Ambient Intelligence in the Classroom: an Augmented School Desk

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ABSTRACT

This paper discusses the opportunities and challenges of Ambient Intelligence (AmI) technologies in the context of classroom education, and presents the methodology and preliminary results of the development of an augmented school desk which integrates various AmI educational applications. The overall objective is to assess how AmI technologies can contribute to support common learning activities and enhance the learner’s experience in the classroom. Young learners were involved from the first phases of the design of the desk and its applications using scenario-based techniques.

Keywords: Ambient Intelligence, educational applications, eLearning, English as a Foreign Language, learner-centered design
INTRODUCTION

Ambient Intelligence (AmI) is an emerging field of research and development that is rapidly gaining wide attention by an increasing number of researchers and practitioners worldwide [13]. As a consequence, the notion of AmI is becoming a de facto key dimension of the emerging Information Society, since many of the new generation industrial digital products and services are clearly shifted towards an overall intelligent computing environment.

AmI will have profound consequences on the type, content and functionality of the emerging products and services, as well as on the way people will interact with them, bringing about multiple new requirements for the development of the Information Society (e.g., [9]). While a wide variety of different technologies is involved, the goal of AmI is to either hide the presence of technology from users, or to smoothly integrate it within the surrounding context as enhanced environment artifacts. This way, the computing-oriented connotation of technology essentially fades out or disappears in the environment, providing seamless and unobtrusive interaction paradigms. Therefore, people and their social situation, ranging from individuals to groups, and their corresponding environments (office buildings, homes, public spaces, etc), are at the centre of the design considerations.

AmI is often claimed to bring a significant potential in the domain of education [1]. Information and Communication Technologies already permeate the classroom environment in many ways. They can play an important role in education by increasing students’ access to information, enriching the learning environment, allowing students’ active learning and collaboration and enhancing their motivation to learn [5]. This paper presents a preliminary attempt to develop an augmented school desk and the related applications, which aim at integrating AmI technology in the learning process. Following a discussion of current issues in technology integration in the classroom, the paper describes the overall concept and the hardware and software characteristics of the prototype desk. Then, a scenario of use, and the related software applications currently under development are introduced. Finally, a formative evaluation experiment with a small group of young learners of English as a Foreign Language is reported and the results are discussed.

BACKGROUND

In the recent past, learning with the use of ICT was strongly related to concepts such as distance learning [2], educational games [11], intelligent tutoring systems and e-learning applications [3]. Overall, two major trends characterize recent efforts:

- Learner-centered design: learner-centered design approaches adopt and enhance traditional user-centered design practices in the educational context. Learner-centered design may be intended as design with the needs of the learner at the forefront, and possibly involving learners at various stages of the design process. Related work has addressed on the one hand
the specific characteristics of the very young population as users of interactive technologies [8, 15], and on the other hand pedagogical and learning-related requirements [16].

- Adaptive and personalized eLearning: these approaches aim at exploiting intelligent tutoring and adaptive hypermedia techniques in eLearning in order to provide educational content matching the individual learning requirements of different learners, and to support content reusability [4]. In particular, in the domain of foreign language learning, which is of relevance to the work reported here, intelligent techniques are targeted to personalized support for learning strategies and error correction [12].

Furthermore, the notion of smart classrooms has become prevalent in the past decade [19]. Smart classroom is used as an umbrella term, implicating that classroom activities are enhanced with the use of pervasive and mobile computing, sensor networks, artificial intelligence, robotics, multimedia computing, middleware and agent-based software [6]. Following the rationale of augmented technology in the educational environments, new means of interaction - such as interactive whiteboards, touch screens and tablet PCs - have gained popularity and have become a major tool in the educational process, allowing more natural interaction. Smart classrooms, for example, may support one or more of the following capabilities: video and audio capturing in classroom [18], automatic environment adaptation according to the context of use, such as lowering the lights for a presentation [7], lecture capturing enhanced with the instructor’s annotations, or information sharing between class members.

The work reported in this paper, which is conducted in the context of the AmI Programme of ICS-FORTH [10], constitutes an initial step towards investigating the role of AmI technologies in the educational context and in the classroom environment. The underlying approach is learner-centered, involving a small group of young learners from the very first steps of the design, and targeting to provide intuitive and seamless tools to improve the learning and classroom experience. On the other hand, adaptation and personalization techniques, as well as techniques in the domain of intelligent computer-supported language learning [12] are revisited here in an AmI perspective, aiming at exploiting the interaction possibilities offered by AmI technologies towards facilitating learning of English as a foreign language. An augmented school desk has been selected as a first AmI artifact to be developed in the context of the project, along with a series of educational applications which integrate ambient interaction as well as digital augmentation of physical paper (e.g., [17]).

**DESIGNING AN AUGMENTED SCHOOL DESK**

**PHYSICAL ARTIFACT DESIGN**

In the context of AmI, the classroom is a challenging environment. In practice,
there are severe space and layout limits to the introduction of AmI equipment, which should be unobtrusive, hidden or embedded in traditional classroom equipment and furniture. It is very important that such equipment can be installed smoothly and easily moved around in the environment, and that space requirements are as limited as possible. This implies several constraints on how the AmI classroom environment can be developed. To address this issue, the AmI Classroom project has adopted an artifact-oriented approach, by stepwise introducing independent AmI augmented artifacts in the environment.

As already mentioned, the first such artifact is an augmented school desk (Figure 1), where an additional piece of furniture has been designed to fit typical school desks of standard dimensions according to EU normative. Such an ‘add-on’ provides a custom plexiglass 27 inches diagonal wide screen whose inclination can range from 30° (with respect to desk surface) to completely horizontal. It embeds almost invisibly all the devices required for the operation of the AmI applications, and has a width of 40 cm, thus requiring relatively limited additional space with respect to the standard desk. A wooden prototype of the desk has been built. The green color has been chosen to facilitate vision processing.

Figure 1. The design of the augmented school desk

**HARDWARE AND SOFTWARE SET UP**

An important consideration in the design of the augmented school desk was that AmI in the classroom should be compatible with the school of today, as the anticipated transition to the paperless classroom does not appear so imminent. Therefore, as a first step, the augmented school desk should smoothly support paper-based learning materials and the use of handwriting. This requires the adoption of vision techniques on the front part of the desk, as well as smart pen

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1 EN 1729-2:2006 Furniture. Chairs and tables for educational institutions. Safety requirements and test methods.
integration. On the other hand, it was considered important to embed in the enhanced desk vision-based back projection multi-touch interaction, in order to avoid ceiling mounted or hanging projectors and cameras and ensure gesture interaction quality under variable lighting conditions. This option had several important implications, as it was not an easy task to realize a back-projection multi-touch set-up within the available space. The resulting hardware set up includes (Figure 2):

- An Intel Core 2 Quad Core PC
- 2 DLP mini projectors located behind the screen
- 1 mirror for reducing the projection distance
- 2 cameras located behind the screen
- 4 infrared projectors located behind the screen
- 1 camera located on top of the screen and capturing images of the conventional desks
- 1 smart pen and its transmitting device\(^2\)

The PC runs MS Windows 7. To better exploit the custom screen dimensions, a horizontal window manager was developed which includes two application and two menu areas. In order to support multi-touch interaction, the software reported in [14] is used. The smart pen input is captured through the Pegasus SDK\(^3\). The necessary front vision software is currently under development. The multi-touch display embedded in the desk (Figure 3) allows augmenting physical learning materials with additional context-dependent information.

**Usage Scenario and Educational Applications**

An important objective of the AmI Classroom project is to ensure that the developed technological artifacts go at the heart of the learning process. To this purpose, learning of English as a foreign language was selected as a testing domain, and current practices were examined to identify useful support which can be offered.

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\(^2\) [http://www.gande.gr](http://www.gande.gr)

through AmI technologies, focusing on preparation for the first and advanced
certificates (thus addressing an adolescent student population). Based on such an
analysis, extensive usage scenarios were compiled. The scenarios mainly address
activities which take place in the classroom; however, an important consideration is
that the software to be developed should be general enough to support also learning
at home or elsewhere, independently from the classroom infrastructure and the
augmented desk itself. In particular, the scenarios address the seamless context-
dependent provision of useful additional information during language-learning
activities. Interaction with the provided facilities is based on gestures, either through
the desk screen or directly on paper resources. For example, the learner can indicate
a word on the page to view additional information about it, or the answer to a fill-
the-gap exercise to receive feedback or hints. Text entry during learning activities is
based mainly on handwriting using a smart pen. However, an on-screen keyboard is
also currently under design to support small text entry tasks on the touch screen.
The desk should also be able to identify each user through a personal object (e.g., a
school diary, pen, etc).

The developed scenarios led to the identification of a set of software
applications for enhancing English learning experience through the augmented desk.
These include the login screen, the welcome screen, an individual personal area
summarizing the current delivery status of all assignments, a dashboard where
students can temporarily save material, the assigned exercises in electronic form
with the supported hints and help, a dictionary-thesaurus application, a personal
dictionary application, a note-taking applications, an application for viewing course
related multimedia, and language-learning games (e.g., hangman). The dictionary-
thesaurus presents a short definition of the word, its pronunciation, a button
allowing the student to hear the pronunciation, some synonyms and a few examples
of use in a sentence. In addition, the thesaurus offers options for extended
descriptions, grammar information, complete list of synonyms, antonyms and
several examples. Figures from 4 to 7 show some mock-ups of the designed
applications.

Although the enhanced desk is designed for individual use, collaboration is
foreseen for some tasks. For example, the students can exchange materials and the
teacher can send materials (e.g., assignments) to the personal areas of all students
through simple gestures. The smart environment automatically restricts actions that
can be carried out by the students according to the current context. For example,
when a reading task is active, the students cannot use some functionality in their
system (e.g., multimedia, saving, printing, etc.), and when an exercise task or a test
is being carried out, students are not allowed to send material to other student’s
personal areas. The system will also produce statistics regarding the hints that have
been requested, per student and for the whole class, so the teacher will be able to
monitor the student’s progress. The system will also monitor the success rate of
each exercise and provide statistics. Teacher can then combine this with the hint
statistics to review results and adjust the difficulty (remove/alter exercise) in order
to improve the learning curve. The system can also measure the time needed by
each person to complete a specific task.
FORMATIVE EVALUATION

A formative evaluation experiment was conducted involving 5 young learners of English as a foreign language (1 male and 4 females, within the age range from 11 to 16, all studying for a first or advanced certificate in English, and all familiar with PCs and mobile phones, but not with AmI environments). The experiment was targeted to collect users’ opinion regarding:

- The desk itself.
- The overall idea of interactive student desk in the AmI class and how it can assist learning.
- The usefulness of each application regarding the English course and in particular the thesaurus, the multimedia application, the personal area for assignments and homework delivery, the myVocabulary area, and the hints and confirmations during exercises.
- The User Interface (UI) layout and aspects of the supported gesture interaction.

The experiment took place individually for each learner. After a very brief introduction, the learners were driven through a simplified scenario illustrating the main aspects of desk and of the related applications.

During the execution of the experiment, the children were asked questions about various aspects of the scenario, and notes were taken with all their comments.

Figure 4. The Personal area with assignments and their delivery status

Figure 5. Gradual hints for solving fill-the-gap exercises
After the completion of the scenario, they were asked to answer a questionnaire composed of 17 questions. Of the questions, formulated in an informal style to appeal the young learners, 15 used a Likert scale from 1 (sure!) to 5 (no way!). The remaining two questions concerned listing aspects of the scenario that the children particularly liked or disliked. The results of the questionnaire are depicted in figure 8, where lower scores correspond to positive and higher scores to negative answers.

Overall, the results are very positive, as all the children involved in the experiment were very interested about the desk and its applications, and some where enthusiastic about having such an artifact available in their classroom.

The preferred features of the desk were the personal area and the dictionary, followed by the educational games, the dashboard, the hints and confirmations, touch interaction, pointing at things and viewing info, and the electronic submission of assignments. The features they disliked most were mainly the desk size and color, and, with respect to the UI mockups, again the colors and the fonts.

The young learners appreciated the educational support which the desk aims to provide, as well as the potential for better organization of work between the classroom and the home environment and collaboration with teachers and other learners.
Some of the children also proposed to include a grammar application similar to the thesaurus application, displaying grammar rules, verb tables, etc, related to the task at hand. On the other hand, the young learners appeared to view the desk as a ‘trendy gadget’ and demonstrated to be very sensitive to aesthetic issues, asking for the possibility of personalizing the desk color, selecting fonts, colors, background images and avatar images. Regarding interaction, they appreciated the gesture-based applications, but they also asked for more traditional interaction means such as the keyboard.

CONCLUSIONS

The results of the conducted study confirmed that AmI technologies have the potential to enhance the classroom learning experience and to be positively viewed by young learners, provided that they are carefully designed and tested. Adolescents seem to be aware of the opportunities offered by novel technologies and willing to embrace them, but also face classroom technologies as fancy personal gadgets which should be colorful, aesthetically pleasant, and fun. They also appear aware of potential technological difficulties, as well as space and practical limitations in the classroom environment. On the other hand, young learners easily grasp the potential of novel interaction techniques, such as gestures, but do not ignore more traditional means with which they are familiar already.

Currently, the prototype desk has been assembled and all the necessary software building blocks have been installed. Fully functional applications are being developed, along with the vision software required for supporting page and word
recognition on paper material. Following full implementation, a larger evaluation experiment is being planned, involving also, besides children, teachers and parents. On the other hand, new collaborative games scenarios are being elaborated in order to fully exploit multi-touch interaction.

The designed enhanced desk is intended to constitute a significant part of a complete AmI classroom environment which will be realized in an AmI Research Facility currently under construction at ICS-FORTH.

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REFERENCES