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Development of Mobile Adaptive Learning Application using Adaptation Layer

Kwang B. Lee
Computer Science
Slippery Rock University of Pennsylvania
Slippery Rock, Pennsylvania, USA

Jamie W. Lee
Machine Learning Machine Intelligence
University of Cambridge
Cambridge, UK

***Abstract*—Education technology is constantly evolving and growing with mobile wireless technology. Learning through the use of mobile phones is becoming a new way of approach towards education, and it is unique in its own way and offers learning opportunities anywhere and anytime. Mobile learning has been receiving more importance in the educational environment. This paper presents the theoretical and technical foundations for designing and developing a mobile adaptive layer for a learning environment. Additionally, we describe a new approach for building an adaptive mobile learning application for mobile technology. Finally, the paper proposes a prototype of an application with an iconic interface, shows an application to adapt learners' preferences, and discusses the flow-chart explaining procedures in the implementation of the adaptive mobile learning application to meet the pedagogical requirements.**

Keywords—Middleware, adaptation layer, adaptive mobile learning application

I. INTRODUCTION

The use of mobile technology for learning has been developed in various ways in accordance with the global market and the advent and deployment of new technologies. The latest technological revolution is the emergence of mobile wireless communication technology, and this rapid progress in mobile technology has created a new area known as a mobile learning technology. With the incorporation of emerging hardware and software technologies in mobile devices, such as motion sensors, cameras, global positioning systems, infra-red, Bluetooth, and other AI technologies supported by broadband connections, mobile devices are beginning to support different types of learning applications. Now, they are more flexible to integrate into existing services by employing web-based interfaces; therefore, mobile devices have become attractive tools to complete the demand for adaptive learning. Along with the rapidly increasing development of mobile technology and communication, the learning process has evolved to become a process that can be done anywhere and anytime. Mobile technology is becoming an integral learning tool for education while it is not intended to replace the face-to-face classroom learning, but to provide a relationship between eLearning and classroom instruction.

Like other applications, mobile applications need to communicate with back-end systems, such as directory services, file servers, databases, or storage services in order to access the data and services they need to conduct the learning process [26]. Developers are required to use middleware platforms to make it easier for them to connect their mobile applications to corporate resources, because the applications run on devices with less processing power and memory than a typical desktop. A developer can build an improved quality distributed software by using the most appropriate, correct, and efficient solutions embedded in the middleware. In order to provide effective learning experiences, mobile learning applications should be usable and compatible with the cognitive skills of students. Thus, the mobile learning system must be adaptive to the demands. Adaptivity allows the applications to modify their behavior, instead of providing a uniform interface to all situations. The middleware needs to monitor supply/demand of the resource, compute adaptation decisions, and notify applications about changes.

In this research, we will develop mobile application technology-based adaptive learning media on information system material. In order to provide effective support for an adaptive learning environment, we mainly focus on the research of the adaptation layer in this article, which enables an effective combination of collected evidence according to adapted elements from various factors. To support these issues, we propose a client and server-based prototype with a middleware containing an adaptation layer to customize mobile learning environment factors. We also design and develop early prototypes of applications that can provide reliable learning applications.

II. RELATED WORKS

In the last few years, mobile devices have grown in popularity, and their technologies have become pervasive and ubiquitous, and they have been networked with enhanced capabilities for rich social interactions. Multiple studies have focused on extracting, parsing, and reorganizing web pages for customizing information. Xiaoyong Su and others [1] propose a four-layer framework prototype for multimedia content generation in mobile collaborative systems. The proposed framework provides the support for users and devices, and session management skill for administrators. Jihen Malek and others [2] define middleware architecture to support connection between M-learning and context, and describe the design of a context-aware middleware (with an emphasis on controlling the environment) along with the aim of supporting M-learning. I Made Agus Wirawan and others [3] implement a program which can support e-learning contents to be displayed on computers, in which the system structure provides users with the ability to obtain the same contents via mobiles. Sergio Martin and others [5] introduce a middleware intended to support the development of mashup applications in mobile and ubiquitous learning environments. Its framework integrates different contextual information (e.g., geographic location, profile, history) and services (from eLearning platforms or other learning tools). The integration of the services into the

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middleware is carried out through a reconfigurable plug-and-play architecture based on Web Services. Furthermore, Brita Curum and others [8] develop a context-aware mobile learning framework, AMBLE, which processes contextual data at four distinct levels: Sensing Layer, Adaptation Layer, Context Processing Layer, and Application Layer, to perform an adaptation of learning contents based on the actual environment and conditions of the learner. Personalized services have a greater impact on the user experience to affect the level of user satisfaction. Jamil Hussain and others [9] propose a domain and device-independent and model-based adaptive user interfacing methodology. This research methodology is implemented as an adaptive UI/UX authoring tool, and this system is capable of adapting user interface based on the utilization of contextual factors, such as user disabilities, environmental factors (e.g., light level, noise level, and location), and device use (at runtime using the adaptation rules devised for rendering the adapted interface). Rabail Tahir and Fahim Arif [10] discuss a usability evaluation for 'mobile learning user interface for children' to measure the usefulness of this application. This usability evaluation consists of guidelines, usability characteristics, goals (interface design criteria), questions, usability metrics (objective and subjective), and two evaluation instruments (task list and satisfaction questionnaire). Lastly, this paper is a revised version published last year by Kwang Lee and Jaesung Sim [20].

III. MOBILE LEARNING ENVIRONMENT

The mobile learning system should include timely access to necessary content and information, reduce cognitive load during learning tasks, and increase interaction with users and other systems. It serves as a default media player supporting audio and video files, and opens the lecture materials without discontinuity. Generally, the following running options must be included in the mobile learning environments:

- Lecture Video
- Lecture Note
- Audio
- Quiz and Test
- Assignment
- User Forum
- Discussion
- Grade

To shape a culturally sensitive learning experience, mobile devices will require multimedia-oriented network environments, so it is important to design and develop the wireless-based middleware architecture based on them.

A. Requirements for the System

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

B. Proposed Infrastructure

The mobile learning system should be designed on the client and server-based infrastructure to avoid overload on mobile devices. On the client-side, mobile devices, notebooks, Tablet PCs, PDAs, cell phones, smartphones, and other devices can access the content server by using wireless technologies. Also, using a wide variety of languages, platforms, and technologies should be considered in designing mobile learning applications.

C. Possible Middleware for Mobile Learning

In the mobile learning system, the middleware structure must be a framework that supports students' learning work and communication vendors' operations in a geographically distributed ubiquitous environment. Many different types of media and streaming files will be executed for learning methodologies, which deal with illiteracy, education programs, and other services. For a structure, this middleware requires a user-oriented design approach to correctly support the educational goal, and to know usability issues and a proper wireless communication protocol fitting for learning mode in mobiles. Furthermore, the university should contact a mobile service provider which is able to support e-learning. This approach can help the institution to provide online course preparations in the interest of students.

D. Learning Applications

The mobile learning application is software for mobile devices. To access lectures for students on their individual mobile devices, the required application should be designed to be downloaded from their university websites or other secure places. Once completed the download, the application must be installed onto their mobile devices as an icon, and it can display an initial process on the mobile screen indicating the group members who are currently accessing the topic or class, besides, the initial display should contain the titles and abstraction of the courses that a student has registered to. This type of software release would be more secure and comfortable for students. For learning applications to be successful, the learning tool should include adaptive processes, collaboration processes, discussion topics, class lectures, tests, interactive quizzes, user forums, and so on.

E. Other Considering Factors

Generally, the mobile learning materials can be obtained from various digital content service providers and should be placed on a server where data or files can be easily saved or retrieved upon users' request. Therefore, many factors will be considered for designing and developing EDW, wireless protocols, and software applications to be able to communicate with students without errors. Also, we should consider the fact that a mobile device by itself includes several weak points in hardware, such as low CPU usage, small memory size, short battery life, and others. Furthermore, it can make many other security-related issues in communication and network.

IV. CONCEPTUAL MIDDLEWARE ARCHITECTURE

As indicated by Sergio Martin and others [5], mobile learning must complement both e-learning and traditional learning. The mobile learning applications should support education out of class, not replace face-to-face class, but also provide collaborative education with other students. The ideal mobile middleware architecture has a server element from which logical applications are delivered, as seen in Figure 1. As software, a middleware connects disparate mobile applications, programs, and systems running on distributed hosts. Furthermore, the middleware, which can support the content construction of such mobile learning applications must be light-weight in order to run on resource-constrained devices.

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Fig. 1. Mobile learning middleware for managing educational contents

The middleware must also adapt variations in the context of execution depending on the mobile hardware computing environments, users' learning modalities, or preferences. Sergio Martin and others [5] introduce the middleware of the mobile learning developments containing four main middleware modules as follows:

- Location Manager - Manages the information from the location sensors (e.g., GPS, RFID, Wi-Fi) to provide contextual information about the user's location. The system has been designed to use open interfaces in order to simplify the addition of other technologies (e.g., new location methods such as cell towers or Bluetooth).
- Profile Manager - Manages a user's personal information, such as preferences, contact information, or credentials. This module also manages other interesting information about the device: operating system, Internet browser version, etc.
- Post-processing manager - Processes the contextual information provided by the location and profile managers to access other services, e.g., information in an LMS, e-mail, etc., to get more contextual information.
- Adaptation layer - This is the most important layer in the architecture because it offers an interface (API) to top level applications.

Various conceptual architectures have been proposed so far. The learning system for this prototype proposed by Xiaoyong Su and others [1] adapts and modifies four-layered components of the collaborative framework which consists of a content generation layer, communication layer, content regeneration layer, and content visualization layer. Additionally, Malek and others [2] propose adapting middleware to manage the context in terms of the learners and mobile learning needs. The architecture has been optimized and clearly defines the inclusion of new sub-components, while each layer is assigned to a different responsibility. To successfully construct an adaptive mobile learning system, we need to organize the architecture with the support of the latest technologies. Figure. 2 depicts the conceptual and architectural framework for the adaptive mobile learning environment. Our middleware supports most of the adaptation tasks involved.

A. Communication Layer

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

B. Content Layer

The content generation layer is the main component of the collaborative framework. If clients require content, then they send the requested message to the content server to deliver the required contents. The requested message includes the device profile, status of previous network condition, and requested URL. Furthermore, this layer performs two types of tasks: first, it forwards the content to display and visualization layer for the next process; second, if clients request to modify the content in the middle of the process, then it also starts to work on the demand.

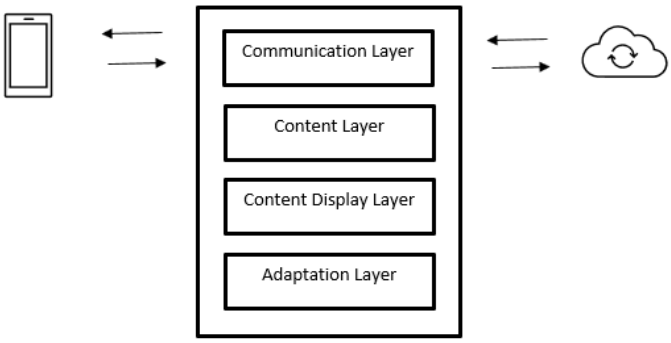

Fig. 2. Conceptual middleware components for adaptive learning

C. Content Display Layer

The function of the content display layer is to display and hand over the contents to clients. This layer can obtain the contents from several media managers, and then begin to display the contents in several different formats, such as graphs, images, voice, and others as per the client's request. Therefore, the main function of this layer is to translate the source program into an object program, which is completed with the support of a parsing engine.

D. Adaptation Layer

The affective learning model uses an adaptation layer for effective user modeling. This layer performs to identify the contextual elements relevant to mobile learning in order to define which elements can be adapted and also build a middleware level support between mobile learning and the context for managing and adapting that context. Therefore, the main operation of this layer is to support the most appropriate learning content to users' actual needs.

V. PROPOSED ADAPTATION LAYER FOR MOBILE LEARNING

The successful development of education-learning services on the widespread diffusion of mobile devices requires the adaptation technologies which must be applied to the mobile learning environment and content, in order to meet learner's needs and preferences, as well as device characteristics. The diversity of mobile device capabilities, learner's needs and preferences, and supported content formats and contexts of use have called for standards, metadata, and adaptation mechanisms. These factors must be applied to the learning environment and content in order to provide the best educational experience to learners. To encourage these factors in the field of mobile learning, some literatures describe the need for standards and adaptation mechanisms throughout open-source projects and libraries. In this section, we present

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some of the different approaches to adaptation methods that are already present in literature, and suggest the proposed adaptation layer in the mobile learning environment.

The purpose of the adaptive mobile learning system is to produce a reliable way of expression to demonstrate what the student understands and can do, what he/she does not understand and cannot do, what he/she wants to do, as well as what he/she should do. The basic idea of using an adaptive mobile learning system is a student-centered and targeted study guide digital platform according to the student mastery and acceptance of knowledge. It has the following characteristics [4]:

- Adaptability: The system automatically provides the learner with the most suitable knowledge to learn through interactions with the learner based on recognizing the knowledge level and characteristics of the learner.
- Autonomy: The learner has the right to choose whether to participate in the system provided learning activities or not, and can also choose the way to participate in the learning process.
- Constructive Resources: The system constructs the appropriate learning resources and makes it adaptive to the learner's types of needs, based on the learners' acquired knowledge.

From the pedagogical point of view, the adaptive learning system should meet requirements, including the learner's prior knowledge, cognitive ability, learning preferences, interests, personal circumstances, and motivation at the same time. Based on the above learning model, we divide the adaptation layer into four components for carrying the adaptation of the learning contents, as shown in Figure 3.

- Personalization: provides personalized physical characteristics of mobile devices to enhance the learner's sensory perception.
- Learner's knowledge: prepares adapted learning materials, facts, concepts, theories, and principles in terms of their knowledge level.
- Cognitive ability: provides appropriate learning languages, contents, and concepts, needed to adapt to the cognitive level of the learner.
- Preferences: provide customized interfaces related to the learner's learning equipment parameters, learning styles, and learning mode.

A radial Venn diagram is used to summarize the problem identified for a new adaptation layer. The four nodes define the issues that need particular attention for the development of the prototype mobile learning system in this paper. The adaptation layer implements all the logic for the adaptation of the learning contents based on the physical model and the user model. The adaptation logic based on probabilistic or deterministic functioning of interpreted contextual information is processed by the adaptation engine. Throughout the adaptation layer, mobile learning holds great potential for improving the way students learn and brings forth positive learning outcomes.

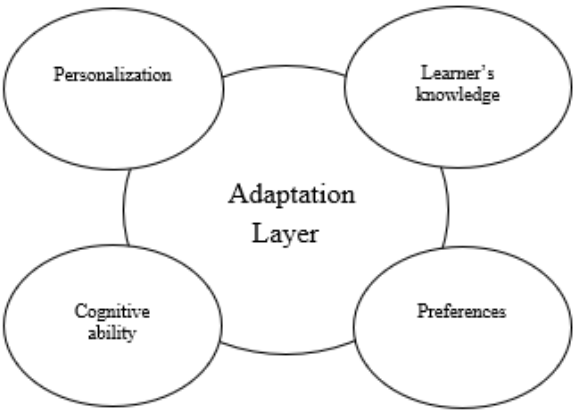

Fig. 3. Adaption layer radial Venn diagram

VI. IMPLEMENTATION OF THE ADAPTATION LAYER USING MODELING APPROACH

In designing and developing the user's adaptation in the learning environment, a model-based design technique well supplies the adaptive mobile learning applications required from tasks to abstract interaction to concrete interaction. Furthermore, Gerrit Meixner, and other [6] mention that a model-based design is to identify high-level models that allow designers to specify and analyze interactive software applications from a more semantic oriented level rather than starting to immediately address the implementation level. Thus, when designing adaptive learning applications, using the model-based design approaches allows the designers to make the learning models easier to specify and more amenable to be fitted in the adaptive system development. The main steps from tasks and content models via abstract interaction to concrete interaction are supported by models about the application core, target platform, working environment, and user characteristics depending on the adaptation. Although there is a need for combining task models with models of the user interface's structure and behavior, they must be kept separate conceptually. Using models allows us to overcome the heterogeneity of users and computing platforms. Hence, the models of abstract interaction objects should provide a natural transition to and from concrete interaction objects [7]. Furthermore, when using a model-based design approach, it is possible to reuse software solutions between different targets, since models should not be affected by the device diversity and its evolution. Many applications have introduced tremendous user interface criteria extracted from human factors used for building the adapted interface in previous research. However, most criteria can be infeasible components over the current mobile application technology. For these reasons, we will present a method of enhancing attention and increasing adaption in the mobile learning environment in this paper. A learner's requirements elicitation can be completed through various icons containing contextual elements that are visualized for the mobile adaptive learning application. Furthermore, visualized icons accommodate to create the abstract user interface by using the multi-models based on the sketch-based modeling operations. This makes the mobile adaptive learning application user interface to include different features, such as ease of use, user satisfaction, attractiveness, and learnability. In addition, the application should be robust and of very high

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quality for wider acceptance of the system, and the developer should minimize functionality in favor of a simple user interface that users can easily perceive and understand. Here, we mainly focus on the adaptation of user interface method depending on the learner's knowledge of the subject, learner's traits, and preferred learning style. Based on these areas, we attempt to extract manageable criteria to manipulate the user interface design factors of education application for the learners via the multi-modals.

TABLE 1. Icons for user interface design of adaptive mobile learning application

Icons	Explanation	Input Elements
	The learner's personal information	• Input user profile such as name, phone number, email, mailing address, age, gender, other personal files • Physical state • Learner's ability and achievement
	The learner's academic information	• Academic level • Knowledge of the subject • Learning experience and outcomes • Time of year
	The learner's communication/discussion board preferences	• Communication styles • Interaction level • Message types, such as text, voice, SMS, multi-media
	The learner's cognitive load for recognition, terminology, concept	• Recognition rather than recall • Use of appropriate language • User of appropriate content • Familiar concept
	The learner's sound preferences	• Use sound where appropriate
	The learner's streaming preferences	• Type of media • Media quality
	The learner's display preferences	• Text presentation • Screen size
	Learning object knowledge base: The learner's course and information	• Choose academic field • Select contents, such as quizzes, assignments, exams, case studies
	The learner's help, tutorials, hints/clues	• Provide sufficient help • Provide tutorials • Provide task related hint and clues

A. Using Icons to Adapt Learner's Preference

To increase the motivation of building an adaptive learning environment, we initially use icons for each learning object. As communication tools, icons can assist learners by visualizing content to extract learners' traits and preferences in their preferred learning styles. Table 1 shows various icons along with criteria and sub-criteria when designing the adaptive models implementation aspect of the application. We initially provide the following nine icons to construct a basic adaptive mobile learning user interface platform, taking into account the adaptive learning environment and personalized content to be visualized for learners. These icons used for building each adaptive model represent tasks for mobile learning tasks with learners and are provided over the adaptation layer to personalize at the interface level using the proposed adaptive user interface concept. The relevant model extraction from the underlying configuration of the proposed adaptive user interface design is based on the offline phase of selecting human factors.

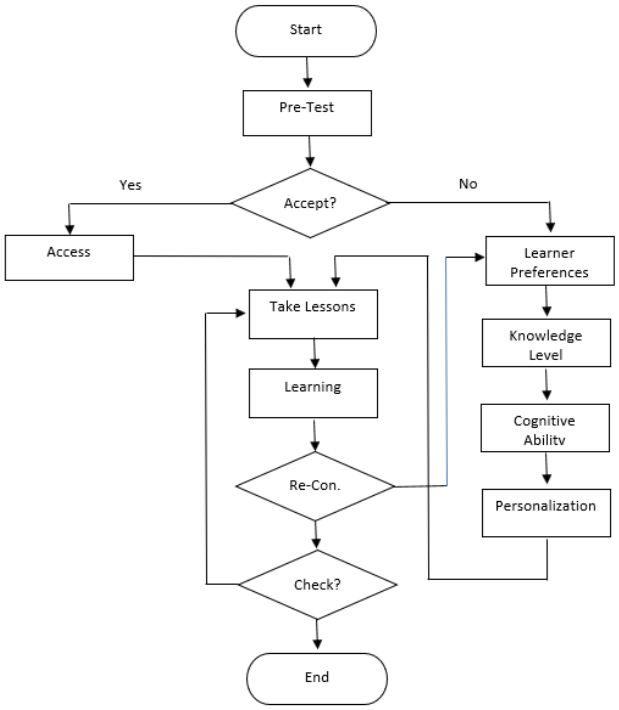

Fig. 4. Flow chart of adaptive mobile learning processes

B. Adaptive Mobile Learning Processes

In this part, we introduce the functional process flow of adaptive mobile learning application as seen in Figure 4. As discussed above, learners input their property using icons based on the functional flow. After the learner selects the basic models from the model database as seen above, he/she will add sections to the models by drawing a shape in the workspace using a pen or a mouse.

1) After starting, the learners perform a pre-test before taking the lesson to know whether the default configuration is acceptable. The pre-test consists of short presentations with the basic user interface, questions, discussions, messages, and other components.
2) Based on the result, the learner can access the lesson or insert their property into the system. The selection of questions is determined through the analysis of test items, such as learner preferences, knowledge level, cognitive ability, and personalization.
3) By taking the lessons, the learners complete the learning actions. Pass/fail results are determined by the percentage of correct answers on the questions in each lesson.
4) The UI can be reconfigured depending on the learner's request. The condition in which learners must take the materials is determined by the input property. After the input process, learners are required to take a lesson again.
5) Finally, if the learners pass, then they can continue to the next lesson. If they do not pass, they will repeat the learning process.

This effective model indicates that the learner's adaptation is related to learner preferences, knowledge level, cognitive ability, and personalization. Before implementing the concrete user interface, we are able to create the abstract user interface by using the multi-models based on the sketch-based modeling operations, which in turn, leads to a concrete user interface.

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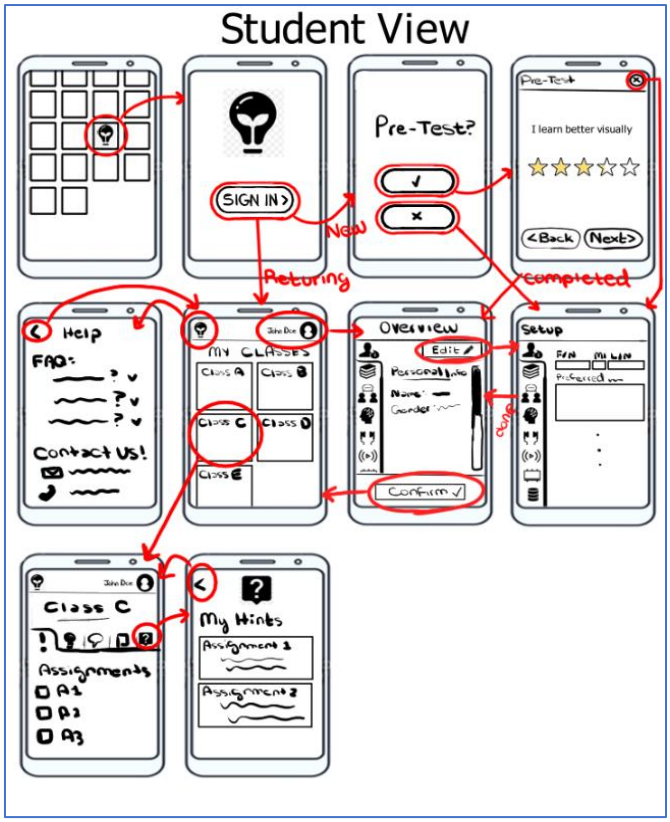
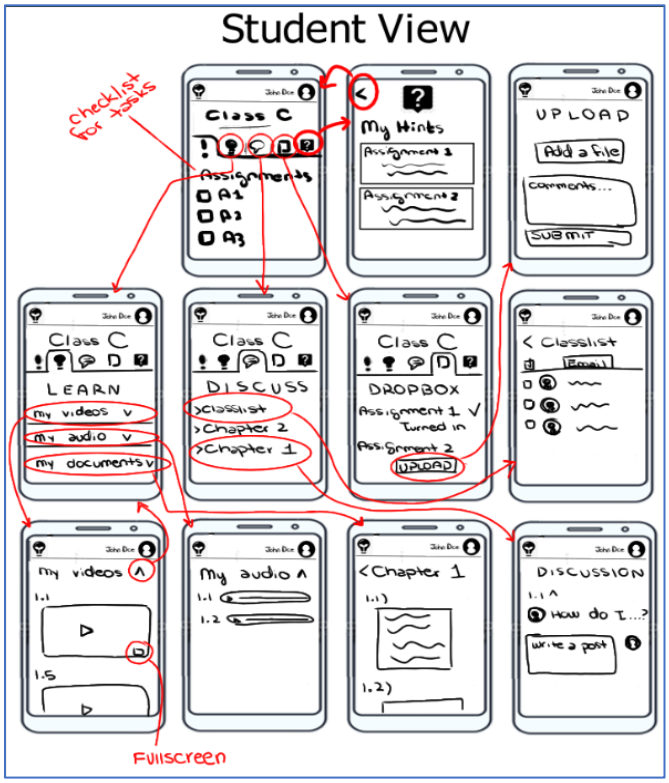
VII. DEVELOPMENT OF MOBILE ADAPTIVE LEARNING APPLICATIONS

In this part, we design and implement the mobile adaptive learning application we mentioned with icon-based user interfaces Figure 5 (a) displays the student view for the mobile learning environment. After the student opens the app, they may sign into their account if one exists. If they have not yet made an account, they should take a pre-test to evaluate their learning preferences and cognitive ability. We conduct an investigation of whether performing a test on the information under study, also called a pretest, could alleviate this problem and promote learning. Survey items that students trust from target users are administered on a 5-point Likert scale. This pre-test provides useful insight based on the user's knowledge level, characteristics, and preferences that enable the app to adapt the presented knowledge and enhance the user's learning experience. The student may also choose not to take the pre-test, which will prompt the app to revert to the default settings. Once the pre-test is complete (or after the student chooses to skip the pre-test), the app will prompt the user to input their personal information under 'Setup'. This information may be edited at any time in the 'Overview' menu, which displays eight different icons as explained in Table 1. For example, Figure 5 (a) displays information shown after a student clicks the 'Personal Information' icon, which includes personal information such as name, address, and email. The home screen titled 'My Classes' displays each of the classes that the student is enrolled in. The lightbulb icon in the upper left-hand corner of the home screen represents the 'Help' menu, which displays the FAQ for the app as well as contact information for the app's administrators. The upper right-hand corner shows the user's name and profile picture. Clicking this icon takes the user back to the 'Overview' menu. The user may press 'Confirm' to return to the home screen. When the user selects one of their classes in the home screen, they are taken to the main screen for that specific class. Figure 2 (b) displays the student view for a specific class in the mobile learning environment. This screen displays five icons, which are as follows:

- **Assignments (Exclamation Point)**: The student can see each assignment required to be turned in for the specific class.
- **Learn (Lightbulb):** This screen displays the educational content provided for the class, which may be supplemented by videos, audio files, and/or documents.
- **Discuss (Speech Bubble):** The student may post comments and/or questions for each module or chapter of the class. They may also reply to comments left by other students.



(a) Student view



(b) Student view of a specific class

Figure 5. The proposed the mobile adaptive learning application

- **Dropbox (Box):** The student can turn in assignments in this screen or confirm which assignments have already been turned in or are still due to be submitted.

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Clicking on an assignment takes the student to the 'Upload' screen, where they may upload files with or without comments when submitting assignments.

- **My Hints (Question Mark):** This screen displays task-related helpful hints or tips for each assignment. Hints may also be in the form of tutorials.

Students may also access the 'Class List' screen, which shows user profiles for all students enrolled in the particular class. Users have access to other students' email addresses to enable quick and efficient communication

VIII. CONCLUSION AND FUTURE WORKS

A web-based education system was encouraged during the COVID-19 pandemic. When it comes to web-based education, mobile learning platforms are considered a safe environment. The main contribution toward this research is the design and development of adaptive mobile learning applications. This model is intended to adapt the learning content to match the learner's traits and preferred learning style. Based on this research, we furthermore indicate a middleware infra-structure containing four layers which facilitate the development of adaptive mobile learning applications anywhere and anytime.

Throughout this research paper, we have proposed several contributions which would accommodate further research topics for improving mobile learning environments. First, we have adapted a 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 adaptation layer to identify the contextual elements relevant to the mobile learning environment in order to provide the best educational experience to learners. Third, by using icon-based interfaces, we have proposed models to adapt elements from the learning environment. These models represent a task for mobile learning operations with the learners, and they are delivered through the adaptation layer to be personalized at the interface level by using the proposed concept of the adaptive user interface. Fourth, we have discussed the flow-chart explaining procedures in the implementation of an adaptive mobile learning application to meet the pedagogical requirements of students, teachers, teacher assistants, and administrators. Finally, we have proposed the design and development of mobile adaptive learning applications by encouraging the development of practical rather than theoretical methods.

Although this approach is to devise a basic method for efficiently building an adaptive mobile learning application, there are still uncovered problems in applying for a commercial mobile application directly. There is a need for a better adaptation in mobile learning applications' design to integrate various adaptation elements and identify their relationship with regards to the mobile learning application under development. This research also feeds the adaptation process with finer information about the contextual features and learners' responses to the learning content under these various contextual features and their values by analyzing the learner's actions or interactions that he/she carries out in the learning activity provided by the mobile learning application. This requirement sows seed to various models in the coming future. We can combine future research with adaptive learning models so that the learning process will be more interactive using the sketch-based modeling operations. We look forward to continuing our research and developing the adaptive application via AI based on the future progress of mobile software and hardware performance. Our future work will investigate more in the role and specification of each factor and its effect on the flow process of our model, as well as compare our model with other comparative research work to produce reliable statistical results via usability testing. Therefore, the biggest contribution of this paper is to provide a small step in the design and implementation of an adaptive mobile learning application to support pedagogical needs.

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