to enhance its functions and experiences: enabling remote students to join in the class, allowing the students to report feedback quietly to the teacher during the class, capturing the whole instruction for students to review after the class and so on. Blending Smart Space technologies with traditional learning and e-learning provides novel and better experience for both of the teacher and the students.

The Learning process encompasses four sub-processes: teaching, reading, discussing and reviewing. Besides teaching and reviewing explained in the above paragraph, Smart Space technologies also augment the reading and discussing process. Paper-based textbook could be fabricated with bits for browsing multimedia learning materials [11] in cyberspace using mobile devices by Pervasive Computing technology and makes the text-object to be the "internet of things" [12]; discussion in one real classroom could be enhanced to be in several connected classrooms. All these features lead to build a more convenient blended learning environment by combining bits from cyberspace and atoms from real world together, which is beyond both of the today's e-learning and the traditional learning environment.

The rest of the paper is organized as follows: We introduce traditional learning, the developing history of the learning and its latest steps blended learning in Section 2. Then in Section 3, we explore blended learning based on pervasive computing technologies and its achievement. Section 4 presents the prospect for future p-blended learning environment. And we make the final conclusion in the last Section.

2   Traditional Learning & Blended Learning

Blended Learning is the latest steps in the history of learning from traditional learning to more and more enhanced technology-based learning [2]. In this chapter, we will first articulate the advantage of traditional learning, introduce the evolution of learning, and then present several important aspects of blended learning.

2.1   Traditional learning

Nowadays, traditional learning mode is still the major modalities of learning. Traditional learning has a classroom-based learning environment with an instructor such as teacher, professor or subject-matter expert. The instructor organizes the

knowledge, adjusts the pace, changes the direction according to the context of students in the classroom, while the students immerse in a learning environment listening to the instruction. It has been proven to be an effective and pervasive mean of learning for years. Besides conveying the knowledge to the students, traditional learning has a cultural effect more importantly: people interact and learn from one another [2] and students have full opportunities to communicate with the instructor and other students, forming strong relationship with others [3].

Additionally, traditional learning still uses real-paper textbook for students. Compared to the e-learning material, although it has several disadvantages such as heavy-weighted, high-cost and hard to search by keyword, paper-based textbook gives the students better experience on much higher resolution, easy annotation, easy skimming and natural reading manner.

The biggest challenge of traditional learning is lack of scale [2]. Cultural benefits are great, whereas teaching thousands of students consumes larger classrooms (reducing effectiveness greatly) and lots of travel (very expensive). The second challenge of traditional learning is lack of equipments in the classroom that sometimes makes the instructor difficult to teacher certain topics effectively [3]. Moreover, because of the limitation of the classroom and the paper-based textbook, the teaching is of less fidelity than multimedia-based e-learning to a certain extent.

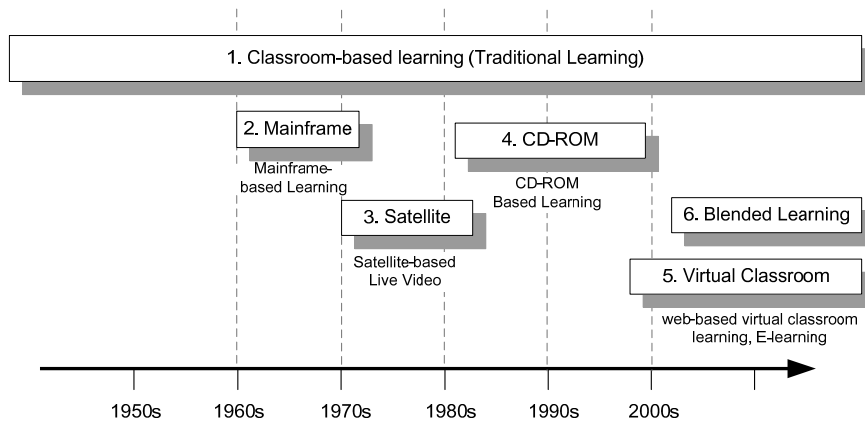## 2.2   The developing trend of learning

Fig. 1. The timeline of the developing trend of learning

As given by [2], blended learning is the latest step in a long history of technology-based training/learning. From the traditional learning to today's blended learning, there are mainly six phases of learning types   (Figure 1); in order is classroom-based learning, mainframe-based learning, distance learning by satellite-based live video, CD-ROM based learning, web-based virtual classroom learning and blended learning. Classroom-based learning is the traditional learning, which suffers lack of scale and lack of fidelity. As to solve the lack of scale problem, the next three types emerge.

Mainframe-based learning forms the basis for the thinking about blending technologies with traditional learning. Satellite-based live video and CD-ROM based learning are two successful solutions for "lack of scale" problem in that era. Satellite-based live video was once very popular in the 1980s in China since the government is lack of instructor and too many students. CD-ROM based learning uses CD-ROM to deliver multimedia learning material to the end user. However, as the rapid development of the high-speed internet and common to normal people, satellite-based live video and CD-ROM based learning are to be faded and replaced by the web-based virtual classroom learning which is cheaper, more effective and less cost of maintenance. Today the training organization and educational institution have a wide range of options for learning. Therefore the last type, blended learning, is born to try to integrate the former learning types in order to build a better learning environment.

2.3   Blended Learning

- Definitions

Graham [13] in his book discusses the three most commonly mentioned definitions of blended learning: combining instructional modalities, combining instructional methods and combining online and face-to-face instruction. The first two suffer the problem that the definitions are given so broadly that almost encompass all learning systems while the third definition is thought to be the more accurate one, which is the foundation of the Graham's definition: "Blended learning is the systems combine face-to-face instruction with computer-mediated instruction".

Won Kim in his keynotes paper [3] defines the blended learning more precisely that it is "a combination of two or more of all possible learning types" with two qualifiers that at least one type must be physical class-based type and one must be e-learning type.

From these definitions, the face-to-face instruction, physical class-based type and e-learning involvement are the key points of blended learning, which is also the foundation of our blended learning environment based on pervasive computing technologies as well.

- Significance of blended learning

Of those advantages that choosing blended learning for the instructor rather than other possible options, there are three important reasons that can not be neglected [13]: 1) Improved pedagogy.   Blended learning provides new modes for the learners to learn, to collaborate and to discuss while keeps the cultural effect of traditional learning; 2) Improved access/flexibility. Aided by the growth of distance learning environment, blended learning enlarges the scope for the learners to access the knowledge and also provides more flexibility for the learners to choose the most convenient learning environment from physical classroom to virtual learning forum; 3) Improved cost effectiveness. Blended learning provides the opportunities for the education and corporate institutions to achieve cost saving while assures the didactical quality enhancement.

Face-to-face instruction in the physical class-based type keeps the cultural effect among the instructor and the students; computer-mediated instruction enhances the

scalability and fidelity of the knowledge transmitting from the instructor to the students. As the rapid growth in computer-technology area, especially coming to the era of pervasive computing, blended learning environment is enhanced by pervasive computing technology and will become more convenient and effective for learners.

3 Blended Learning based on Pervasive Computing Technologies

3.1 Smart Space

Smart Space embodies the key features of pervasive computing and is thought to be the test-bed for it. As Smart Space focuses in a limited-space such as classroom or meeting room, it is suitable for using Smart Space technologies to enhance blended learning environment.

As Smart Space develops, we propose three successive phases of Smart Space, each of which brings new opportunities to provide better experience for blended learning environment (Figure 2). The three phases are listed in logical order rather than temporal order, where new features added continuously from the left to the right to make Smart Space more powerful.
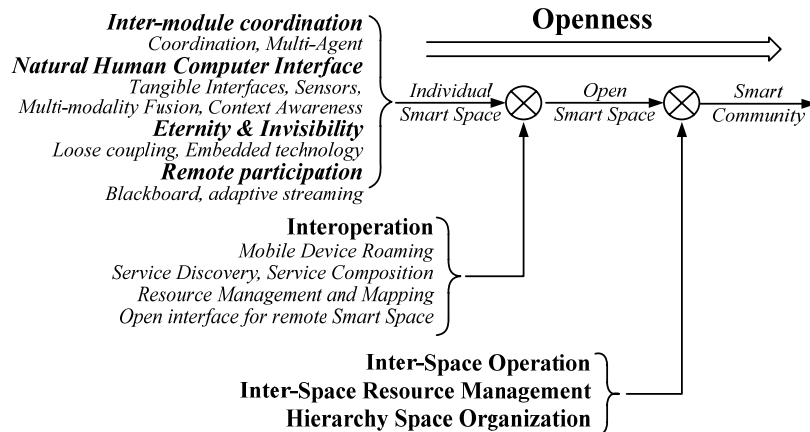

Fig. 2. Three successive phases of Smart Space.

● Individual Smart Space.

In first phase, the research focuses on building a smart human-computer interactive space. Communication and the coordination mechanism among the software modules is the basis for building the computer-mediated learning environment. Also, lots of tangible UIs [14], such as sensors and awareness modules, have been applied to achieve natural human computing interaction. Modules in Smart Space are loose-coupled in order to maintain system robust and embedded technologies are involved to remove the computing devices from people's sight. Remote participation enables the people outside Smart Space to communicate and collaborate with the people inside. Rebuilding the traditional classroom into the Smart-Space-based classroom

provides enhanced experience for the instructor to give class to large number of students outside of the classroom at the same time while keeps the similar fashion as before with the help of natural tangible UIs.

- Open Smart Space.

In the second phase, Smart Space becomes more open. The mobile and handheld devices roaming with users, which becomes more and more popular in pervasive computing environment, can discover the existence of smart space environment and spontaneously take use of the resources and the services in the space to perform tasks of the users in an enhanced fusion. Other Smart Spaces could connect in to build a virtual larger Smart Space. Classroom based on Open Smart Space enables the instructor and the students to bring their personal mobile devices to augment teaching and learning experience. Instructor could bring learning materials such as PPT or interesting video via his Smart Phone to show and share to the students. Students can also using their mobile devices to give real-time comments or questions to the teacher while not interrupt the teacher's talking. Other classrooms settled in different places or even in different countries with different languages could connect in and have class with local classroom together.

- Smart Community.

In the third phases, as [15] refers that it is almost impossible to establish an union pervasive computing environment all over the world in the near future, while great plenty of self-governed Smart Spaces exist by their own. Smart Community consisting of multiple Smart Spaces needs to address the inter-space operation and inter-space resource management mechanism issues. For blended learning, this would refer to the future collaborating learning environment involving many classrooms together, which combines with others automatically in terms of the shared schedules.

3.2   p-Blended Learning

Based on pervasive computing technologies and Smart Space, blended learning environment could be enhanced to provide better features than ever before. We call this type of blended learning as p-Blended learning. P-Blended learning emphasizes on combining face-to-face instruction in the classroom built as a Smart Space (regardless of whether it is a Individual Smart Space, Open Smart Space or Smart Community) with pervasive computing technologies enhanced instruction (such as synchronous distance learning by remote participation, asynchronous learning by the experience record of the past class, textbook fabricated with special tags for browsing multimedia learning materials).

Graham [13] introduces four dimensions of the interaction in face-to-face and distributed learning environment in order to explain the trend of fusion between these two archetypal learning environments: space, time, fidelity and humanness. Space reaches from live or physical to virtual reality; time ranges from live synchronous to asynchronous. Fidelity reflects the level of the interaction from high (all senses) and Medium (e.g. audio only) to Low (text only). And the humanness addresses the ratio of human interaction and machine interaction. Based on above dimensions, we extend the dimensions of the interactions to show the features of p-blended learning type in Figure 3.

P-blended learning fuses synchronous and asynchronous learning mode in the Time dimension. For the synchronous mode, the local students receive face-to-face instruction with high fidelity aided by multimedia learning material displayed by the interactive blackboard in the classroom. The interaction of synchronous mode is the mix of high humanness interaction and human & machine interaction, in which the latter provides better experience thanks to natural human computer interaction provided by Smart Space. The remote students attend the class in real time by their personal computer, which is a little longer lag time. The remote students have to interact with the class by the help of the machine. For the asynchronous mode, the learning environment turns to be like web-based learning. Moreover, p-blended learning takes cultural differences and language barrier into account in the class. P-blended learning provides mechanisms for the students to solve these language differences problems by involving language transformation services.
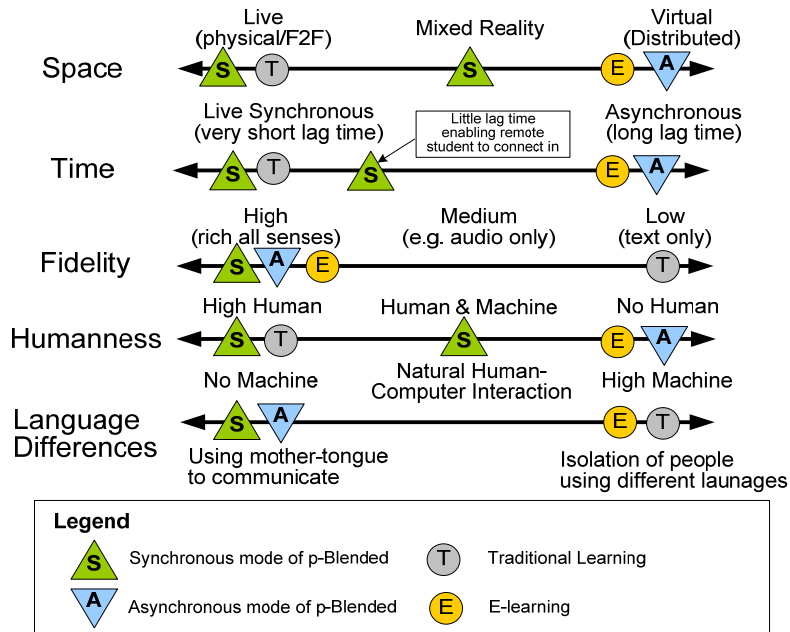

Fig. 3. Dimensions of p-blended learning.

3.3 Progress achieved: Smart Classroom

P-blended learning combines the face-to-face and computer-mediated learning together based on pervasive computing technologies. Some achievements have been made in building such kind of learning environment: Smart Classroom [7] and Open Smart Classroom [9].

Smart Classroom aims at building a primitive prototype of futuristic p-blended classrooms, which integrates voice-recognition, computer-vision, experience record, natural human interfaces and other technologies to provide a tele-education experience similar to a real classroom experience. By applying pervasive computing

technologies in a real classroom, the Smart Classroom combines the tele-education or web-based education mode with the traditional classroom activities and makes these two separate educational practices seamlessly bound together. Figure 4 gives an overview of the Smart Classroom. As in a real classroom, the teacher can gives his class while moving freely and using conventional teaching methods to instruct both of the local and remote students. Beside this kind of synchronous learning, the whole process of the lecture which contains the live video of the whole class, all of the context and events occur in this lecture will be recorded as a hypermedia courseware, which is available for playback after class for the asynchronous learning mode.
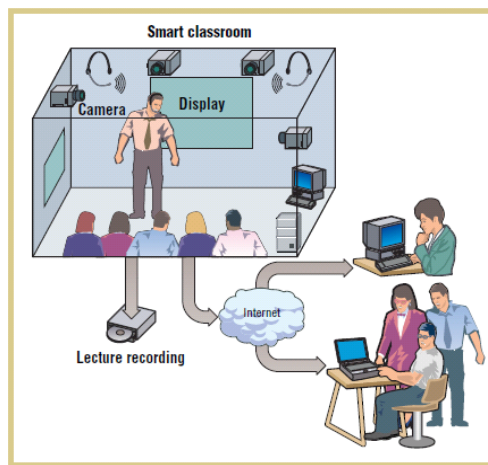

Fig. 4. The Smart Classroom system. [7]

Additionally, Smart Classroom provides multiple human computer interfaces and modalities to enhance the teacher's experience of teaching. We extend the user interface of a legacy desktop-based tele-education system into the real augmented classroom. The teacher uses SMART Board [16] similar to the blackboard in traditional learning classroom, while it can show multimedia learning materials and could be controller by the teacher's hand. Laser Pointer interface enables the teacher to make annotations on the blackboard and interact with remote students while roaming in the classroom. Speech-capable assistant enhances the effectiveness of the class by saving the teacher from sending some common command (such as "turn to next page of the slide") by hand.

Smart Classroom successfully embodies several convenient features of p-blended learning: it holds the benefit of the cultural effect in face-to-face instruction, even for remote students; it enhances the experiences of the teacher by involving a multimedia blackboard; it keeps the interactions in the traditional learning as much as possible, naturally to the experienced instructors; it provides both of the synchronous and asynchronous learning mode to meet the needs of different learners.

Smart Classroom has been proven to be effective and used in real campus for several years. As the technology develops from Individual Smart Space to Open Smart Space, we enhance the Smart Classroom to be more open and therefore develop the prototype of Open Smart Classroom.

Beside the features Smart Classroom provided, Open Smart Classroom emphasizes on enabling other Smart Classrooms to connect in and have class together. Language

barrier may occur when the classroom from another country speaking of different languages joins in the learning environment. Language Grid [18][19] and Langrid Blackboard [20] as aid tools are involved to help the students with different mother-tongue to communicate with each other together. As the primary experiment, two Smart Classrooms settled in Japan and China respectively are combined together. We constrain the teaching language to be English which is understandable to both of the participations from the two classrooms. Participations are able to use aid tools to discuss with each other and give feedback to the teacher as the class goes on. It is an interesting attempt to form two communication channels at the same time: teacher is giving his class to the students as formal channel while the students are discussing with other in different languages as the informal channel. Another interesting experimental approach in Open Smart Classroom is supporting personal devices (e.g. Smart Phone, PDA and Laptop) to seamlessly connect into the classroom system and even has some access rights to interoperate with the system, such as the teacher is able to use his personal Smart Phone as a controller of the classroom to navigate the slideshow.

At last, organizing this kind of class is valuable experience. Japan and China has lots of difference, from complicated cultural difference to simple one-hour time difference. How the p-blended learning system leverage the issues caused by difference is still an interesting open question.

4 Future prospect of p-Blended Learning

After introducing achieved progess, we are going to make a prospect for future p-Blended learning. Organizing the p-blended learning encompasses four separate steps: teaching, reading, discussion and reviewing, which will be explained in detail as follows.

4.1 Teaching

As Derntl in his research results [21] indicates that "faculty preferred a more traditional, discipline-based course design model for online course planning and shunned high-level instructional design, opting for lighter-weight, dialog-rich instructional design emphasizing real-time, faculty-student interaction." Therefore, p-blended learning environment should provide a teaching mode whose experience is more similar to the traditional one in the classroom for the instructors. Classroom-based teaching mode while enabling the remote students to join in and to interact with the class in real-time is a good approach.

Moreover, [22] and [24] point out different skills are required on the side of the instructor, both socially/didactically and technically. The instructors always lack time and technical expertise to use e-learning platforms or other "high technology" tools conveniently. Smart Space technologies, which tend to make computer invisible, proactively provide the service for the user and the natural human interface alleviating the instructor to learn and adapt to the new "classroom", enable the instructors to give

the class in the similar fashion with what happens in the traditional learning but with enhanced experience.

As the Smart Space technologies improve, although it is easier and more natural for the teacher to give class to the people all over the world synchronously and asynchronously, the educators still need to think about how to design and develop new learning theories making full use of the new p-blended learning mode. Neither learning platforms nor learning theories in isolation can provide effective p-blended learning scenarios. Therefore co-considering educational concerns and p-blended learning platforms in order to take full advantage of pervasive-computing-enhanced educational practices is crucially important and needs further research.

4.2   Reading

Paper-based textbook is still the main reading material in learning process. It is interesting to realize that the emergence of e-book based on internet does not eliminate the traditional paper-based book. However, the total number of the paper-based book even continues to grow in a faster speed. Having several advantages such as saving space, full of fidelity by multimedia technology, fast searching, easy sharing and delivering, the e-book is still lack convenience of reading than traditional book in several aspects so far: low resolution, hard to make annotation, reading is restricted by the screen of computing devices and uncomfortable feeling caused by unnatural reading manner. Many people choose to print out the e-material to read instead of reading it directly. It is quite obvious that the e-book and textbook will co-exist for such a long time in the near future.

In p-blended learning environment providing an enhanced classroom-based fashion, local students are still suggested to use paper-based textbook as their main reading material and make notes on it while listening to the class, as well as the remote students, whose PC screens are used for displaying live-video and blackboard of the class and no room for displaying reading material. However, paper-based textbook is only able to show text-based knowledge lacking of vitality and animation, which should be enhanced in p-blended learning environment.

Therefore, the paper-based textbook "connected" with the cyberspace by embedding tags that can be identified by students' mobile devices such as PDA or Smart Phone is recommended. The tags could be a website link, 1-D/2-D barcode embedded with corresponding cyberspace's information or just predefined patterns. Mobile devices recognize these tags, fetch the related multimedia learning material from the internet and show it to the reader. Through this mechanism, paper-based textbook is enhanced to be more vivid and animated, and more importantly, connect with p-blended learning environment more tightly to improve the effectiveness of the students' reading.

4.3   Discussion

Class discussion is one of the pervasive instructional methods focusing on students interaction, aiming at having the students negotiate and co-construct an understanding

of the learning topic. Traditional class discussion is more spontaneous but hard to ensure the participation and flexibility, while web-based discussion is more "Depth of reflection" [23] and flexibility but difficult to ensure spontaneity and weak to build human connection.

P-blended learning combines these two types of discussions together: traditional class discussion during the class and the web-based discussion after the class. Both of these discussions should take language barrier into account for supporting multi-language multi-space discussion in the new p-blended learning environment.

4.4   Reviewing

Traditional learning environment is hard for the students to review the whole class after the class. In p-blended learning environment, the whole class, not only the live-video of the class but also all the notes of the blackboard and all of the events occur will be captured by the learning environment in order to help the students to make further review and absent students to catch up with the learning progress. Also, with the help of current developing summary and index technologies of the class [25], the class record could become more and more effective for students to learn and understand.

5   Conclusion

This paper aims at introducing the idea of building more convenient blended learning environment based on pervasive computing technology. Blended learning environment absorbs the advantages of traditional learning and e-learning and it may even become so pervasive that eventually we just call it as "learning" itself [13]. Pervasive Computing and Smart Space technologies augment the blended learning environment in each of its aspects including teaching, reading, discussing and reviewing, assisting both of the teacher and students through the learning process and finally provide enhanced experience for the class which is beyond today's e-learning.

References

1.   Electronic learning. http://en.wikipedia.org/wiki/Electronic_learning
2.   Josh Bersin: How Did We Get Here? The History of Blended Learning. In The Blended Learning Handbook: Best Practices, Proven Methodologies, and Lessons Learned. Pfeiffer Wiley (2004).
3.   Won Kim: Towards a Definition and Methodology for Blended Learning. In the Proceedings of Workshop on Blended Learning 2007, p1-8, 2007.
4.   M. Weiser. The computer for the twenty-first century. Scientific American, 1991, 265(3):94-100.
5.   Lynne Rosenthal, Vincent Stanford.: NIST Smart Space: Pervasive Computer Initiative. In proceedings of IEEE 9th International Workshop on Enabling Technologies: Infrastructure for Collaborative Enterprises (WETICE), p6-11, 2000.

6. Abowd, G. Classroom 2000: An Experiment with the instrumentation of a living educational environment. IBM Systems Journal 38, 4 (1999), p508-530.
7. Yuanchun Shi, Weikai Xie, Guangyou Xu, et al.: The smart classroom: merging technologies for seamless tele-education. IEEE Pervasive Computing, Vol 2, No 2, 2003, pp. 47-55.
8. Ratto, M., Shapiro, R.B., Truong, T.M. & Griswold, W.G (2003): The ActiveClass project: Experiments in encouraging classroom participation. In Proceedings of CSCL 2003, p477-486.
9. Yue Suo, Naoki Miyata, Toru Ishida, Yuanchun Shi: Open Smart Classroom: Extensible and Scalable Smart Space Using Web Service Technology. In the Proceedings of ICWL 2007, pp. 428-439, 2008.
10. Brad Johanson, Armando Fox, Terry Winograd: The Interactive Workspaces Project: Experiences with Ubiquitous Computing Rooms. IEEE Pervasive Computing, 2002.1(2): 67~74.
11. Shih, T.K., Wen-Chih Chang, Te-Hua Wang, et al: The hard SCORM LMS: reading SCORM courseware on hardcopy textbooks. In the proceeding of Fifth IEEE International Conference on Advanced Learning Technologies, p812-816, 2005.
12. The internet of things. http://www.itu.int/internetofthings/
13. Graham, C.R.: Blended Learning system: definition, current trends and future directions. Bonk, C.J. & Graham, C.R.: The Handbook of Blended Learning. San Francisco Pfeiffer (2006).
14. Tangible User Interface. http://en.wikipedia.org/wiki/Tangible_User_Interface
15. Kindberg T, Fox A. System software for ubiquitous computing. IEEE Pervasive Computing, 2002 1(1):70~81
16. SMART – SMART Board interactive whiteboards. http://smarttech.com/products/smartboard/index.asp
17. Yue Suo, Naoki Miyata, Hiroki Morikawa, et al.: Open Smart Classroom: Extensible and Scalable Learning System in Smart Space using Web Service
18. Technology. Submitted to Special Issue of IEEE Transactions on Knowledge and Data Engineering for e-learning, Major Revision.
19. Toru Ishida: Language Grid: An Infrastructure for Intercultural Collaboration. IEEE/IPSJ Symposium on Applications and the Internet (SAINT-06), pp. 96-100, 2006.
20. Yohei Murakami, Toru Ishida, Takao Nakaguchi: Language Infrastructure for Language Service Composition. International Conference on Semantics,Knowledge and Grid (SKG-06), 2006.
21. Language Grid – Langrid Blackboard. http://langrid.nict.go.jp/en/blackboard.html
22. Michael Derntl and Renate Motschnig-Pitrik: The Role of Structure, Patterns, and People in Blended Learning. The Internet and Higher Education, Volume 8, Issue 2, p111-130, 2005.
23. Motschnig-Pitrik, R., & Mallich, K. (2004). Effects of Person-Centered Attitudes on Professional and Social Competence in a Blended Learning Paradigm. Educational Technology & Society, 7 (4), 176-192.
24. Mikulecky, L.: Diversity, discussion, and participation: Comparing web-based and campus-based adolescent literature classes. Journal of Adolescent & Adult Literacy, 42(2), p84-97, 1998.
25. Michael Power: A dual-mode university instructional design model for academic development. International Journal for Academic Development, Volume 13, Issue 1, p5-16, 2008.
26. Z.Yu, M.Ozeki, Y.Fujii, Y.Nakamura: Towards Smart Meeting: Enabling Technologies and a Real-World Application. In the Proceedings of the 9th International Conference on Multimodal Interfaces (ICMI 2007), p86-93, 2007.