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Agent based Collaborative Ubiquitous Mobile Learning Architecture using JADE-LEAP

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Abstract: In this paper, we propose an agent based collaborative mobile learning architecture. The architecture aims to allow learners to learn ubiquitously at any time and from any place. It enhances both teaching and learning activities, allowing teachers and students to cooperate using common mobile devices to transfer information among each other. We describe the requirements for creating such collaborative learning environment on mobile devices and the design process for the architectural model components, focusing particularly on the social interactions and collaboration learning between learners and teachers. The proposed architectural model was implemented using JADE-LEAP which is a platform that can be deployed on a wide range of mobile devices. Moreover, this model provides new way of support collaborative learning using mobile device. The architecture model divided into four components, which are device agent, learner agent, teacher agent, and social agent. The social agent is responsible for evaluating the collaborative interactions among learners. It offers an evaluation indicator for learners' collaboration, and supplies a teacher with leaner participation reports about group collaboration. Using these reports, teacher can assess the quality of learner collaboration on learning tasks, and determines the collaboration skills for the group members to provide a feedback.
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1. Introduction

Technology plays an increasingly important role in education to enhance learning and teaching activities. Mobile learning (M-Learning) is a hot research area that enables learners to access learning resources ubiquitously from anywhere and at any time using mobile devices. Most of the progress made in this field has been influenced by the evolving mobile technological infrastructure [1].

In the M-learning environment, there are many advantages that enhance leaning experience. For example, M-learning takes the advantages of mobile wireless communication where the learners are no longer restricted to time, space or cable network infrastructure. They can learn flexibly, conveniently and at anytime, anywhere for different purposes, in different ways. Additionally, M-learning is considered as a real-time learning, it can provide opportunities for the learner to interact with other learners and to have the possibility of giving a feedback. This learning process should help learners to improve their grades, confidence, communication ability, knowledge sharing, student interaction and learning efficiency [2]. Using the mobile agent technology, the agents could be distributed in the M-Learning environment and becomes responsible for specific tasks. The design of distributed M-Learning architecture to support collaborative learning based on agents offers a new technique to manage the learners' interactions and allows a high degree of flexibility to utilize mobile resources and process.

In this paper we aims to design and develop an architectural model for collaborative mobile learning environment enabling learners to access learning resources ubiquitously from anywhere and at anytime using mobile devices. The proposed architectural model for M-Learning is implemented using Java 2 Micro Edition (J2ME) with JADE-LEAP services enabling agent interaction. The architecture of the system is composed of multi-agents, which are device agent, learner agent, teacher agent, and social agent. We deployed the agents on mobile devices and experiment the platform in real environment. We followed different step towards achieving our goal. First, we Conducted a comprehensive survey in M-Learning, mobile agent,

adaptive content, collaboration learning, system architecture and/or model. Then, we constructed a valid working scenario using a specific architecture. Finally, we run and analyzed the simulation results.

The rest of the paper is organized as follows; in section 2 literature reviews is described, in section 3 M-learning architecture is proposed, the Collaborative Mobile Learning Model Design Based on Agent is presented in section 4, In section 5 the architectural model analysis and social agent tasks in collaborative M-Learning environment. Collaborative Mobile Learning with Social Agent is described, the experiments and simulation are showed in section 6 and finally conclusion and future work is presented in section 7.

2. Literature Review

In [3] Education or teaching is defined as "any act or experience that has a formative effect on the mind, character or physical ability of an individual. In its technical sense, education is the process by which society deliberately transmits its accumulated knowledge, skills, and values from one generation to another". Learners experience various educational methods during their study. According to Martel et al. (2006)[4] these methods are classified into three situations, frontal, open or collective. These situations can be combined to produce an integrated educational situation.

The term 'collaborative learners' in the educational field refers to studying course material or sharing course assignments (problem solving), so a student or a trainer acquires and builds his/her knowledge by interacting with others within a group[5]. Computer-supported or online collaborative learning (CSCL) is one of the methods that supports collaborative learning using computers and Internet to improve teaching and learning with the help of modern information and communication technology [6]. Instructors are considered a central role in enhancing online collaborative learning. In [7] it is Shown that strong instructor support frequent instructor-student interaction, and advanced organizational skills are important elements of successful online collaborative learning. Mobile Computer Supported Collaborative Learning (MCSCL) refers to use of mobile devices as a way of interaction between the student and resources employed in the educational instruction [8]. As mobile devices operate in different ways and have different capabilities; therefore some learning resources may not be in a format that is acceptable for different learners' needs and that fit the capabilities of different mobile devices, consequently content adaptation is needed to provide learners with appropriate course view[1].

Mobile agent is a software object that is running on execution environment. It can sense the changes in the environment and acts accordingly to those changes. Also, mobile agent has control over its own actions, and able to communicate with other agents. It can move from one host to another, and adapts in accordance with previous experience [9].

Mobile agent technology for wireless environment has many advantages that make them a good solution for many areas. All existing mobile devices platforms provide many services to mobile agents but they differ in some aspect like performance, scalability, and communication. On other hand, existing platforms share the main aspects which are execution, communication, mobility, tracking, directory, and security. In [10] it presents a number of features that should be presented in using wireless mobile environment such as security features, network features, platform features and Development of agent-based systems features. Many security issues arise when using mobile agent on wireless environment, so it is important to ensure the privacy and integrity of data, and consider authentication and trust issues. As data are transmitted on wireless communication over mobile devices, data will not be received only by the destination but also by any node within the range of the communications device. Therefore most wireless communications protocols (such as Wi-Fi or Bluetooth) encrypt the data before transmission. But in some cases the communications can be unencrypted (such as public access point).

There are many advantages of using agents in M-learning process for creating distributed systems. The mobile agent has the ability to move in different environments which is an important characteristic due to different mobile devices environments, capabilities and limitations. Also mobile agent is independent in its knowledge and management. Another benefit of mobile agents is its ability to adjust its own actions by the information gathered from its surroundings communication [9]. Moreover, mobile agents can reduce the network load moving to the node where the data are stored to process the data locally instead of throughout the network. Because of these characteristics, building system architecture design for M-learning based on mobile agent would a good solution.

3. M-Learning Architecture

In M-Learning learners can access learning resources and communicate or cooperate with other learners from anywhere and at anytime using mobile devices. In [11] it describes a Framework for the Rational Analysis of Mobile Education (FRAME). This model shows that mobile learning is composed

from intersection between three parts: mobile technologies, human learning capacities, and social interaction. The FRAME model illustrated in Figure 1 represents three main intersected aspects which are: device (D), learner (L), and social (S). The interaction between two circles create an attribute belong to both aspect. D and L create device usability (DL), L and S create an interaction learning (LS), D and S create a social technology (DS). The intersection of the three aspects creates mobile learning (DLS).

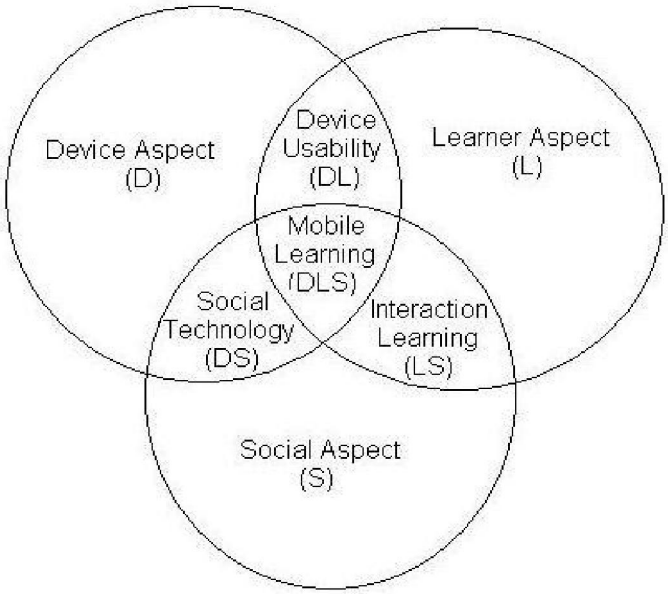


Figure 1: The FRAME Model [11]

The device aspect (D) illustrates the physical, technical, and functional characteristics of a mobile device; it concerns about physical attributes, input capabilities, output capabilities, file storage and retrieval, processor speed and error rates. The mobile learning device provides the interface between mobile learner and learning task.

The learner aspect (L) refers to an individual's cognitive abilities, memory, prior knowledge, emotions, possible motivations, and transfer information. Mobile learning enhances this aspect by allowing learners to access content in multiple formats, highlighted contexts and uses of the information.

The social aspect (S) refers to the processes of social interaction and cooperation. The learner must realize the role of cooperation to communicate with others and can exchange information.

The overlap of (D) and (L) Device Usability Intersection (DL) affect the user's sense of psychological comfort and satisfaction by affecting cognitive load, the ability to access information, and the ability to physically move to different physical and virtual locations.

The Social Technology Intersection (DS) represents social interaction between one learner and a device; it shows how mobile devices enable communication and collaboration amongst multiple individuals and systems. So learners can exchange information and collaborate with people with various goals and purposes (e.g. collaboration tool allow coordinating tasks, providing lecture, holding meeting). The Interaction Learning Intersection (LS) refer to social interaction or collaborative with meaning ability to understand, negotiate, integrate, interpret, and use of new ideas.

The Mobile Learning Process (DLS), the central of the three cycles, results from the integration of the device (D), learner (L), and social (S) aspects. DLS provides the collaboration among learners, the ability to access the information. It considered as mediation which includes the interaction between learner, communities and information.

4. Collaborative Mobile Learning Model Design Based on Agent

The proposed model is based on FRAME. The model divides the mobile environment into different components such as device agent, learner agent, teacher agent and social agent. These agents interact with each other to create a mobile learning environment as shown in following Figure.

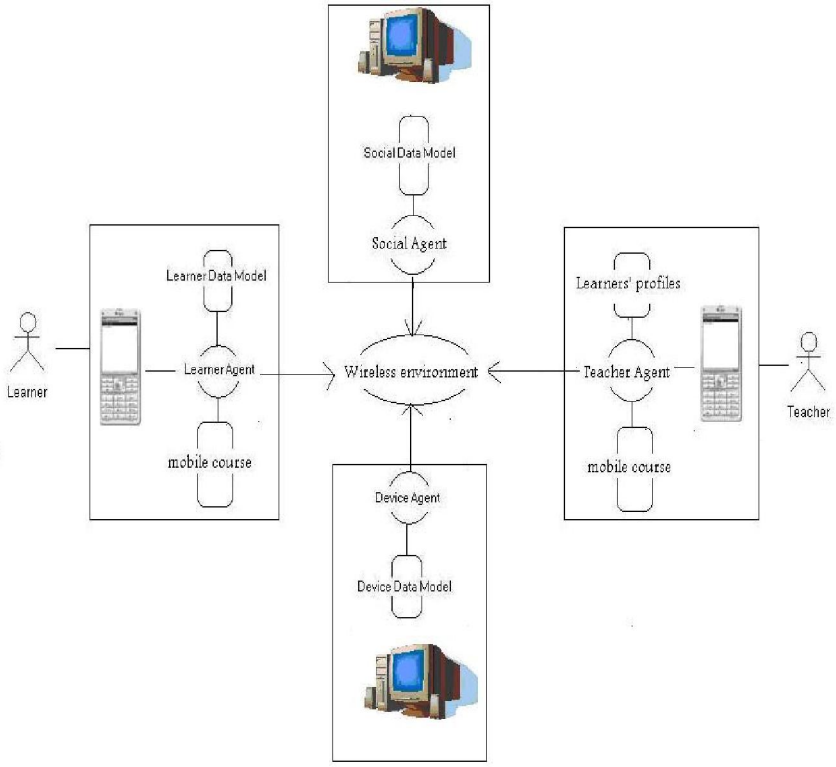


Figure 2: Agent Interaction with environment

The learner agent concerns with learner aspects in FRAME model, it is responsible for keep tracking the learner's profile which includes learner development, learner evaluation, and learner characteristics. It is connected with the learner data model in order to assess the learner's abilities and deficiencies, which will be constructed by the observation actions of the learner. The learner data model is composed of learner interactions, learner understanding, learner performance, learner personality. The teacher agent concerns with the evaluation and guiding the learning process. The learner agents inform teacher agent about learners' performance, then the teacher agent provides a teacher a learner's evaluation report. This helps teacher to provide a feedback to learner and monitor the learner progress. Teacher agent can guide the learner during learning study, gives explanation, and provides exercises and discussion to enhance understanding and collaboration degree. The device agent concerns with device aspects in FRAME model, it is responsible for all functions related to mobile technologies like mobile platform and network. The device agent connects with device data model which contains a device specifications and properties in order to configure mobile learning environment in proper way and identify different types of device terminals. The device data model is composed of the following information: display formats, platform, operating system, screen size, network protocol, network bandwidth and so on. The device agent is responsible for providing the services that needed in the collaborative learning processes. The social agent concerns with social aspects in FRAME model, it is responsible for social interaction and cooperation which includes managing group interactions, monitoring collaborative learning activity, evaluating group performance, and increasing collaborative learning within the group. The social agent connects with social data model which contains all information related to groups in order to assist progress of the learner's group. The social agent in this model is responsible for monitoring and assisting learners in their collaborative activities. All learners are interacting socially using social agents. The learner agent is responsible for monitoring and interacting with one learner, while the social agent interacts with every learner agent in the group.

4.1 Analysis of Collaborative Mobile Learning Model Based on Agent

Figure 3 shows sequence diagram that represents the interactive scenario between elements in the model as follows:

Teacher agent finds learner agent location (IP address) in order to communicate with learners' agents, so it requests this information from device agent, the device agent maintains this information in

device data model. The teacher agent sends the teacher learning task to the learner agent.

When a learner agent receives new teacher's instruction, it informs the learner with the teacher instructions using mobile user interface.

The learner agent gathers the information related to the learner by observing the learner's interaction, then update learner data model.

The social agent request information about the learner's agent location from a device agent. Then it requests the learner data model, finally it updates the social data model.

The social agent provides teacher an evaluation report about collaboration among learners. It sends the social information to the teacher agent, and then the teacher agent informs the teacher the social information using mobile user interface.

Using the information gathered from the learner agent, the social agent provides the learner agent instructions to engage learner in collaboration with other learners.

Figure 3: Collaborative Mobile Learning Sequence Diagram

5. Collaborative Mobile Learning with Social Agent

Since the goal of social agent is to help the learner and the teacher to collaborate in a learning environment, then these services are required:

1. Assessment of Quality Group Collaboration Service: This service is important for social agent to monitor, assess learner, and encourage learner on learning tasks. It helps in analyzing learner's interaction by providing a feedback about learners contribution in learning task. Social agent uses Quantitative Content Analysis (QCA) to assess the quality of group collaboration Service [12].

2. Assessment of Group Performance Service: The social agent can measure the group performance by assessing the interpretation of learners' interactions. This is done by classifying all interactions received from learner agent and assigns a rank for everyone, the rank can be a number or an interpretation, and then it assesses the rank of interpretations to measure the group performance. Group performance can be computed by multiplying the frequency of each class and multiply it with the class rank them then sum the total ranks to obtain the overall group performance.

3. Learner Group Participation Service: Learner group participation estimates the learner participations in group interactions, and how learner contributes in group task relative to all group members. Social agent can calculate the learner group participation by dividing the total number of interactions on the total number of interactions of the whole group.

5.1 Social Data Model and Interpretation

Social data model contains social profile of learners and interactions classifications. It maintains classes of interactions table to identify a class for each interaction. For example, you may have class type called class1 and constructed from three interaction types such as interaction1, interaction 2 and interaction 3 etc. Also social data model should maintain learner's social profile. The learner profile consists of learners' interactions classes that resulted from collaboration learning. For example, Learner (1) interaction profile may be consists of the following sequence: Class 1 – Class 1 - Class 3 – Class 4 – Class 2 … etc. In order to assess quality of group collaboration, social agent constructs a learner's participations table which contains learner class participations number such as (N1, N2, N3) and total its total N. Total N reflects the quality of group collaboration in learning class as shown in Table 1.

Table 1: Learners participations table

Learner /Class	Class 1	Class 2	Class 3
Learner (1)	N1	N2	N3
Learner (2)	N1	N2	N3
Learner (3)	N1	N2	N3
TOTAL	Total N1	Total N2	Total N3

In order to assess group performance, social agent constructs an interactions ranking shown in Table 2 which contains a class rank, total learners class participations number, and the overall total rank which reflects the overall classes group performance.

Table 2: Learners interactions ranking

Class	Rank	Interactions Number	Total Rank
Class 1	R1	Total N1	R1*N1
Class 2	R2	Total N2	R2*N2
Class 3	R3	Total N3	R3*N3
Total			Overall total rank

In order to assess leaner group participations, social agent calculates the ratio for learner classes by dividing learner class participations number (N1, N2, N3) to total learners class participations number (Total N1, Total N2 , Total N3). We can use these statistics to analyze leaner participations during problem solving in collaborative environment, e.g., if R1 is low we can conclude the learner have a low collaboration in class1. In this case, social agent encourage leaner to make more contributions with other group members.

5.2 Design Social Agent Workflow

The social agent workflow includes the following steps:

Determine category for each interaction in social data model.

Define each construct (interactions among learners) and assign it to a category.

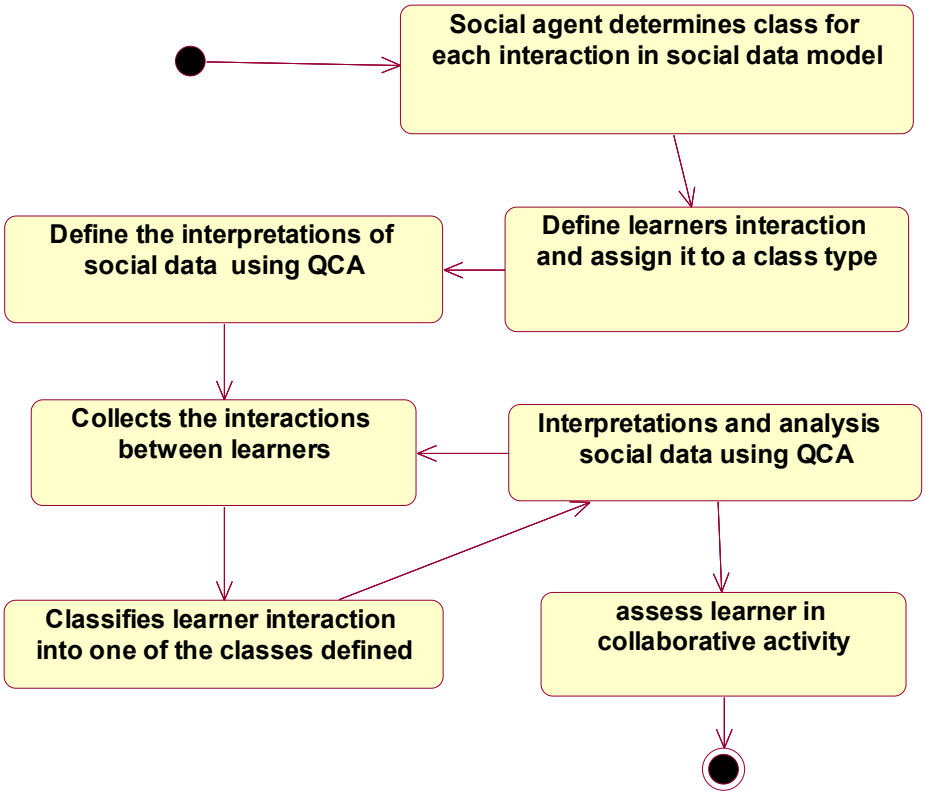
Define the interpretations for social data using QCA.

The social agent collects the interactions between.

The social agent classifies each interaction to one of the defined categories.

The social agent makes an interpretations and analysis of social data using QCA.

According to interpretations resulted from the previous step, the social agent can monitor and assess learners in collaborative activities and provides a feedback to the teacher.



6. The Implementation of Collaborative Mobile Learning Model Based on Agents Using JADE-LEAP

We developed our architectural model using Java 2 Micro Edition (J2ME) with JADE-LEAP services enabling agent interaction. Java Agent Development Framework (JADE) is a middleware that facilitates the development of multi-agent systems [13]. The JADE runtime environment is called a Container. Each Container can manage several agents. One container needs to be set as main container and must always be active in the platform and all other containers register with it. JADE-LEAP (JADE powered by Lightweight Extensible Agent Platform (LEAP)) is a platform that can be deployed on a wide range of devices varying from servers to Java-enabled cell phones. It replaces some parts of the JADE kernel forming a modified runtime environment to be executed in different environments [14].

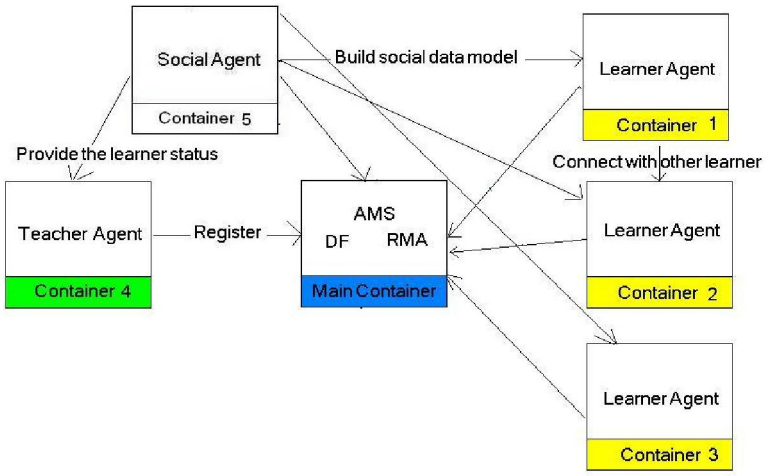


Figure 4: Architectural Design for Collaborative Mobile Learning Platform Based on Agent Using JADE-LEAP Platform

In Figure 4 the architecture is composed from four agents: device agent, learner agent, teacher agent, and social agent. According to JADE-LEAP specifications every agent must be held within a container. The DF and AMS agents work as device agent and there are a three learner agents. Each learner agent registers with the main container using DF and AMS agents. The DF and AMS agent keep track of agent services and provide Agent Identifier (AID) to enable agent communication with others. Learner agent receives other's AID from the DF agent in order to be able to interact with other leaner agents. Also, The social agent needs to interact with other agents in order to keep track all collaborative activities among group members. it communicates with learners agents by downloading the learner's agents AID. Also it communicates with the teacher agent to inform it about the learners' status.

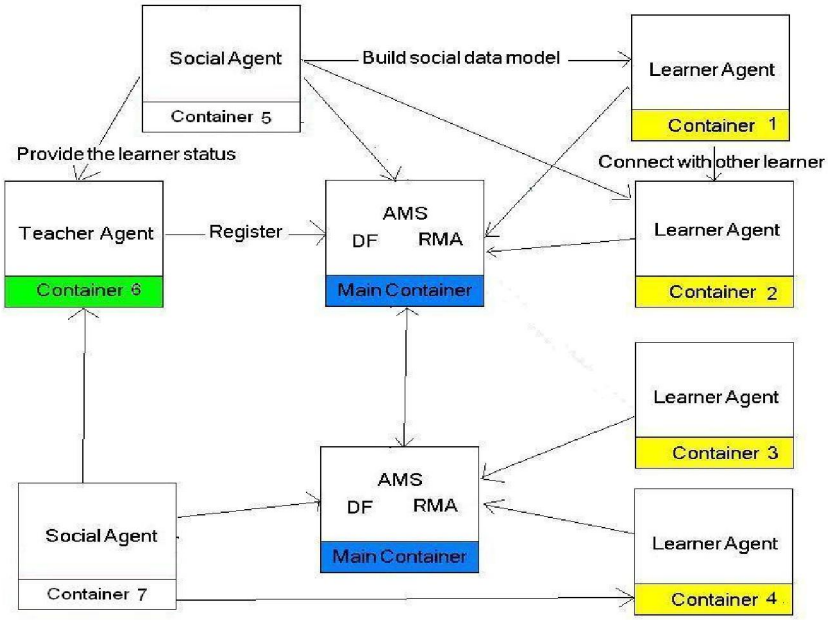


Figure 5: Architectural Design for Collaborative M-Learning Multi-Platform Based on Agent Using JADE-LEAP Platform

According to JADE-LEAP specifications we can build a multi-platform system enabling us to extend the system out bound of local platform i.e. several platforms distributed in different locations. Each platform connected with other platform by connecting main containers with other. So every agent in the system can interact with other agents inside or outside this platform as shown in Figure 5.

7. A Case Study for Collaborative Mobile Learning Model

In order to evaluate the model we test the model on a group of student at the University of Jordan. Two classes at the University of Jordan in king Abdullah II School for Information Technology are invited to use the developed collaborative M-Learning system. Students were asked to complete a questionnaire after using the M-learning program. This questionnaire evaluates students' acceptance and perceptions of the effectiveness of the collaborative M-Learning software. On a five-point scale (ranging from 1= "strongly disagree" to 5= "strongly agree"), students were asked to indicate their response to 21 statements about the collaborative M-Learning Frequencies and descriptive statistics such as means and standard deviations (SD) for each question on the questionnaire were calculated.

7.1 Experiment Results

In this study, 26 students participated in using the developed system and in answering the accompanied questionnaire. Students were divided into four collaborative students groups where in each group between four to eight students cooperated to solve the give problem. Each group was asked to collaborate for solving a problem in data structure. The means and standard deviations for each questionnaire item are displayed in Table3.

Table 3 The means and standard deviations for each questionnaire

Question number	Mean	SD	Question number	Mean	SD
Q1	3.88	1.01	Q12	3.88	0.97
Q2	3.73	0.90	Q13	3.96	0.85
Q3	3.73	0.76	Q14	3.54	1.01
Q4	3.92	0.67	Q15	3.69	0.61
Q5	2.58	0.97	Q16	3.85	0.60
Q6	3.31	1.26	Q17	3.65	0.73
Q7	3.15	1.46	Q18	3.65	0.62
Q8	3.73	0.90	Q19	3.85	0.72
Q9	2.69	0.72	Q20	3.77	0.70
Q10	3.62	1.08	Q21	3.62	0.84
Q11	3.50	1.08			

Scale: 5=Strongly Agree; 4=Agree; 3=Neutral; 2=Disagree; 1=Strongly Disagree.

7.2 Analyzing the Experiment Learners Interactions

The following Table presents FCS Interactions sequence for group A, it can be noticed that learners began to analyze the problem firstly, then they determine the development criteria for the problem with some orientation. After that they started suggesting a solution development for the problem. Finally they evaluate the suggested solution. Also we note that some students e.g. leaner (1) did not collaborate with other group members; sure this is considered as a learning form – learning from other group - but we need the learner to be more social with other group members. As a result, the social agent encouraged him to more collaboration. Teacher can evaluate member interactions and send some hints to group members for problem clarification.

Table 4: A case study of FCS interactions sequence for group A

Learner Number	Interactions sequence
Learner (1)	PA - PA
Learner (2)	PA – PC – OO
Learner (3)	NT -PA – CD – SD
Learner (4)	NT - NT - SE
Learner (5)	PA - PA - CD - NT - OO - SD - SD – SE
Learner (6)	PA - PA - CD - SE – NT
Learner (7)	PA - CD - SE – NT
Learner (8)	PA - PC - CD - SD – SD

After building interaction sequence, social agent built FCS learner's participations ranking as shown in Table 5. We can note the group performance for class PA is equal 10 and the total group performance is 28.

Table 5: A case study of FCS learners participations ranking for group A

Class Name	Rank	Interactions Number	Total Rank
PA	1	10	10
PC	1	2	2
OO	1	2	2
CD	1	5	5
SD	1	5	5
SE	1	4	4
NT	0	6	0
Total			28

The FCS learner participation table for group (A) is shown in Table 6; it contains a record for learner participation within each class.

Table 6: A case study of FCS learner participation for group A

Learner /class	PA	PC	OO	CD	SD	SE	NT
Learner (1)	2	0	0	0	0	0	0
Learner (2)	1	1	1	0	0	0	0
Learner (3)	1	0	0	1	1	0	1
Learner (4)	0	0	0	0	0	1	2
Learner (5)	2	0	1	1	2	1	1
Learner (6)	2	0	0	1	0	1	1
Learner (7)	1	0	0	1	0	1	1
Learner (8)	1	1	0	1	2	0	0
TOTAL	10	2	2	5	5	4	6

The FCS learner's participation ratio for group A is shown in Table 4; it contains the collaboration percentage for each learner within each class.

Table 4: A case study of FCS learner's participation ratio

Learner /class – Group A	PA%	PC%	OO%	CD%	SD%	SE%	NT%
Learner (1)	20%	0	0	0	0	0	0
Learner (2)	10%	50%	50%	0	0	0	0
Learner (3)	10%	0	0	20%	20%	0	16%
Learner (4)	0	0	0	0	0	25%	33%
Learner (5)	20%	0	50%	20%	40%	25%	16%
Learner (6)	20%	0	0	20%	0	25%	16%
Learner (7)	10%	50%	0	20%	0	25%	16%
Learner (8)	10%	0	0	20%	40%	0	0

The comparison for learner's collaboration for each class for group A is shown in Figure 6, we can note that learner 5 has the most group participation in problem solving within the group (PA=20%, OO=50%, CD=20%, SD=40% ,SE=25%), and on the other hand learner 1 has the minimum group participation (PA=20%).

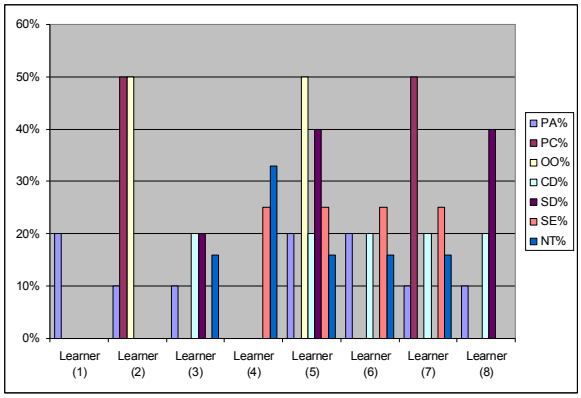


Figure 6: Learners Participation Ratio Graph for Group A

Figures 7, 8, and 9 show learners participation ratio graph for groups B, C, and D respectively.

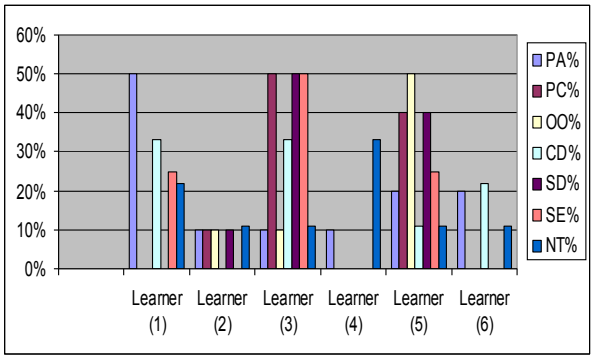


Figure 7: Learners Participation Ratio Graph for Group B

The comparison for learner's collaboration within each class for group B is shown in Figure 29, we can note that learner 3 (PA= 10%, PC=50 %, OO=10 %, CD=33 %, SD=50 %, SE=50 %, NT= 11%) and learner 5 (PA= 20%, PC=40 %, OO=50 %, CD=11 %, SD=40%, SE=25 %, NT= 11%) have the most group participation in problem solving within the group, and on the other hand learner 4 has the minimum group participation (Non-task=33%, PA=10%).

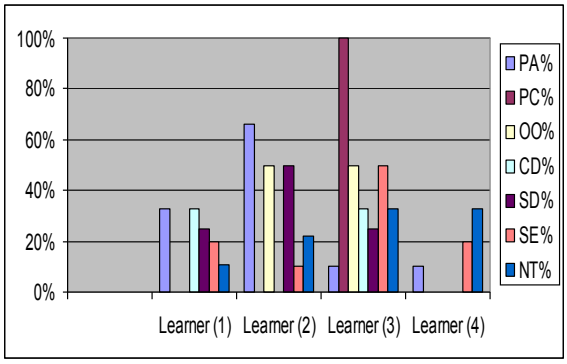


Figure 8: Learners Participation Ratio Graph for Group C

The comparison for learner's collaboration within each class for group C is shown in Figure 7, we can note that learner 3 has the most group participation in problem solving within the group (PA= 10%, PC=100 %, OO=50 %, CD=33 %, SD=25 %, SE=50 %, NT= 33%), and on the other hand learner 4 has the minimum group participation (PA=10%, SE=20%, NT=33%). Moreover, we can note the leaner 3 has (PC=100%).In this case, social agent engages other leaner in the group to more contribution with learner 3 in PC. The comparison for learner's collaboration within each class for group D is shown in Figure 8, we can note that learner 1 has the most group participation in problem solving within the group (PA= 30%, PC=40 %, OO=22 %, CD=22 %, SD=11 %, SE=57 %, NT= 9%), and on the other hand learner 8 has the minimum group participation (SD=10%, NT=18%).

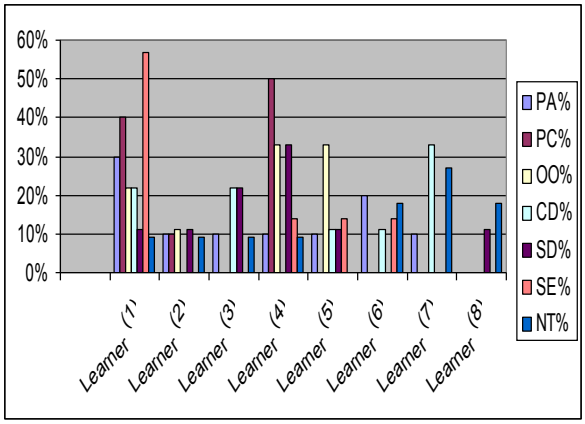


Figure 9: Learners Participation Ratio Graph for Group D

8. Conclusions and Future Work

This paper aims to create a collaborative mobile learning architectural model; the model is based on mobile agents. The new architecture model is implemented using JADE-LEAP platform and is applied on mobile devices. The agent interactions were analyzed. The questionnaire results show that collaborative proposed M-learning system is easy to use, well-organized, convenient, and easy to access. Moreover, the collaborative M-learning system enhances leaner's skills in problem solving, increase learners' knowledge, and encourages learners for more participation in learning tasks. The experiment and simulation of an architectural model show that we can integrate collaborative E-learning with collaborative M-learning;

As a future work, more investigation is needed to integrate collaborative M-learning system based on agents with other E-learning or M-learning systems which have different architectural models. Furthermore, more research is needed to add another component into the proposed model to enhance learning requirements like teacher profile. It can be used by teacher to store his/her information, so he/she can reuse this information when it is needed.

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