# Smart Classroom: Enhancing Collaborative Learning Using Pervasive Computing Technology

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## Abstract

*Smart Classroom facilitates collaborative learning among college students. Students in such an environment form small groups to solve a specific problem or develop a group project. In a Smart Classroom, each student has a situation-aware PDA. Students' PDAs dynamically form mobile ad hoc networks for group meetings. Each PDA monitors its situation (locations of PDAs, noise, light, and mobility) and uses situation to trigger communication activity among the students and the instructor for group discussion and automatic distribution of presentation materials. Middleware can effectively address the Situation-awareness and ad hoc group communication for pervasive computing by providing development and runtime support to the application software. We have developed a Reconfigurable Context-Sensitive Middleware (RCSM) for such purposes. In this paper, we will present the characteristics of Smart Classroom, how we can use RCSM to develop such an environment, and how to use it to greatly enhance collaborative learning. We will use the senior group software engineering project course as an illustrative example.*

**Keywords:** Smart Classroom, collaborative learning, pervasive computing, situation-awareness, and Reconfigurable Context-Sensitive Middleware.

## 1 Introduction

Over the year technology has been used to improve the quality of instruction. However, effective use of technology to enhance the quality of teaching is a very challenging problem. Technology can be used to improve the quality of teaching in many ways. For example, it can help to improve the interaction between the instructor and the students or help in-group collaboration between the students.

Pervasive (or ubiquitous) computing technology makes the actual computing and communication essentially transparent to the users [1,2]. This transparency is partially possible and important to allow easier and seamless interaction of computers with humans. A pervasive computing environment is a collection of embedded, wearable, and handheld devices wirelessly connected, possibly to fixed network infrastructures such as the Internet. The two major characteristics of pervasive computing are: situation-awareness and ad hoc group communications [3-6]. Situation-awareness is the capability of a device to determine “What’s going on?” in it surroundings. On the other hand, multiple devices can use their ad hoc group communication capabilities to dynamically form networks, which may facilitate different types of collaborative computing.

Among the currently existing research prototypes that use various emerging computing and communication technology [8-14], only a few have addressed collaborative learning among students [8,11]. For example, in Interactive Classroom, the students share a virtual whiteboard, electronic textbook, and the World Wide Web over a networked environment to actively participate in-class discussions [8]. On the other hand, projects that use pervasive computing technology have so far mainly focused on easing the note- or exam-taking or student-tracking applications in a classroom. For example, Smart Kindergarten uses sensor data collected from children or toys to make a record for the instructor to review children's activities and track their learning progress [12]. Classroom 2000 captures classroom context (teaching material or student notes) to automatically generate Web-accessible multimedia class files for the instructor and students [13]. Chen and others have developed a system for test taking using handheld devices [14].

In this paper, we will present Smart Classroom that use pervasive computing technology to enhance collaborative learning among college students. We integrate mobile and handheld devices, such as Personal Digital Assistants (PDAs), with fixed computing infrastructures, such as PCs, sensors, etc. in a wireless network environment inside a classroom. The mobile devices in Smart Classroom are situation-aware in the sense that they can capture different situations in a classroom dynamically to form ad hoc networks to facilitate both student-student and student-instructor collaboration.

## 2 Background: Collaborative learning

Collaborative learning creates an environment that involves students in doing things and thinking about the things they are doing and reaches students who otherwise might not be engaged [15]. Collaborative learning encourages active student participation in the learning or small group learning. In collaborative classrooms where students are engaged in a thinking curriculum, everyone learns from everyone else, and no student is deprived of this opportunity for making contributions and appreciating the contributions of others. Collaborative classrooms have four general characteristics [15-16]:

**S1)** *Sharing knowledge*: Teachers have vital knowledge about content, skills, and instruction, and still provide that information to students. In a collaborative classroom, teachers also value and build upon the knowledge, personal experiences, language, strategies, and culture that students bring to the learning situation.

**S2)** *Sharing authority:* In a collaborative classroom, teachers encourage students' use of their own knowledge, ensure that students share their knowledge and their learning strategies, treat each other respectfully, and focus on high levels of understanding.

**S3)** *Mediation:* In a collaborative classroom, teachers as mediators adjust the level of information and support so as to maximize the ability to take responsibility for learning, since successful mediation helps students connect new information to their experiences and to learning in other areas, helps students discover what to do when they are stumped, and helps them learn how to learn.

**S4)** *Heterogeneity:* In a collaborative classroom, heterogeneous groupings of students enrich learning in classroom, since the perspectives, experiences, and backgrounds of all students are important for enriching learning in the classroom.

The first two characteristics capture the nature of relationships between teachers and students in a collaborative classroom. The third characterizes teachers' new approaches to instruction. The fourth addresses the composition of a collaborative classroom. Smart Classroom enhances the above characteristics of collaborative learning. In the next section, we describe the characteristics and functionalities of Smart classroom. Further, we present an example scenario where Smart Classroom enhances collaborative learning.

## 3 Major Characteristics of Smart Classroom

Our Smart Classroom facilitates collaborative learning using RCSM, which is a middleware for pervasive computing applications. Devices in a smart classroom can be divided into two categories: infrastructure-devices and mobile-devices. The infrastructure-devices are stationary in each classroom, and these devices provide the necessary facilities to the mobile-devices. The mobile devices usually belong to the students and instructors. Using these mobile devices, the instructor and the students engage in collaboration in a classroom. In our current implementation, we mainly use PDAs as mobile devices. The infrastructure-devices currently consist of PCs and PDAs with additional capabilities. Both types of devices run our RCSM with different types of collaborative applications. We describe the major features of our Smart Classroom below and describe how these characteristics facilitate collaborative learning:

A) **Ephemeral Group Formation and Communication:** Group discussion is one of the most important functionalities of Smart Classroom to facilitate collaborative learning. Depending on the current situation, such as the location of the current classroom, class schedule, and availability of other group members, the PDAs in classroom can form device groups so that students can collectively work to solve different in-class exercises. These device groups are dissolved when the group-forming situations are no longer true. This feature of Smart Classroom addresses S1) and S4). In addition, an instructor's PDA can dynamically join a student group to monitor and evaluate a group's progress and provide timely feedbacks during a classroom exercise. This feature addresses S2).

**B) Situation-Aware Interactions Among PDAs:** In order to address S3) among students and the instructor in different cases, we use our RCSM in PDAs to provide situation-aware interactions among PDAs. In this type of interactions, different PDAs detect each other dynamically and exchange useful information depending on their respective and desired situations. For example, at the beginning of a class session, the instructor's PDA detects students' PDAs in the classroom and distributes lecture slides to the students' PDAs whenever the instructor becomes ready to start the lecture by turning down the light (to use the projector).

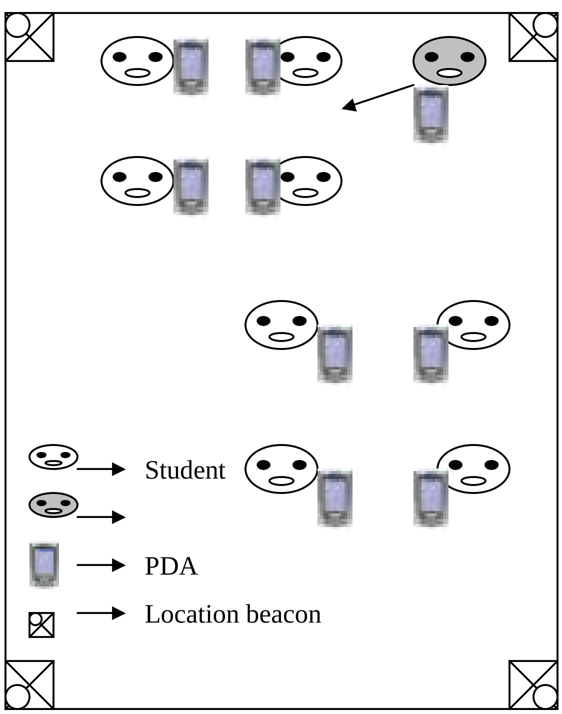

Figure 1: Conceptual Figure of a Smart Classroom.

## 4 Functionality of Smart Classroom Applications

In this section, we will describe how our Smart Classroom application suite facilitates collaborative learning applications. Our Smart Classroom application suite facilitates different collaborative learning activities of a student, an instructor, and a teaching assistant (TA). The suite also provides different functionalities for communication between the students, the teacher, and the TAs. The functionalities of Smart Classroom Applications are listed below:

1) For a single student

§ The application suite reminds the student of his/her homework and class schedule based on current time and current location.

§ The application module will synchronize the lecture notes between a student's PDA and desktop computer before and after class.

2) For instructor/TA

- § The application suite synchronizes the lecture notes between instructor or TA's PDA and desktop computer before and after class.

3) For student-to-student communication
   - § The application suite enables students to exchange and share their design documents in drawing.
   - § It also enables students synchronize drawing document among their PDAs.

4) For instructor/ TA-to-students communication
   - § The application suite distributes teaching material (lecture notes/survey forms/grade sheet/course schedule) from instructor or TA to all students at proper situations, such as: beginning of a class, when light turns dark and noise is low.
   - § Instructor can create exams for students and groups by using the application suite. Instructor can also send exams to the students and groups. Instructor can collect answers; grade and send the grade back to the students by using he application suit.

5) For student-to-instructor/TA communication
   - § The application suite facilitates students to store their questions or concerns in text format in their pocket PCs. When instructor or TA is available (in classroom), the questions are automatically transferred to instructor or TA's PDA.
   - § Students submit their progress report in a similar way by using the application suite. At the end of class, their reports are submitted to instructor or TA automatically.
   - § Students make appointments with instructor by using their PDAs to send the request to instructor's PDA and get a confirmation by using the application suite.
   - § Students write answers of the exams and send answers to the instructor by using the application suite.
   - § Students run and display their homework or project on the PDAs and video projector with the help of the application suite.

## 5 Smart Classroom Test Bed

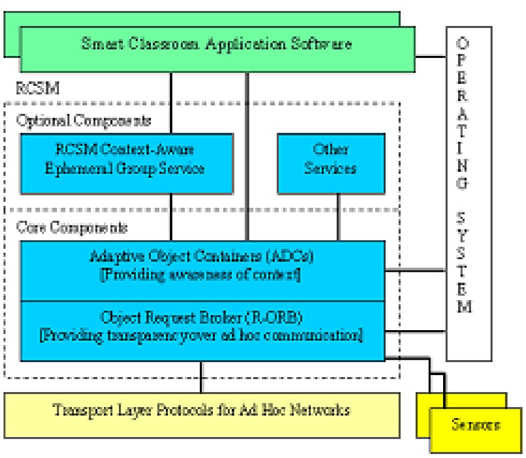


Figure 2: RCSM Architecture in Smart Classroom Test Bed.

In Smart Classroom, instructor and students carry PDAs. Each PDA has different kinds of sensors. Students' PDAs dynamically form mobile ad hoc networks based on proximity and specific contexts, such as location, light intensity, to collaboratively solve a specific problem. Application software is interoperable across different programming languages, PDAs, and mobile ad hoc networking protocols. RCSM will be installed in each PDA of Smart Classroom.

### 5.1 Overview of Reconfigurable Context-Sensitive Middleware (RCSM)

*1) RCSM's Situation-Aware Application Development Framework:* We have developed an application development framework in RCSM to facilitate the development of situation-aware application software. We have developed a situation-aware interface definition language (SA-IDL) to specify the "situation-awareness" properties of application objects. As described in [5], this allows dividing an application object into a situation-aware interface and a situation-independent object implementation. A SA-IDL specification can also be used to generate a custom-made situation-analyzer for an application object. A situation-analyzer performs the necessary situation analysis on behalf of an application object [5].

*2) RCSM' Situation-Aware Object Request Broker:* We have developed RCSM Object Request Broker (R-ORB) to facilitate the following runtime services [4-6]:

*3) Situation Data Acquisition:* Situation-aware applications may need runtime situation data from various sources. These sources can be local to the device or remote. In cases of remote sources, situations must be collected periodically. R-ORB provides this basic facility. Situation-aware applications may also need to exchange information with remote applications in a point-to-point or ad hoc group settings.

*4) Situation-Aware Communication Management:* R-ORB provides a lightweight framework for transparently connecting distributed and mobile situation-aware application objects over ad hoc networks. The R-ORB protocol spontaneously senses the peer devices in the vicinity and establishes short-duration connection by efficiently analyzing the situation-readiness and the desired communication partners of specific application objects. In addition, R-ORB provides a lightweight client-server communication primitive for letting the application objects communicate with stationary or enterprise computing resources.

### 5.2 Infrastructure and Application Development

For mobile devices for the students and instructors, we have chosen the Casio E-200 PDAs, because the running versions of RCSM, including R-ORBs, were already implemented in these PDAs. Each PDA used an Intel Strong Arm 1110 with 206 MHz clock speed CPU. Each PDA had Flash ROM and RAM of 32 MB and 64 MB respectively. Each PDA was also equipped with a D-LINK Air DCF-660W Compact Flash 802.11b adapter. These adapters were configured in ad hoc network configurations. As such, no infrastructure, such as an access point, is necessary to provide the communication support.

For infrastructure development, each PDA is also programmed to function as location beacons. In addition, each PDA is also connected to external hardware components to provide noise, light, and motion sensing support. To accomplish this, each such PDA was connected with a Trenz Electronic USB-compatible Xilinx Spartan II FPGA board equipped with noise, light, and motion sensors.

For the Smart Classroom application suite, we have developed the situation-aware ephemeral group communication service (SAEG). We are currently implementing a chat module and exam-taking and grading tools using the facilities provided by RCSM.

## 6 An Example

We will take CSE 461 Software Engineering Project I class of Arizona State University as an example of collaborative learning class. Smart Classroom fulfills the requirements of students and instructors in CSE 461 classroom. Students and instructors carry PDAs in CSE 461 classroom. Students are provided with the group project specification and development schedule in CSE 461. They follow a specific project process model to develop the group project. Students finish the requirement specification, software analysis and software design on schedule. Students develop risk management plans. Each group member participates in the project actively in the classroom. In CSE 461 classroom, students communicate with each other orally and exchange documents through PDAs. Students of each group view the analysis and design document of the projects, discuss, and make necessary corrections and make one final copy and distribute among themselves. Instructor frequently interacts with each group and each student for monitoring their progress in the classroom.

CSE 461 provides students a hands-on group-working experience. It prepares students to develop oral and written communication skill in a team environment. It also prepares students to use Unified Modeling Language (UML), software development process, which includes process definition guidelines, risk management, Capability Maturity Model (CMM) guidelines, and configuration management. In CSE 461, students form self-directed teams and finish software requirement specification, software analysis and software design. Students know how to use the technique (for example object-oriented analysis and design, component based analysis and design, framework based analysis and design) to analysis and design a given project. Students turn in complete requirement specification and design documents on time after actively participating in the group discussions and collaborating to prepare one document for each milestone. Students present what and how they have done for the projects at each major milestone. Each student makes presentations and participates in preparation of the project documents.

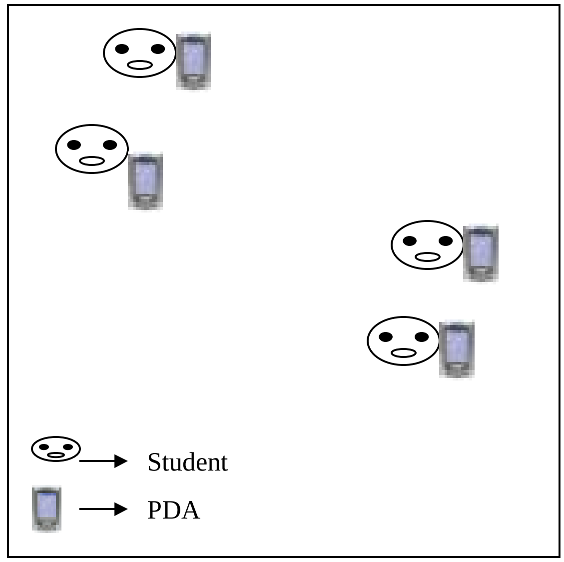


Figure 3: Four students are forming two groups in the Smart Classroom.

Instructor assigns students in different groups according their background, qualification and experience. Students of a group discuss different aspect of analysis and design and often change document and put different members idea together. Instructor often participates in the group discussions and often gives feedback. This scenario is given below in Figure 3-8:

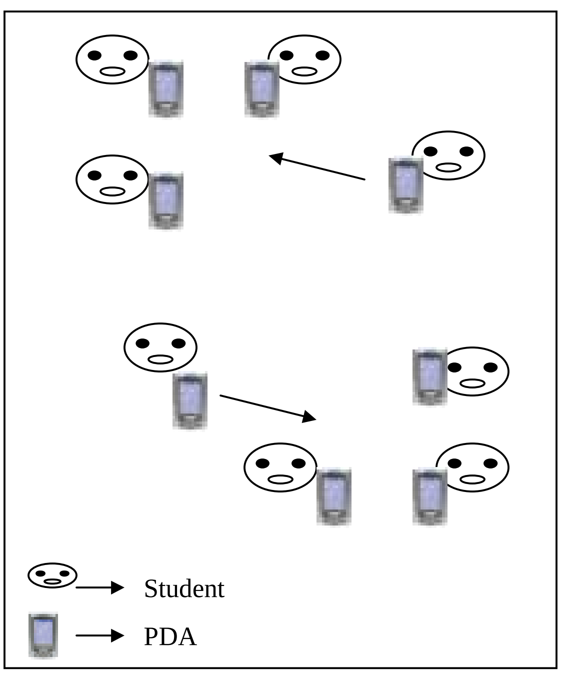


Figure 4: More members have joined and groups are formed in the Smart Classroom.

**Group formation:** At least two group members in the classroom start to form a group, which is shown in Figure 3. Location detection sensor of RCSM detects the location of the students' PDA inside the classroom. SAEG of RCSM establishes communication between two or more PDAs when they are in communication range and groups are formed.

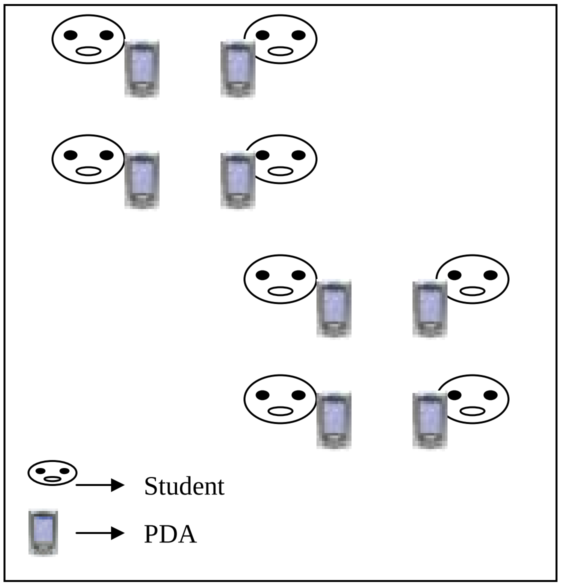


Figure 5: Students are discussing in groups in the Smart Classroom.

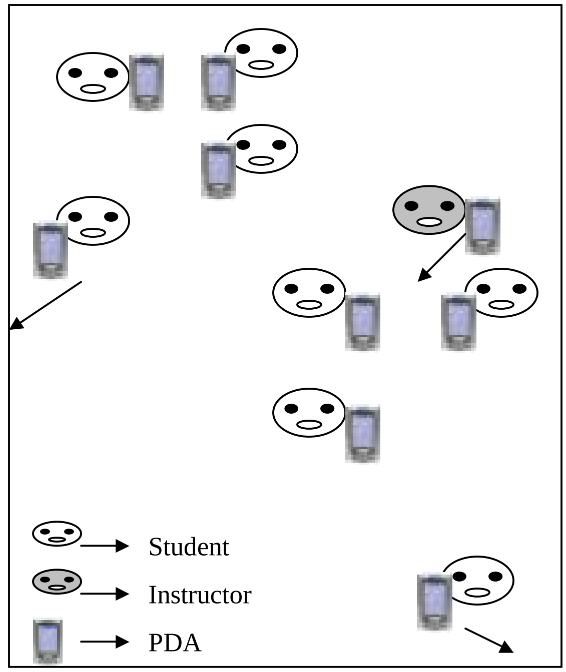


Figure 7: Group discussion is over in the Smart Classroom.

**Additional students join:** Additional students are coming in to join the group, which is shown in Figure 4. Students of the same group come closer. PDAs of the students are within communication range and groups are formed. Location detection sensor of RCSM detects the location of the students' PDA inside the classroom. SAEG of RCSM establishes communication between two or more PDAs when they are in communication range and groups are formed. SAEG of RCSM helps to discover the group.

**Groups are formed:** PDAs of the students are within communication range and groups are formed which is shown in figure 5. Students discuss in-group and send design document to group members and give feedback and collaboratively come up with a design. The application suite is used for sending and receiving design document and feedback.

**Instructor's feedback:** Instructor comes near a group. Instructor downloads group discussion materials (design document), which is shown in Figure 6.

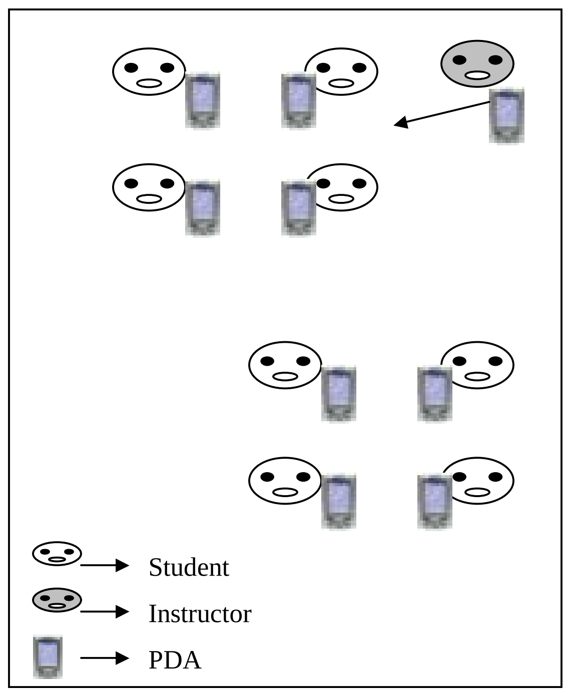


Figure 6: Instructor is giving feedback in the Smart Classroom.

The application suite is used for receiving and sending design document with comments from the student's PDA. Location sensor is used the to check the vicinity.

**Group discussion over:** Group members leave when the discussion session is finished shown in Figure 7. SAEG of RCSM is used for termination of groups smoothly.

## 7 Conclusion

In this paper, we have presented the details of Smart Classroom, which facilitates collaborative learning. It is designed to increase the level and quality of collaboration between students and instructor in a classroom. Functionalities of Smart Classroom including an example course were described. We have already implemented different functionalities of Smart Classroom. Currently, we are evaluating different scenarios of Smart Classroom. Future work includes addition of new features and extensive evaluation of our Smart Classroom.

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