The Design and Development of Mobile Collaborative Learning Application Using Android

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***Abstract*— Mobile devices are quickly becoming devices powerful enough to run personal computers with the advancement of wireless and mobile technology. Learning by means of mobile phones is becoming a new approach towards education, and it is unique in its own way and offers learning opportunities anywhere and anytime. Mobile Collaborative Learning (MCL) has been getting more importance in educational environment as one type of mobile learning application. This paper introduces the theoretical and technical foundations for designing and developing an effective MCL environment as well as describing a new approach for building a learning application towards mobile technology. Finally the proposed prototype will be designed and constructed using the Android operating system with a suggestive infrastructure for this type of system**.

Keywords-Component; Mobile Learning; Mobile Collaborative Learning; Usability Test; Usability Factors

I. INTRODUCTION

Use of mobile devices has steadily grown in popularity to become one of the most common consumer devices. Mobile devices have expanded in functionality from merely a device to dial numbers to personal digital assistants, and also they are cheaper in comparison to laptop computers so that we can carry and use them anywhere. These technologies have also been changing the educational landscape and the programs of colleges/universities since new technologies propose different learning skill. Mobile applications these days are more flexible and can integrate the existing services by employing web-based interfaces. Several attractive learning tools have been designed and developed by integrating with such emerging technologies as motion sensor, camera, global positioning system, Wi-Fi, Bluetooth, and etc. Many attractive tools and techniques will be continuously integrated for creating an effective learning environment in the future.

Collaborative learning is based on the idea that learning is a naturally social act in which the learners talk among themselves. It is becoming more and more important everyday within all educational environments as being implanted from primary school to university. With the advanced wireless technology, mobile devices are reaching all levels of our educational learning levels. Mobile technology has been adapted as a main communication since it is well suited in engaging collaborative learning environments. The concept of Mobile Collaborative Learning (MCL) is completely different from classroom-based learning. This pedagogical method of the learning provides many possibilities, such as providing opportunities to the group of people, working in same or different organizations to participate in accomplishment of specific goal using mobile devices.

Thus, the demand of collaboration learning over the mobile device has been increasing as a major education element. Major research challenges are raised in developing MCL for educational object such as sharing knowledge, requesting for modified contents, fully accessing to Enterprise Data Warehouse (EDW), delivering large rich multimedia contents, selecting technological components in designing appropriate architecture and adapting application protocols. In this paper, we propose a conceptual prototype including a communication protocol to deliver large rich multimedia contents, an improvement of knowledge sharing process, a provision of easy access for all users, and a containment of content modification facility. Another contribution in the paper is to indicate usability issues which are necessarily considered to make the application easily obtain succinct information and take fast feedback through MCL.

II. RELATED WORK

Multiple studies have focused on MCL applications. There are various classifications about designing and developing collaborative learning on wireless mobile technology. Basically these approaches have focused on how to support mobile devices, how to use wireless communication technologies, and how to make digital contents provide for user-required information. We introduce several salient features of related published articles which contributed to our work. D. Digenti, [4], concerns the practice of collaborative learning – a practice that comprises a vital organizational capability in the twenty-first century. She also mentions collaborative learning cycle to build, enhance, or transfer learning competence. X. Su and others [2] proposed a four- layer framework prototype for multimedia content generation in mobile collaborative systems. The proposed framework provides support for users, devices, and session management skill. This research offers a novel framework for multimedia content generation, representation, and delivery for Mobile Collaboration. However, the framework is not completely elaborated and lacks incorporation of many components.

V. Zanev, and R. Clark, [3] suggest the procedures for developing a prototype used for wireless course management system focus on login and authentication, wireless syllabus, wireless calendar and wireless testing. In addition, these authors describe the course content by explaining how a teacher can interact with students by using a HTML interface. F. Lahner, and H. Nosekabel, [5] have implemented a program which can support e-learning contents to be displayed on computers, and the system structure provides users with the facility to obtain same contents via mobiles. J. Barbosa and others [6] proposed a prototype for undergraduate course reference, called Grefe, which employs mobile and ubiquitous computing. Authors claimed that their approach will improve academic and learning activities. The prototype is based on

user profile which stores the information regarding learning process and uses location system, so it can identify users' physical location and support learning procedures by generic architecture. However, the proposed prototype does not provide mobile collaborative learning; it suggests a generic idea of online learning process.

A. Druin and others [7] discuss the prototype for their ongoing participatory design project with intergenerational design group to create mobile application and integrate into iPhone and ipod touch platforms. R. Gafni, [17] examines the quality problems resulting from the characteristics of mobile learning systems; propose some metrics to measure their quality and some practical implications for the designer and developers. C. Bouras and others [8] have introduced INVITE architecture and discussed user requirements to meet the demand of e-learning in collaborative virtual environment. Although it does not lead to the existence of any solid prototype; it can show the technology and standards required for designing MCL. Finally, K. B. Lee, and R. A. Grice, [13] refer to the usability testing method for mobile devices. They introduce a general theoretical background for the usability testing, describe several evaluation methods, and show how to fit the mobile product being designed. An extension is done to R. Salman's research [19] propose that a simple mobile internet application for course scheduling would be a successful in future development.

III. MOBILE COLLABORATION LEARNING ENVIRONMENT

Collaborative learning is an umbrella term for a variety of educational approaches involving joint intellectual effort by students or students and teacher together. Collaborative learning represents a significant shift away from the typical teacher or lecture-centered milieu in college classroom. To build collaborative learning competence, generally the following cycle is proposed as a road map. Fig. 1 shows the phases of the collaborative learning cycles [4].

- Collaborative Capability Assessment
- Creation of Boundary-Spanning Skills
- Practicing Collaborative Learning
- Capturing and Disseminating Learning
- Creative Value
- Enhancing Interdependence

To collaborate is to mainly work with another or others. In practice, collaborative learning has come to mean students working in pairs or small groups to achieve shared learning goals. To perform collaboration learning well, basically we will request to make parallel learning groups which are created to open new channel of communication outside and parallel to the normal, hierarchical structure of each organization. The parallel learning group should be composed of a diverse group of individuals, from different divisions and functions.

Today, there is no doubt that we are becoming a much more mobile society. Mobile technology is able to support ubiquity and mobile is the "go to" device for staying connected. Mobile learning is defined as all "knowledge in the hand" and by using mobile communication, it can include the use of mobile devices to perform any of the following [21]:

- Deliver education/learning
- Foster communications/collaboration
- Conduct assessments/evaluations
- Provide access to performance support/knowledge

Any type of mobile devices can quickly and easily deliver and support these functions. Sharing and gathering knowledge and materials are the major difficulty in the traditional process of collaborative learning environment. However, there is not much difficulty in organize grouping of diverse generation, cultural and national background in parallel by using mobile devices and communication.

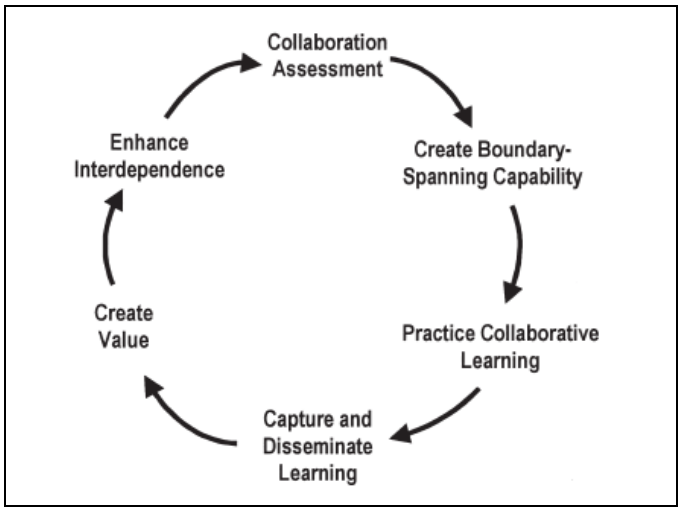

Figure 1 The collaborative learning cycles[1]

Furthermore, the collaboration learning system with a mobile should include greater access to necessary content and information timely, reduced cognitive load during learning tasks and increased interaction with diverse users and other information systems horizontally. Mobile devices are becoming one of the necessary tools to improve collaboration learning performance. Therefore, for a successful development of collaborative learning with mobile devices, many hardware and software components will be considered to be integrated with users to promote effectively knowledge delivery. Usually, a number of items should be involved in the implementation of MCL, in general, the following items will be considered.

A. Learning Mobile Devices

In the mobile learning environment, the mobile devices are classified by the type of hardware size (notebooks, tablet PCs, PDAs, cell phones, or smart phones) and the type of wireless communication technologies (GSM, CDMA, WiFi, IEEE 802.11, Bluetooth, etc.) according to the information and communication technologies (ICT).

B. Middleware Structures

The mobile learning system should be designed to support mobile learning application using a wide variety of languages, platforms, and technologies. In the learning system, the middleware structure should support basic frameworks for students' learning work. And also the system should be developed to be used in different types of devices and communication vendors in a geographically distributed ubiquitous environment. Many different types of media and

[1] D. Digenti, "Collaborative Learning: A Core Capability for Organizations in the New Economy," Society for Organizational Learning, Vol. 1, Issue 2, 1999, pp. 45-57.

streaming files will be run for learning methodologies to deal with illiteracy, education programs, and other services.

To implement a system, it will require a user-oriented design approach to correctly support educational goal, know usability issues, and also know a proper wireless communication protocol fitting for learning mode in mobile devices. For constructing these middleware, the universities or organizations need to find co-workers who are able to support students' learning methodology and design a protocol which can support stable communication environment for running the application.

C. Learning Applications

The mobile learning application is a software product for mobile devices. To access lectures on an individual student mobile device, the required application should be downloaded from their organization website or other places. The application provides a great mobile- based platform for learners to use the learning system and to develop templates that would be useful in the workplace.

Once completely downloaded, it must be installed into their mobile devices. The application displays a process icon on the mobile screen indicating the group members who are currently accessing the topic or class. Also the learning application should include a media player supporting audio and video files, and opening lecture materials without discontinuity. The initial display should contain titles and abstraction of the courses that a student has registered.

To be a successful MCL learning application, basically the running tools should be included to support the following options: visualized collaborating processes, discussion processes, accessing users, and also other mobile learning options such as class lectures, tests, interactive quizzes, grade and so on. Furthermore, to shape a culturally sensitive learning experience, the application will require multimedia- oriented network environments. Finally, it is very important to elaborately design a learning application that will be developed to be combined with the support of middleware architecture configuration.

D. Other Factors

Mostly, mobile learning materials can be obtained from service providers that are able to support various digital educational contents. Learning materials will be placed on a server database, so that data or files can be easily saved or retrieved upon users' request. Therefore, many factors will be considered for designing and developing learning database on server's side. Furthermore, we should consider mobile devices themselves which possess several weak points in hardware, such as low CPU usage, small memory size, short battery life and others. And also it can make many other security related issues to be used in communication and network.

IV. DESIGN ISSUES FOR MCL APPLICATION

One of the highly challenging tasks for designing and developing the prototype of MCL application is to recognize current limitations and understand what users' requirements are, so that we get to learn how to reflect and satisfy the required functionalities of application and architecture. MCL application is part of mobile learning systems; it may suffer from the same problems as the general e-learning systems have undergone. In this part, we review the existing problems and try to search for design concerns from two prospective: mobile communication and MCL application.

A. Finding Problems

Mobility is the largest benefit in MCL process as we mentioned above. However there are still unique problems caused by mobile hardware limitation and carrier network environment [17]. The mobile devices cause problems as follows:

- The devices have technical limitation such as small memories, short battery life, limited calculation, and computation capabilities.
- There is a wide variety of devices possessing different characteristics, so the application must be adaptable to all of them.
- The devices' use is uncomfortable because of their size: tiny screens, small keyboards.
- Security problems can arise when mobile devices are lost, due to possible unauthorized access.

Also, when using the learning system over the wireless network for wide audience, the network causes other problems as follows:

- Limited bandwidth that influences video-clips' display directly.
- Slow or inconsistent connections stability and transfer delays that interfere with learning continuity.
- Varied standards and protocols, some with high overhead, decrease performances level.
- Issues of security, privacy, and confidentiality will arise.
- High costs of operations, especially when users are low-budget students.

Successful mobile applications tend to consider the above restrictions when installing and developing a new MCL. However, various conceptual collaborative learning applications proposed do not suggest a total solution covering these issues. There lies a small difference between designing a new MCL in the paper and other forms of previous learning applications.

B. Searching Tips

We found five guidelines for developers who are setting and implementing a new MCL over the networks as follows:

- Keep it short and simple: This is a significant rule applied to all types of learning content and mobile learning content.
- Low information density: Do not try to duplicate the length and information density of learning modules.
- Include elements of collaboration: When using a part of a blended program, mobile devices can be used to facilitate interaction among peers, experts, mentors, etc.
- Easy to access multimedia: This is important because visualized presentations are much better than others.

- Easy to integrate with 3rd applications: Mobiles' ability to compute and display, to combine with their tools, to access into searching and information databases, games, and simulation.

In addition, awareness of the constraints of novel user interfaces is also vital because mobile devices suffer from small screens and restrictive input modes as we mentioned above. Most literatures concerning to mobile learning design tend to simply map learning context and objectives. However, collaborative learning activities are different since they have turned toward students' collaborative capability. Therefore, before designing a new MCL application, we suggest proper middleware architecture providing well organized protocol based on four layers in the following part. It will make us explicitly identify functionality and content representation support over learning application.

V. PROPOSED MIDDLEWARE ARCHITECHTURE

To make a successful collaboration meeting for users' expectations, we need to organize architecture with support of the latest technologies. Learning system should be designed on client-server based infrastructure to avoid running overload on mobile devices. In the client side, mobile devices, notebooks, tablet PCs, PDAs, cell phones, smart phones and other devices can access to content server using wireless technologies. M. Shanmugapriya and A. Tamilarashi [11] suggested a mobile learning architecture in their previous paper as seen in Fig. 2 Students learn anywhere outside classroom and they use diverse devices to link the server module that runs on university server through web services middleware architecture in order to attend learning process.

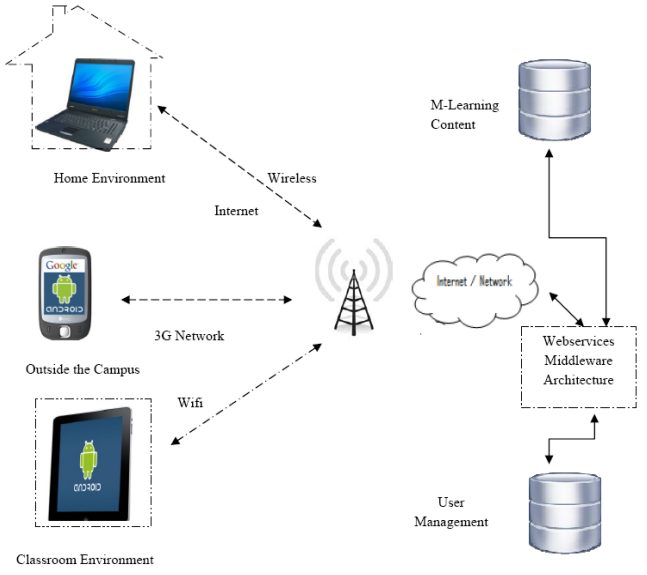

Figure 2 Mobile learning applications for ubiquitous learning environment

The learning system for this prototype also adapted and modified four-layered components of collaborative framework proposed by X. Su and others [2], which consists of content generation layer, communication layer, content regeneration layer, and content visualization layer. The architecture has been optimized and clearly defined with inclusion of new sub components, and each layer has been assigned a different responsibility. Fig. 3 depicts the conceptual and architectural framework for the mobile collaborative learning environment. Thus, for constructing these middleware, the university or organization should need to co-work with a mobile service provider which is able to support e-learning. This approach can be more helpful for the institution to provide online course preparations on the interest of students.

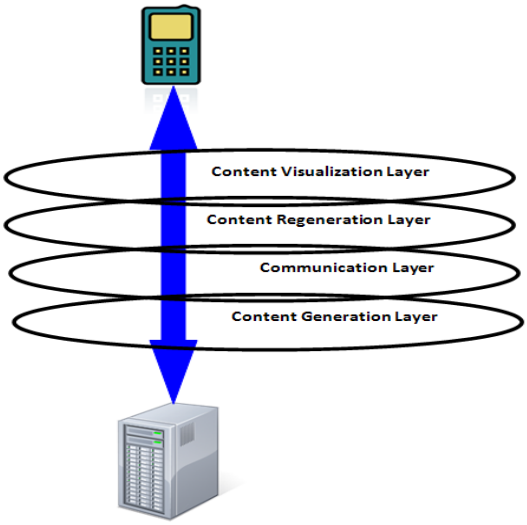

Figure 3 Conceptual and architectural framework for the mobile collaborative learning environment

A. Content Generation Layer

Content generation layer is the main component of collaborative framework. If clients require contents, they send the request message to the content server for delivering required contents. The request message includes device profile, status of previous network condition and requested URL.

B. Communication Layer

This layer functions as a transport layer. By detecting network status and amount of data, the layer decides whether to store messages or to use additional function such as content fragmentation. In the case of no network connectivity network disconnectivity, the layer forward stored messages to recipients.

C. Content Regeneration Layer

This layer performs two types of tasks: first, it forwards contents to display and visualization layer for the next process; second, if clients request to modify the contents in the middle of a process, the layer also starts to work on the demand.

D. Content Display and Visualization Layer

The function of this layer is to display and hand over contents to clients. The layer can obtain contents from several media managers, and then start to display contents in several types of forms, graphs, images, voice and others as clients' request. Therefore, the main function of this layer is to translate the source program into an object program that is done with the support of parse engine.

This proposed middleware architecture can be applied to mobile collaboration activities. It is also easy to allow collaboration via wireless network and mobile devices. In general, types of media content which are commonly transmitted in a collaborative system include graphics, text messages, images, voice, and so on. Within this framework, a multimedia format that can be represented as a single, unified format and transmitted as a messages queue would simply the overall communication mechanism. So it can simplify data

stream between client and server, and effectively improve efficiency of collaboration.

VI. DEVELOPMENT OF MCL APPLICATION

MCL applications will be a stand-alone application that use and terminate services when they are no longer needed. It also should be designed as a client-server model using Window forms or Web browser application as seen in Fig 4. Android is an open-source mobile operating system and an application framework supported by Google. By providing an open development platform, Android offers developers ability to build extremely rich and innovative application with a rich set of user interfaces.

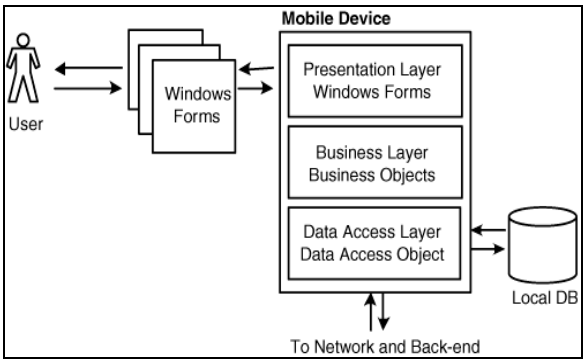

Figure 4 Basic MCL architecture

MCL allows users to obtain computer-based information through mobile devices. Using MCL provides various advantages, such as context awareness, portability, connectivity, and social interaction. As we mentioned early, a mobile can be a successful tool for collaboration that allows students to share information to involve in pedagogical activities. While factors of a development plan may vary according to organization size and extent of work, the best MCL development should begins with a well-designed collaboration plan. Fig. 5 shows the MCL running processes on the prototype.

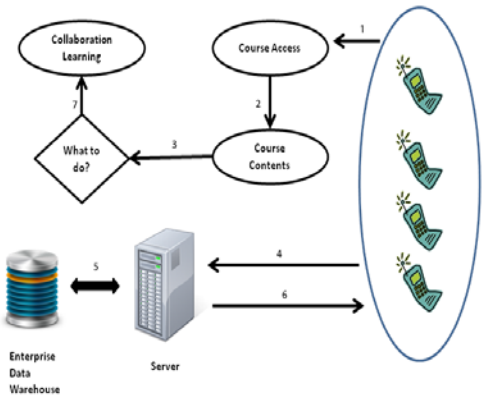

Figure 5 Collaborative learning processes

Once students have an access into registered class, they receive inquiry on whether participating collaboration learning process depending on class requirements. The prototype for MCL is designed for users to easily make collaboration with a mobile. In general, it requires enterprise database warehouse (EDW) to help students find and search necessary information or contents when logging into a class. Initially, EDW provides standard course information which comprises of textbook information, course name, course ID, course description, discussion topics, etc. In a well-organized collaborative learning environment, it is very important to set suitable group members and build a study forum based on topic.

Communication with the forum is necessary to construct a more get-together and affinity group, and also it accommodates easy ways to set a goal and find the same goal. Generally, the following collaborative activities will be required for the MCL application [12]:

- Grouping members
- Monitoring each member
- Displaying member status
- Synchronizing multiple discussion
- Delivering messages

A. Authentication Process

As seen in Fig. 6, an icon displays on mobile devices after being downloaded. To protect user profile and system security, MCL requires authentication process. Thus, after executing the application, it requests user authentication in order to avoid fault users or lost of priority data, as it can be seen in Fig. 6. Once the process completes, the application should forward to a new page containing the course a student has registered in the quarter or semester.

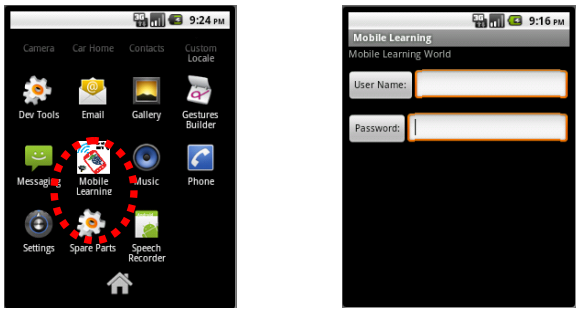

Figure 6 Launching MCL application on mobile devices

B. Join Collaborative Learning

After completing the login process, a new application "Join Group" with a new feature is ready to support a user to mange group communication method as seen in Fig. 7. Students input their name to join the selected group, so they can research the current topic to go into the collaborating procedure.

Figure 7 Joining collaboration

By displaying the progressing bar on each collaboration procedure as seen in Fig. 7, a student can check the current progress and also measure maturity for discussion over given topics. It also can increase collaborative capability assessment which is a factor to increase collaboration strength. Ultimately, the bar should be changed on the numbers of feedback from

students, thus it can be used to measure knowledge value over the topic.

C. Post Opinions and Interact with Others

Students post their opinions about a topic on the board like other online education tool. To avoid information density, the application encourages users to use one page screen space and not to use any decoration. Uploading information should be split by the one page space size, and also by adding overview screens to review the abstraction. Users can easily find and search individual post to expand short-term memory for users.

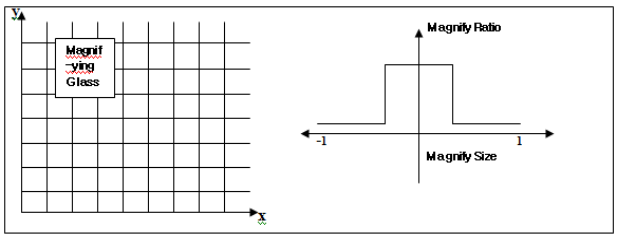

Figure 8 Magnifying glass

As seen in Fig. 8, a magnifying glass comprised of discontinuous zooming methods adds into viewing tools with the support different zooming screen. When moving the glass, the movement area is done with interactive magnification. Students are always able to magnify what is being displayed. In Fig. 9, the magnifying area shows detailed view of a two-dimensional form and other regions remain to be seen de-magnified according to their physical position. Thus, display is generated by cutting and pasting various sections of these bit maps in real time to generate a magnifying area.

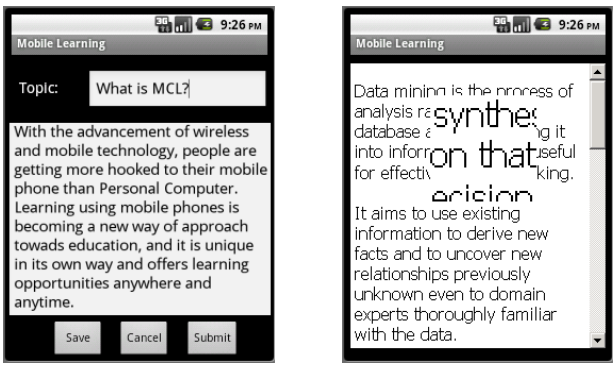

Figure 9 Posting and viewing operations

Although the magnify glass does not provide good spatial continuity between regions, it is a relatively simple approach in terms of use and implementation, and it can avoid much of computational power of hardware and system memory that was needed in distorted view. This approach helps to reduce cognitive load by exploiting the human perceptual system. It is low occupied memory storage and supports a good viewing on relatively small memory and low CPU mobile devices.

D. Add and Share Resources

Allowing group members to add and share resources is a necessary factor in collaborative learning procedures because resources shall be a backbone to promote knowledge and be a conductor to encourage students to join a topic, as it can be seen in Fig. 10. To add a resource, students input their names and tell the media resource type. If students want to share resources to a specific group, they must notify the group name and write a small note on the board for easy tracing resource information. Definitely, these media resources should be played on media window which adapts the 3rd applications in Android.

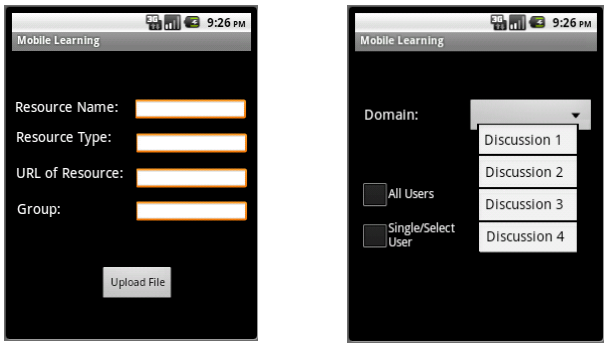

Figure 10 Adding and sharing resources

E. Interact with a Mobile Learning Class

MCL should connect with online classes, in which way, students can go out for accessing and completing the class room upon their request. In MCL, online classes should include three types of windows, namely media windows, lecture window, and class network window, as seen in Fig. 11. Each window was originally designed on employing zooming technology for increasing usability.

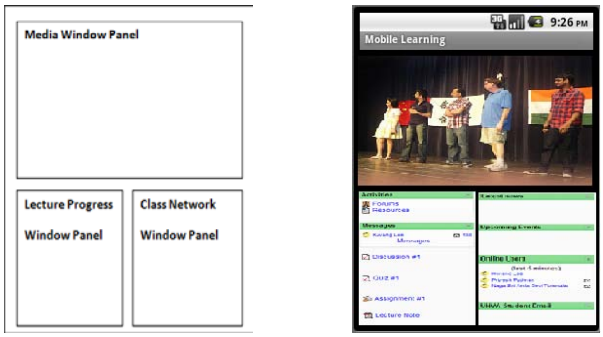

Figure 11 Mobile Learning class

By using zooming interfaces, users can have much opportunity to adjust screen based on their focus. If user selects one window panel out of three, then other two windows should be shrunk, which was known as fish-eye lens. By adapting the approach, the learning system would overcome one of the open problems caused by small sized screen.

For implementing a new MCL application, we would set to conduct the final empirical testing plan which will affect the way of modifying and redesigning the prototype. From this part, we will discuss usability factors for the testing procedures which shall be used to extract and find human factors from MCL applications.

VII. FINDING USABILITY FACTORS

One of the most challenging activities for designing and developing the prototype is to understand what user requirements are and how to reflect and satisfy the required functionalities of application and architecture. MCL application is not an exception. Determining groupware users' needs in advance and creating correspondent software may seem uncomplicated. Therefore, before conducting the final usability test, we should know the factors that will deeply affect MCL usability, so that we can more easily conclude setting basic user needs and requirements. It is also a necessary process to develop empirical testing procedure, which is a combined

testing approach based on heuristic and other formal methods [13].

A. Collecting Users

To find meaningful issues, 106 testing users including 58 students, 23 teachers, 14 teaching assistants and 11 administrators from fifteen universities, are involved. To find pilot usability issues, these people would join in the test as online status.

B. Selecting Evaluation Items

In order to take initial valuable suggestions for building an efficient MCL structure, we have surveyed evaluation items via previous literature [9], [10]. Then we identified and collected necessary items in Table 1. All of the items were selected based on pedagogical needs for supporting MCL throughout interviews and consultation with experts. To classify and find more valuable usability items, a heuristic based questionnaire test will be conducted by the above users using the evaluation items.

TABLE 1 EVALUATION ITEMS

Selected Evaluation Items
• Should be easy to use
• Asynchronous collaboration
• Synchronous collaboration
• To support multi model MCL
• To provide archive updating
• Should be user friendly interface
• To get a help from middle ware
• To give virtual support
• To provide application sharing facility and make easy text communication
• To provide admission functionality, if any user wants to participate in the middle a session
• The administrators should be provided with opportunities to record the collaborative activities of students and teachers during the whole session or any specific period of time
• To provide the opportunities for interactive and shard white board
• Users may need short start time for collaboration
• Server should provide content adoption service
• Students should have alternative choices in selecting any topic for discussion
• Students should have access to check comments given by teachers regarding their performance and grades
• Teacher should include critical notes for performance of each student after completion of MCL session and provide feedback to improve students in the future
• To provide audio and video communication only
• To provide connectivity management support
• To provide support for session management
• To provide checking facilities to instructors to check group members
• To provide freedom of thoughts to participating group members
• Server should give messages of information updating
• To provide facilities of translation of audio, video and text to other languages
• Client should give notification of his/ her availability
• To provide support for users' role
• Portfolio should be created in order to store information regarding to courses
• To include group manager component
• Methods of communication should be direct or mediated
• Available digital materials should be integrated easily
• Instructor should dedicate time to monitor the progress of participating members
• To provide support to handle shared information
• To provide privacy and safety
• Communication should be based on broadcast with support of multicasting
• To make small participating group for collaboration
• To provide support for floor control administration
• To be flexible to collect and extract the data
• To provide text, graphs, images, audio and video services to meet the requirements of related course of study
• Teachers should have complete access to administer their courses and evaluate progress of students

C. Conducting the Test for Finding Usability Factors

The usability test is completed by 106 people using Vista survey. Basically, all of questions focus on finding parameters which are mostly efficient factors when designing the MCL application. To completely evaluate each item, we employ five-point Likert Scale method. In the testing questionnaires, the five-point Likert items are specified such as Strongly Agree=1, Agree=2, Neutral/No Opinion=3, Disagree=4 and Strongly Disagree=5. Finally, we sort out main points from the obtained result, and add mean value to each item, basic requirement = (strongly agree + agree + no opinions)/3×100. The final result can be shown in Table 2.

TABLE 2 MAIN VALUES FOR SELECTED ITEMS

No	**Description of Basic Requirement**	**Mean Response**
1	Should be easy to use	100%
2	Should be User friendly interface	100%
3	To be flexible to collect and extract data.	99.69%
4	To provide text, graphs, images, audio and video services to meet requirements of related course of study	99.49%
5	Teachers should have complete access to administer their courses and evaluate progress of students	98.99%
6	To support multi model MCL	98.09%
7	Administrators should be provided with opportunities to record the collaborative activities of students and teachers during the whole session or any specific period of time.	97.59%
8	Teachers should include critical notes for the performance of each student after	97.48%
9	Students should have alternative choices in selecting any topic for discussion.	97.28%
10	Students should have access to check comments given by teachers regarding to their performance and grades	97.28%
11	To provide privacy and safety	88.35%
12	To provide facility to contact and invite participation for collaboration	83.83%

According to the results, we can set a new plan to modify and redesign the prototype, and then conduct the final empirical testing over the new MCL application. All these testing procedures shall be useful to understand the type of applications required for designing and developing the new MCL application.

VIII. CONCLUSIONS

The main contribution of this research is the design and development of a MCL prototype. Collaborative learning seems to be a teaching and learning innovation whose time has come. It will make a student actively engage in building their own minds. Basically, the main objective of MCL is to obtain learning advantages on hand-held devices particularly mobile devices which allow accessing and sharing of learning materials anywhere and anytime.

Several contributions are proposed to accommodate further research work for improving MCL environment throughout the research paper. First, we have adapted four-layered architecture which was explained previously. The adapted four-layer architecture can provide an efficient and fast way of delivering the contents to mobile devices. Second, we have introduced the client-server based MCL prototype architecture for improving

education environments. The design and development of MCL using client-server based architecture should be a fast and secure method to share and deliver contents. Third, we have proposed and implemented the MCL application prototype with recommending and explaining valuable suggestions on how to use Android operating systems and how to meet course objectives. Finally, we have discussed the MCL user requirements by conducting a usability test to design and develop a new MCL application to meet the pedagogical requirements of students, teachers, teaching assistants, and administrators.

Although this approach is to devise a basic method for efficiently building an MCL application, there are still uncovered problems in applying for a commercial mobile application directly. However, the architecture will properly meet the current challenge of MCL and we will keep focusing on implementing the whole group application to meet new user needs and requirements. We look forward to continuing our research and developing an application based on the future progress of mobile software and hardware performance. Therefore, the biggest contribution of the paper is to provide a small step for how to design and implement MCL in order to meet pedagogical needs.

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