Social Knowledge Awareness Map for Computer Supported Ubiquitous Learning Environment

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ABSTRACT

Social networks are helpful for people to solve problems by providing useful information. Therefore, the importance of mobile social software for learning has been supported by many researches. In this research, a model of personalized collaborative ubiquitous learning environment is designed and implemented in order to support learners doing learning tasks or activities. It utilizes RFID technology to detect the surrounding environmental objects and then provides social knowledge awareness map for peer helpers dynamically according to the detected objects. The map visualizes the learners' surrounding objects, peer helpers and the strength of the relation in the social network perspective. It is experimentally tested and evaluated in a small special community. The quantitative and qualitative data of the experiment indicate the important role of the map in augmenting the collaboration between the learners.

Keywords

Knowledge awareness map, Social network, Computer supported ubiquitous learning, Personalization, Recommendation

Introduction

Educational technology is now growing rapidly in order to satisfy the learner's needs. Learning at anytime and anywhere is one of the strongest trends that researches focus on. A ubiquitous computing environment enables people to learn at anytime and anywhere. Ubiquitous computing is a model of human–computer interaction that enhances the computer use by making many computers available throughout the physical environment in invisible way. The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it (Weiser, 1991). A ubiquitous computing environment utilizes a large number of cooperative small nodes with computing and/or communication capabilities such as handheld terminals, smart mobile phones, sensor network nodes, contact-less smart cards, and RFID (Radio Frequency Identification)…etc (Sakamura and Koshizuka, 2005).

The RFID tag makes it possible to tag almost everything, replace the barcode, help computers to be aware of their surrounding objects and to detect the user's context (Borriello, 2005). We believe that, in the near future, RFID tags will be attached to almost all products; therefore we will be able to learn at anytime and anywhere from every object by scanning its RFID tag. The RFID system (Klaus and Rachel, 2000) consists of a tag, which is made up of a microchip with an antenna, and an interrogator or reader with an antenna. The reader sends out electromagnetic waves. The tag antenna is tuned to receive these waves. The chip modulates the waves that the tag sends back to the reader and the reader converts the new waves into digital data.

The challenge in the information-rich world is not to provide information at anytime and at anywhere but to say the right thing at the right time in the right way to the right person (Fischer, 2001; Fischer and Konomi, 2005). The use of ubiquitous computing tools within a situated learning approach is recommended to facilitate the students' attainment of curricular content, technology skills, and collaboration skills (Lin et al., 2005). The main characteristics of Computer Supported Ubiquitous Learning (CSUL) are permanency, accessibility, immediacy, interactivity, and situating of instructional activities (Chen et al., 2002; Curtis, et al., 2002). However, the fundamental issue is how to provide learners with the right information at the right time in the right way. Hence, the ubiquitous environment should be personalized according to the learner's situation. Personalization can be defined as the way in which information and services can be tailored in a specific way to match the unique and specific needs of an individual user (Renda and Straccia, 2005).

Many teachers and learners believe that learning by doing (Schank, 1995) is one of the best ways for learning. In learning by doing model, the teachers identify a specific set of skills to teach, embed that skills in a task, an activity, or a goal that the student will find it interesting or motivational, then the teachers can evaluate the learner's understanding and skills according to how much the learner successes to reach to the goal. While the learner is doing a task, he usually looks for some knowledge. In order to get help from another learner you have to be aware of his interests and past actions. Therefore, it is very difficult to find suitable partners at the beginning of the collaboration. Dourish and Bellotti (1992) defined awareness as the understanding of the activities of others, which provides a context for your own activity. Collaborative awareness is frequently achieved by means of lightweight messaging tools and dynamic information displays that function as notification systems (Carroll et al., 2003). Knowledge Awareness (KA) is defined as awareness of the use of the knowledge (Ogata et al., 1996). KA has a close relation to the learner's curiosity (Ogata and Yano, 2000). KAM (Knowledge Awareness Map) graphically displays KA information. It provides the learner with information about the others' activities in the shared knowledge space.

While a learner is doing learning task or activity, he usually looks for some knowledge. In a ubiquitous learning environment, it is very difficult for a learner to know who has this knowledge even though they are at the same place. In this case, the learner needs to be aware of the other learners' interests that match his request (El-Bishouty et al., 2010). This paper presents a model of personalized collaborative ubiquitous learning environment in order to support learners doing learning tasks or activities. It utilizes RFID tags to detect the surrounding physical objects and provides personalized recommendations based on the detected objects. It provides the learner with social knowledge awareness map for the peer helpers. The map visualizes the learners' surrounding environmental objects, peer helpers and the strength of the relation in the social network perspective. The learner can contact, interact, and collaborate with the peer helpers to address the learning goal. The remainder of the paper is organized as follows. A background about the social networks in learning systems is presented, after that the proposed model is illustrated, followed by an explanation of the recommendation methodology, then the software prototype is described, after that the concept of the social KAP is presented, followed by the procedure and the discussion of the evaluation phase, and finally the conclusion is illustrated.

Social Networks in Learning

In CSCW (Computer Supported Cooperative Work), researchers are interested in the role of social networks among the members of an organization. Clement stated that users developed informal collaborative networks to learn how to use a new software (Clement, 1990). Private networks are thus important for people to solve problems by providing helpful information. A number of studies indicated that one of the most effective channels for gathering information and expertise within an organization is its informal network of collaborators, colleagues and friends; such a network is called a *Help Network* (Eveland et al., 1994). Therefore, it is very important for network members to use interpersonal connections effectively in the course of their activities (Ogata et al., 2001). In an organization, however, information seeking is not straightforward information transfer. Colleagues choose not to go to the channel of the highest quality of information, but rather to go to the channel of the highest accessibility (Allen, 1977). Accessibility is concerned with the psychological costs in the potential lack of reciprocity between giving and obtaining information.

The importance of mobile social software for learning has been supported by many researches. Knight (2005) highlights the importance of situated learning support by defining learning as a social practice in which learners develop their identity through participation in specific communities and practices. Anderson (2005) has also emphasized the importance of social software for learning. Mobile social software offers the learner an opportunity to become a part of a learning community and at the same time enables learning in authentic contexts. Mobile social software applications combine virtual and real-world support for social interactions and collaboration in a real-world context. Additionally, learners themselves seem to be enthusiastic about using the mobile devices for collaboration and communication (Jong et al., 2008).

Bull et al. (2001) presented I-Help system to facilitate the communication among learners; the user models are used to match students who can help each other in their learning. Each user has a personal agent, which uses its owner's student model as a source of information for negotiating help sessions with other users, through their respective personal agents. Various information types are modeled: knowledge, interests, cognitive style, eagerness,

helpfulness, interaction preferences, opinions of peers and user actions. Awareness features within iHelp Courses can be classified into two categories: collaboration awareness and consequential awareness (Brooks et al., 2006); whereas, the learner is not able to be aware of the accessibility of other learners. PERKAM system (El-Bishouty et al., 2007) provides the learners with three different types of Knowledge Awareness Map, which visualizes the environmental objects, the educational materials and the peer helpers' space. It supports the learners with personalized recommendations based on the detected objects and the physical location. However, the social relation of the learners is not considered in the learner model. In contrast with these systems, following the vector space model, the recommendation in the proposed environment is based on the learner's profile, location and the social network as well. It allows the learner to be aware of accessibility of the other learners in terms of the social relation, in addition to the physical distance. We believe that this may increase the chance of establishing collaborations between the learners, which advances the development of their social networks.

A model of personalized collaborative ubiquitous learning environment

Consider the following scenario (as an example), it is based on learn-by-doing model that enables students to work towards desired goals, which exploits the fact that "people typically learn during their experiences while addressing desired goals" (Schank, 1995). Learner1 (Figure1 and Figure 2) is a research student in a genome center. She is concerned with the purification of DNA by using DNA purification robot. This robot is the main instrument she depends on in this experiment. She studied theoretically the way of operating it but she does not have enough practical experience in using it. She has to deal with it by using the available instruments and chemicals, or the whole run may be destroyed which consists of very expensive materials.
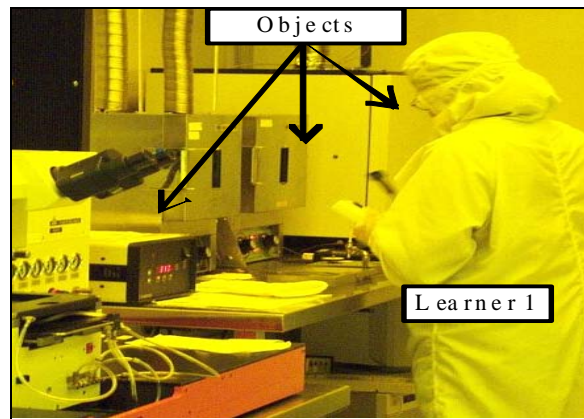

Figure 1. Learning environment

In this case, the proposed system recognizes the surrounding objects in addition to the location, and then recommends best-matched peer helpers who have faced this situation before or at least have enough related knowledge. She contacts and collaborates with them to address the experimental goal.

The main principle underlying the peer helper recommendation in the proposed environment is based on the learner's profile, location and the social network as well. On the one hand, the learner's profile formulates the learner's interests and experiences; on the other hand, the social relation and the relative physical distance represent the accessibility. Around this principle, the model consists of the following items (as shown in Figure 2).

Learner

Consider the set L of learners l where $l \in L$. Each learner l_j has his own profile lp_j where $lp_j \in LP$. The learner's profile represents his interests and experiences, it is represented as a set of keywords, and it is determined from the following sources:
- **Learner's explicit registration:** the learner introduces his personal information and his interesting topics.

- **Learner's academic level:** the system detects the knowledge that the learner gained from his past academic records.
- **Learner's actions:** the system records the learners' actions while using it.
- **Learner's folder:** the learner's folder contains the educational materials that the learner is aware of or intending to gain it. For every learner $l \in L$ there is a folder $f \in F$ where F is the set of folders.
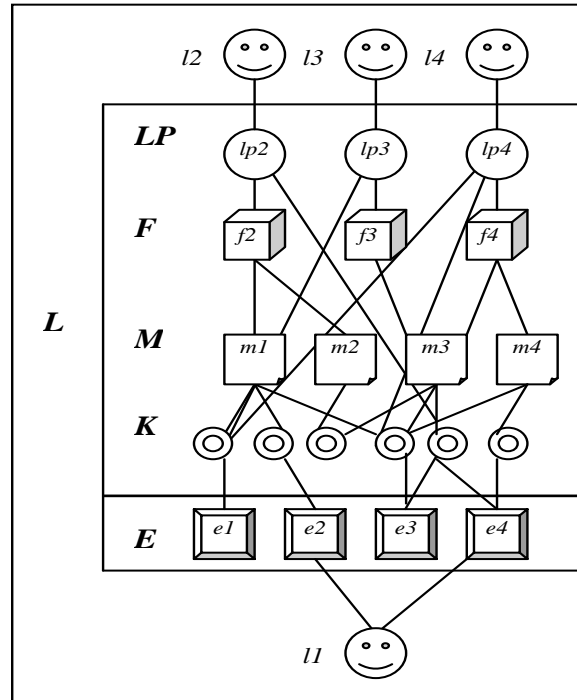

Figure 2. The model of the environment

Educational Material

It represents the available educational materials that the learner may refer to during his learning process. Consider the set M of the educational materials m; such as books, video lectures…etc. Each material m_j is represented as a set of keywords $k \in K$. These keywords indicate the educational material contents. It is clear that more than one educational material can share one or more keywords.

Environmental Object

The environmental objects surround the learner during his study. The learner may use one or more of them during his learning process. Consider the set E of the environmental objects e. Each object is represented as a set of keywords.

Recommendation Methodology

We assume that the knowledge space consists of a number n of unique keywords, which can be represented as a vector $<k_1, k_2, ... k_n>$ of keywords (El-Bishouty et al., 2008). For ease of presentation, following the well-known vector space model (Salton and McGill, 1983), each item in this model can be represented as a vector, which is corresponding to the keyword vector.

Consider that the number of users is g, and the learner's profile lp_j of a learner l_j can be represented as a vector of weights $<w_{j1},w_{j2},...w_{jn}>$ that represent the importance of each keywords, where w_{ji} is corresponding to k_i and $0 \le w_{ji} \le 1$. For ease of presentation, w_{ji} is calculated by the following formula:

$$w_{ji} = \frac{\text{the number of occurance of } k_i \text{ in } lp_j}{\text{the total number of keywords in } lp_j}$$

It is worth noting that our weight formula can be extended to consider more parameters. Therefore, the learner's profile matrix can be represented as shown is Table 1(a).

Table 1. (a) Learner's profile matrix. (b) Educational material matrix. (c) Environmental object matrix

	k_1 k_2 ...... k_i......k_n		k_1 k_2 ...... k_i......k_n		k_1 k_2 ...... k_i.......k_n
lp_1	$w_{11} w_{12}$...............w_{1n}	m_1	$w'_{11} w'_{12}$............w'_{1n}	e_1	$d_{11} d_{12}$.................d_{1n}
lp_2	$w_{21} w_{22}$...............w_{2n}	m_2	$w'_{21} w'_{22}$............w'_{2n}	e_2	$d_{21} d_{22}$.................d_{2n}
.	. .	.	. .	.	. .
.	. .	.	. .	.	. .
.	.	.	.	.	.
lp_j	$w_{j1} w_{j2}$...... w_{ji}......w_{jn}	m_j	$w'_{j1} w'_{j2}$... w'_{ji}......w'_{jn}	e_j	$d_{j1} d_{j2}$...... d_{ji}.........d_{jn}
.	.	.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.
lp_g	$w_{g1} w_{g2}$...............w_{gn}	m_v	$w'_{v1} w'_{v2}$............w'_{vn}	e_r	$d_{r1} d_{r2}$.................d_{rn}

Whenever a learner acquires new knowledge (such as: using new objects, referring to new educational materials, getting new credits), the corresponding set of keywords will be added to his profile; consequently, the weight of each keyword in the learner's profile matrix will be updated according to the previous formula. In a similar way, the educational material can be represented as a vector of weights $<w'_{j1},w'_{j2},...w'_{jn}>$ that represent the importance of each keywords, where w'_{ji} is corresponding to k_i and $0 \le w'_{ji} \le 1$. Whereas, w'_{ji} is calculated by the following formula:

$$w'_{ji} = \frac{\text{the number of occurance of } k_i \text{ in } m_j}{\text{the total number of keywords in } m_j}$$

Therefore, the educational material matrix can be represented as shown is Table 1(b).

Consider that the number of the environmental objects is r, and the environmental object e_j can be represented by a vector of occurrence of keywords $<d_{j1},d_{j2},...d_{jn}>$ where d_{ji} is corresponding to k_i and it takes the value *one* if a certain keyword k_i belongs to this object, otherwise it takes the value *zero*. Therefore, the matrix of the environmental objects can be represented as shown is Table 1(c).

Recommendation of peer helpers

For a certain task t, consider that a learner is using a number h ($h \le r$) of environmental objects. This task can be represented as a vector $<s_1,s_2,...s_n>$ of occurrence of the keywords that belong to the task environmental objects. Therefore, the Profile-Based Recommendation Score (*PBRS)* function of a peer helper l_j for a task t is calculated from the following formula:

$$PBRS^t(l_j) = \sum_{i=1}^{n} w_{ji} s_i \text{, where } 0 \le PBRS \le 1$$

In addition, we assume that the relative physical distances between any two different locations p and q, (denoted RPD_{pq}) are predefined in the system where $0 \leq RPD \leq 1$. In case that RPD is equal or close to 1, it means that p is so close to q. Therefore, the recommendation score function of a peer helper l_j for a certain task t (denoted $PHRS$) is represented as a linear equation of the profile-based recommendation score function and the relative physical distance as follows:

$$PHRS^t(l_j) = [PBRS^t(l_j)] * \alpha + [RPD_{pq}] * \beta$$

Where p denotes the task location, q denotes the peer helper's current location, and α and β are constants defined by the user according to his priority. The greater the recommendation score function, the more recommended the peer helper.

Recommendation of educational materials

In a similar way, the Content-Based Recommendation Score (*CBRS*) function of an educational material m_j for a task t is calculated from the following formula:

$$CBRS^t(m_j) = \sum_{i=1}^{n} w'_{ji} \, s_i \, , \text{ where } 0 \leq CBRS \leq 1$$

Therefore, the recommendation score function of an educational materials m_j for a certain task t (denoted *EMRS*) is represented as a linear equation of the content-based recommendation score function and the relative physical distances as follows:

$$EMRS^t(m_j) = [CBRS^t(m_j)] * \alpha + [RPD_{pq'}] * \beta$$

Where q' denotes the educational material location. The greater the recommendation score function, the more recommended the educational material.

Software Prototype

In the proposed environment, each learner uses a PDA device connected to the Internet through wireless connection, each device is equipped with a RF (Radio Frequency) reader, and for every object and place, there is RFID tag attached to identify it. During the implementation of the system prototype, the limited CPU speed and memory capacity of PDA devices is taken into consideration. In order to get high performance software, most of the computing processes are done on the server side. The main application is a web-based client-server application, which dynamically visualizes the social KAM and provides the learners with an easy tool to exchange messages. The map is an embedded flash object developed using Macromedia Flash ActionScript.

System Architecture

Figure 2 illustrates the system architecture; it consists of the database and the models of learners, physical objects, locations and educational materials, in addition to the following modules:

- Message system: It provides the learner with an easy tool to exchange messages with other learners. Consequently, it keeps track of the interactions between the learners.
- Detection manager: It detects the location and the objects that surround the learner and updates the learner model according to the received information.
- Recommender system: It calculates the recommendation score functions, and provides the best-matched peer helpers and educational materials.
- Map generator: It prepares the metadata of the KAM.
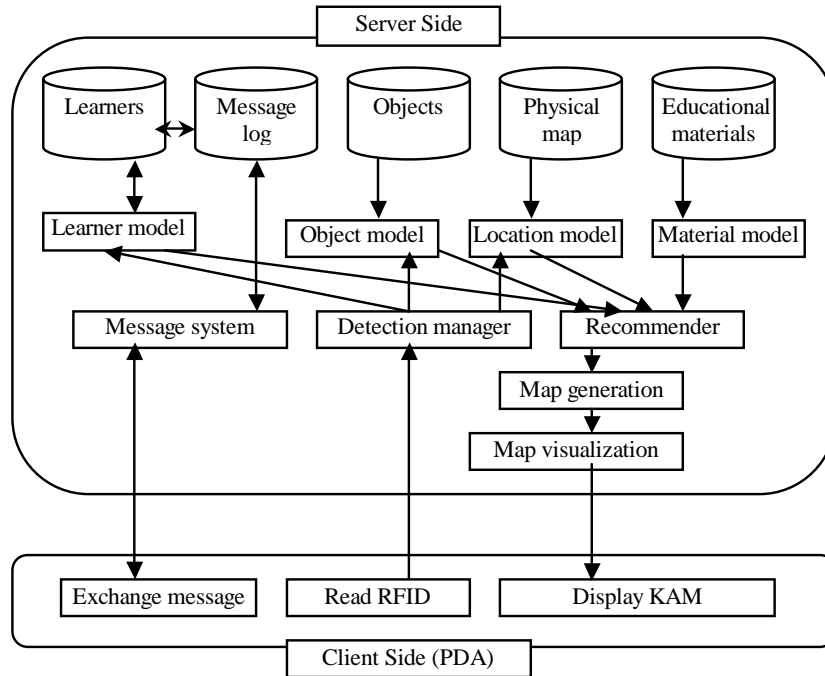- Map visualization: It visualizes the KAM.

Figure 3. System architecture

Social Knowledge Awareness Map

The social KAM visualizes the peer helpers in the acceptability perspective. Hence, the acceptability is expressed in terms of social relations and physical distances. According to the recommendation score function of the peer helpers, the system recommends the best-matched and nearest peer helpers for a certain task. Then, the system calculates the frequency of interaction (*FOI*) between the learner who is doing that task and each of the peer helpers. Whenever the learners exchange messages using the system, the *FOI* is increased. It indicates the strength of social relation between the learners. Consider a learner l_i and a peer helper l_j, n_{ij} denotes the total number of exchanged messages between the two learners, and N_i represents the total number of exchanged messages between l_i and all other learners. *FOI* is calculated as follows:

$$FOI(l_i, l_j) = \frac{n_{ij}}{N_i}, \text{ where } 0 \le FOI \le 1$$

The system visualizes the top three peer helpers who have the highest *FOI*. In the case of *FOI* equals zero, the system recommends a mediator. A mediator is a learner who has social relation with both the learner doing the task and the peer helper. The role of the mediator is to establish a new connection between the learners.

This map displays two dimensions knowledge space of the peer helpers who are using the system and have knowledge about the learner's task. As shown in Figure 4, the map represents the strength of the social relation of peer helpers in one dimension, and how far their physical locations are from the learner's location in the other dimension. In addition, the map shows the set of detected objects that the task consists of as symbol icons according to the object type. White-blue circles denote the peer helpers. When the learner selects a peer helper by clicking on a white-blue circle, the circle color is changed to dark-blue color and the peer helper's name and photo are displayed. Also, the objects that the selected peer helper is aware of are highlighted. Therefore, the learner can at once be aware of the peer helper's social relation, relative physical distance and experiences. The learner can recognize the peer helper from his name or photo. For unfamiliar peer helper (unknown person for the learner), the map shows a mediator (denoted by a red circle) who has social relationship with both the learner and the peer helper.

By clicking on compose-button, the learner can send instant message attached with the map to the appropriate peer helper asking for help and/or inviting him to discuss it face to face if his location is at a nearby area. Also, the learner

can send a request to a mediator in order to introduce him for unfamiliar peer helper. The peer helper/mediator can look at the map, see the learner's photo, recognize the task objects, and notice his position regarding the peer helpers; then he can reply to the learner's message or forward it to another peer helper.
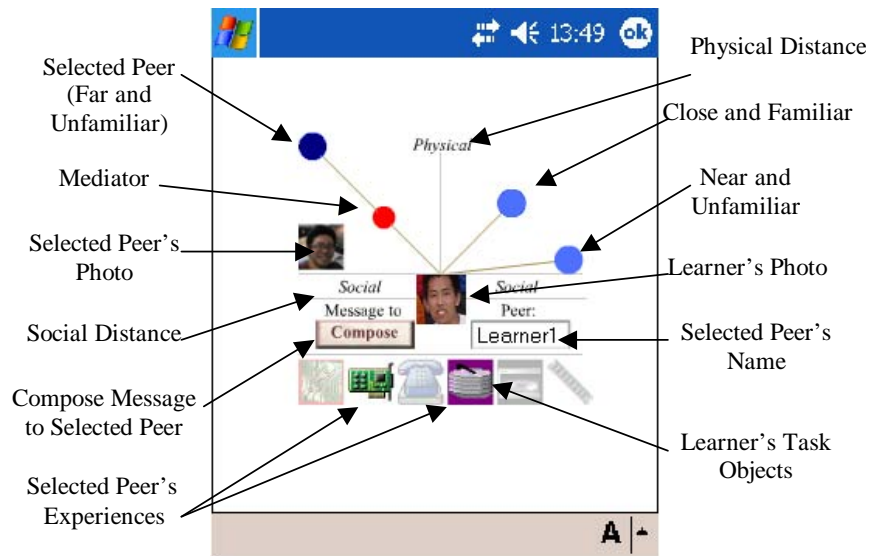

Figure 4. Social KAM

Evaluation

In order to evaluate the role of the social KAM in augmenting the collaboration in the ubiquitous environment, we experimentally tested and evaluated it in a small community. A group of 21 (9 fourth year undergraduate, 11 master and 1 PhD) students from the department of information science and intelligent systems were involved in this experiment. The time of the experiment was the first week of the new academic year, where a group of new students have just joined a research group. Therefore, it was expected that a lack of communications between some of the participants could be arisen for unfamiliarity issue.

Procedure

In the experiment, the system was applied in PC (Personal Computer) assembling domain, where all participants were interested in exchanging experiences about PC components. At the beginning of the experiment, each participant was asked to fill in a pre-questionnaire. In order to measure their knowledge and experiences about PC assembling, the participants rated their experiences in plugging different PC components, for example VGA card, Hard Disk Drive, RAM Module…etc. On the other hand, each participant rated the strength of social relation between him and each of the other participants. Based on that questionnaire, the participants were divided into two groups:

- Expert group: 7 students who were experts and had strong knowledge about PC assembling.
- Beginner group: 14 students who did not have any previous experience about PC assembling.

In the first phase of the experiment, each learner from the beginner group was assigned a task. A task consisted of a set of PC components. The beginner was asked to use the social KAM and choose a peer helper to contact and exchange knowledge about the task. In this phase, no mediator was recommended by the system. Consequently, the expert group was asked to login into the system and interact with the learners' requests.

In the second phase, the system suggested mediators for unfamiliar peer helpers; the participants were asked to repeat the first phase of the experiment and interact with peer helpers through mediators if possible. After that, all participants from both groups (expert and beginner) were asked to fill in a post-questionnaire in order to obtain the learners' reflections and comments.

Results and Discussion

During the experiment, the participants exchanged 175 messages. All participants collaborated actively with each other. They exchanged knowledge about computer hardware. Most of the messages related to the assigned task, however, many learners asked general questions. It implies that the map excited the learners' two types of curiosity: particular curiosity and extensive curiosity (Hatano and Inagaki, 1973). By analyzing the message log, a help network was developed and enriched. Also, it was noticed that new connections were established between the learners in the second phase of the experiment. Figure 5 represents the social network extracted from the exchanged messages between the participants in the first phase (left side) and in the second phase (right side). Whereas, each node represents a participant number, and each line (connection) indicates that at least one message was exchanged between the two end nodes. As an example, let us consider learner number 18, in the first phase he had only one connection with learner number 3. However, in the second phase 3 new connections were established with learners 1, 13, and 20. In addition, in some cases in the first phase, a peer helper played as a mediator, checked the social KAM, and introduced another peer helper who had much knowledge about a beginner' request.

Table 2 shows the post-questionnaire results, it consists of 8 questions; Q1 to Q5 were measured using five-point Likert scales varied from '1- strongly disagree' to '5- strongly agree'. Q6 to Q8 received a value 'Yes' or 'No'. Also, the participants were asked to comment on their answers and to provide some suggestions for improving the map. From Q1, the participants agreed that the map (as a whole) provided them with enough information about the peer helpers and efficiently visualized that information in the limited size of the PDA device. More specifically, Q2 to Q4 presented the learners' acceptance of the three elements of the map: social relation, physical distance, and experiences, respectively. However, the mild rates were related to the learners' suggestion to show a numerical recommendation score of each peer in order to aid in choosing the appropriate peer helpers.
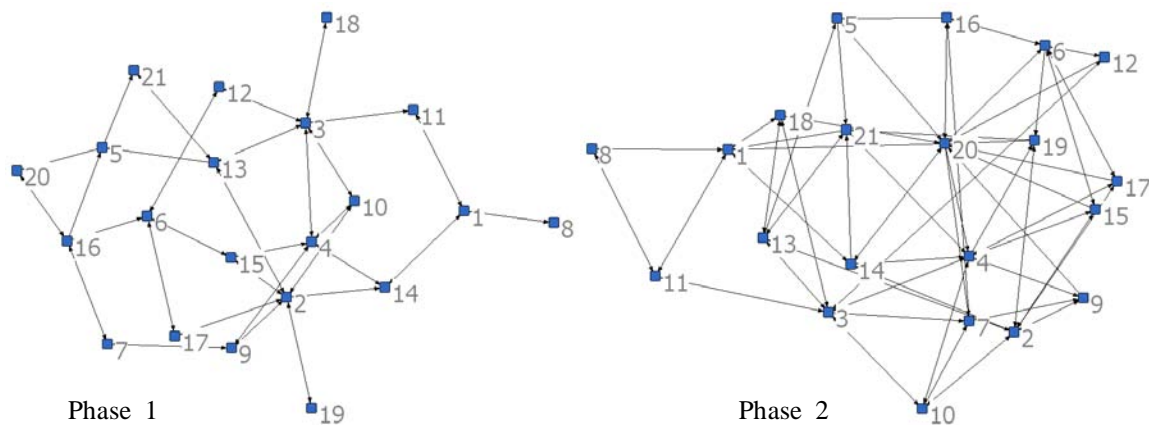

Figure 5. Social Network

Table 2. Post-Questionnaire results

	Question	Mean
Q1	**Social KAM** efficiently visualizes enough information about peer helpers?	4.2
Q2	**Social KAM** is helpful to be aware of a peer helper's **social relation?**	3.5
Q3	**Social KAM** is helpful to be aware of a peer helper's **physical distance?**	3.9
Q4	**Social KAM** is helpful to be aware of a peer helper's **experiences?**	3.3
Q5	**Social KAM** is helpful to establish collaborations between the learners?	3.9
		PCT
Q6	You did successful interactions with other learners using the system?	85%
Q7	**Social KAM** is easy to be recognized?	75%
Q8	A **mediator** is helpful to establish collaboration with unknown learner?	95%

Q5 and Q6 showed the obvious impact of the map in introducing peer helpers and establishing collaborations. Some learners asked to display more peer helpers, however, we worried about the overlapping problem that might let it difficult to recognize the map; whereas, Q7 indicated that the map was not so easy to be recognized by all

participants. From Q8, the participants strongly confirmed the important role of the proposed mediators in augmenting the collaboration between the learners. Many other comments were received from the participants; most of them were related to the user interface, they were looking for larger map size, bigger object icon and text font size, and more peers; however, we were restricted by the PDA limited screen size. The participants suggested showing indicators for a peer who was received a message, message status, and the number of exchanged messages. Also, they recommended allowing them to rate the peer helpers according to their satisfaction of the collaboration with each of them.

The above results show that the social KAM facilitates providing peer helpers in the social network perspective. The exploration of social networks is essential to find capable helpers at the beginning of the collaboration (Ogata et al., 2001). The map provides opportunities for efficient help network building. By using the proposed system, the learners were able to exchange messages and to hold conversations, which are the key element for constructing knowledge in collaborative tasks (Sharples et al., 2007). It is obvious that letting a learner be aware of the social relation with other learners has a strong impact in finding the suitable partner. The mediator has a valuable effect in augmenting the collaboration among the learners because it is helpful to establish a new collaboration. The proposed system can enhance the social learning process through increasing the opportunity of collaboration.

Conclusion

In this paper a model of personalized collaborative ubiquitous learning environment is presented in order to support learners doing learning tasks or activities. It utilizes RFID tags to detect the surrounding physical objects and provides personalized recommendations based on these objects. The proposed system provides a social knowledge awareness map for the peer helpers. The map visualizes the learners' surrounding environmental objects, peer helpers and the strength of the relation in the social network perspective. According to the proposed recommendation score function of the peer helpers, the system recommends the best matched and nearest peer helpers for a certain task. Then, the system visualizes the top three peer helpers who have the highest frequency of interaction. Also, the system recommends mediators. A mediator is a learner who has social relation with both the learner and the peer helper who is able to establish a new connection between the two learners. In order to evaluate the role of social KAM in augmenting the collaboration in ubiquitous environment, we experimentally tested and evaluated it in a small community. The quantitative and qualitative data of the evaluation experiment confirmed the important role of the map and the mediators in augmenting the collaboration among the learners. The map allows the learner to be aware of accessibility of the other learners in terms of the social relation, in addition to the physical distance, which enhance the chance of establishing collaborations among them. Such enhancement can further advance the development of their social networks. In the future, we are planning to enhance the KAM according to the learners' comments and suggestions in order to make it more efficient, rich and adaptive. Also we are planning to allow the learners to reuse the constructed knowledge during the collaboration for future learning.

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