Using pervasive computing and open space design to transform the schoolyard into an educational setting

Chritsos Goumopoulos
Research Academic
Computer Technology Institute
Patras, Greece
goumop@cti.gr

Dimitris Papalexopoulos
Architect, Assoc. Prof.
School of Architecture NTUA
Athens, Greece
dplxs@otenet.gr

Achilles Kameas
School of Science and Technology
Hellenic Open University
Patras, Greece
kameas@eap.gr

Athina Stavridou
Architect, MSc N.T.U.A., PhD candidate Adjunct Lecturer
School of Architecture N.T.U.A.
Athens, Greece
athinast@central.ntua.gr

Sonia Tzimopoulou
Architect, MSc VE UCL, PhD in Architecture
Postgraduate researcher NTUA
Athens, Greece
soni@ath.forthnet.gr

***Abstract*—Educational process' experimental implementation with the support of Information Communication Technologies (ICT) integrated to the elective course "Principles of Environmental Sciences" of the Second High School Class that combines environmental education, principles of space design, introduction to information technologies in ecology and "green" ICT, and sustainable development through the digital management of planting and of the introduction to the crucial wider issue of precision agriculture. The experimental implementation is realized in collaboration with the professors of the 1rst General High School of Agios Dimitrios. Temperature sensors, humidity and illumination are placed in structures parametrically designed according to the bioclimatic conditions of the space of the school yard and have been sited in accordance with the operational needs of the complex. Students interact with plants and offer maintenance services when plants request it.**

Keywords-Educational process; interaction; environmental education; space; parametric design; ecology; sustainable development;school court;

I. INTRODUCTION

Modern pedagogic approaches claim that learning is a constructive process, the result of which can be greatly enhanced if it takes place within a social context [9]. Thus, methodologies have been proposed that emphasize on the need to support learners in constructing knowledge, and more specifically, on facilitating collaboration among them during study time. A plethora of tools have been developed that support these methods, ranging from intelligent multimedia tutoring systems to social networking systems.

The advent of pervasive computing created a whole new spectrum of possibilities in ICT-based education, which could help even more in applying the principles of constructive learning methods [8]. The aim of this paper is to present a pervasive computing application that could be introduced to the High School curriculum. The proposed system combines the principles of open space design and the services of a pervasive computing agricultural application to persuade High School students to grow and take care of plants in their schoolyard. Expected learner benefits include a large body of knowledge on modern ICT and architecture, skills in combining methods of these disciplines to solve an everyday problem, a positive attitude towards plants and the environment, and soft skills that include collaboration and tolerance of fellow students. Clearly, this set of benefits outperforms those the students could acquire from a traditional face-to-face lecture taking place in the classroom.

The paper firstly presents the history behind the project. Then the project set-up is described. In section IV the educational process is described, followed by a discussion of the expected impact on learners. The paper concludes with a presentation of future developments.

II. HISTORY

Within the framework of the elective course of the Second High School "Principles of Environmental Science" during the

2009-2010 school year, an environmental education program was carried out on the study, design and planting of the school yard from 1rst General High School of Agios Dimitrios. The process of organization, preparation and development of the combination of course - program is presented in http://sites.google.com/site/scholikiauli/home. The course is taught by Professor Georgia Papageorgaki and responsible teachers for the program are Maria Thanou and Georgia Papageorgaki.

As part of the course a presentation of the history of the school, the architect who had designed in 1969 (Takis Zenetos) and the principles he had implemented (bioclimatic design and information technology in education) as well as the design of the recent renovation (2005), was made by Associate Professor School of Architecture NTUA Dimitris Papalexopoulos. Furthermore, the architects Angela Kouveli, Dimitris Papadopoulos, Athina Stavridou and Sonia Tzimopoulou, presented principles of open space design, in line with environmental objectives. A discussion followed and then collaboration between architects and students for designing and planting the school yard. Today the yard planting is underway and will be completed the next school year.

In the evolution of the course, students expressed a desire to design sitting spaces and shading (pergolas), both in the yard and inside the atrium of the school. The desire is viewed positively by the team of architects and is now at the planning stage; its implementation is planned in the coming months.

At the same time, the idea of introducing an **application of intelligent environments**, developed by the DAISy group (Dynamic Ambient Intelligent System) in the European research project Plants (http://daisy.cti.gr/plants/) arose [6]. The prototype system supports receiving data on the status of the plant through sensors and draws conclusions about their needs and their situation (as may be the moisture, the levels of chlorophyll, the temperature of their immediate environment, etc.). The proposed system is adapted with the help of agriculturists of the research team to the specific characteristics of the plants that will be planted and it will also support remote management of resources associated with each plant, the transmission of this information through web node or mobile phone and sms and the activation of processes to meet the occurring needs and resolve any problems found.

III. THE PROCESS

Students participate in an Environmental Educational programme concerning the school yard:

1) In the first phase **they design and implement the planting of the school yard** and propose sitting spaces and shadings.

2) In the second phase they **place in plants that they planted a network of sensors**, which communicate wirelessly, and inform them on the web node of the course, but also on mobile by SMS on the status of the plants, "talking" with them.

3) At the same time, the **web node** of the course is created in the form of **interactive educational application** in which, by focusing on environmental education will be integrated related applications on architecture and IT, on the occasion of the design of the courtyard and the "conversation" with plants.

4) An **application of social software wiki type** is created, through which students and teachers create a communities and participate in discussions on issues related to plant development, ecology, green ICT, architecture of space.

A pilot implementation is currently under way at the 1rst General High School of Agios Dimitrios. In the next stage, based on the achievement of educational objectives it could be extended to other schools yards, creating a network of environmental education, with the exchange of information and knowledge about the plants used and about how the design of the yard has been implemented.

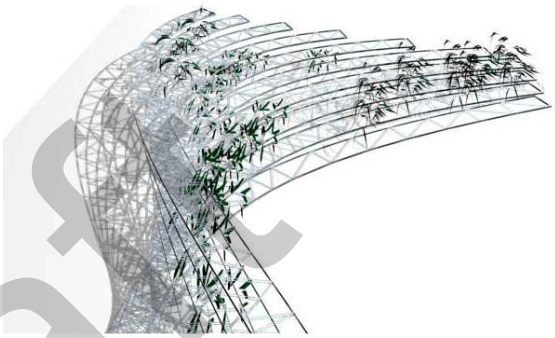

Figure 1. Parametric structure supporting plants and sensors

Figure 2. The School of Agios Dimitrios

In the development and implementation of the idea collaborate:

- The 1rst General High School of Agios Dimitrios and Professor Maria Thanou and Georgia Papageorgaki. The 4o EPAL Patras and professors Aikaterini Gika and Karmella Roussou
- The Laboratory of Building - Architectural Technology, School of Architecture of NTUA

Identify applicable sponsor/s here. *(sponsors)*

coordinated by Dimitris Papalexopoulos Assoc. Prof. NTUA and the architects Angela Kouveli, Vassilis Kyriakopoulos, Giannis Orfanos, Dimitris Papadopoulos, Athina Stavridou and Sonia Tzimopoulou (www.ntua.gr/archtech).

- The DAISy Research group (Dynamic Ambient Intelligent Systems), namely: Achilles Kameas Asst. Prof.HOU, Christos Goumopoulos, Computer & Information Technology Engineer, Ioannis Calemis, Computer and Informatics Engineer (http://daisy.cti.gr).
- The consultants on interactive educational application: Eleni Kalafati architect - interactive educational applications, Stavroula Kylintirea, educator, interactive educational applications.

The project aims at the **combined introduction to the environmental education and information technology**, and utilizes the experience from the course "Principles of Environmental Science" during the school year 2009-2010, whose content was the "School Yard", in the open space of the 1rst General High School of Agios Dimitrios and in the space of the fourth EPAL Patras.

The architecture of the proposed system is shown in figure 3.

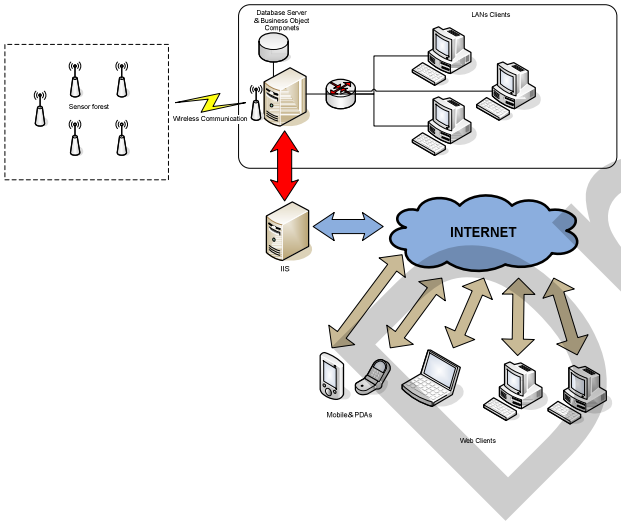

Figure 3. Architecture of the system under development

IV. THE EDUCATIONAL PROCESS

A complex experimental educational process is created, which, through its different included activities will also have multiple objectives:

As for the design of the school yards:

- Design of planted areas for the school break.
- Optimization program of existing yards in all schools with environmental criteria and improvement of the life quality of students.
- Creation of a list of parametrically designed school yards equipment constructions for pergolas, climbing plants, seating, meeting points for student events.

As for the introduction to issues of IT management of the environment:

- Receiving information from students about the plants that themselves have planted in areas that they also have designed and developed.
- Knowledge related to sensors and actuators
- Knowledge related to a network of receiving environmental data and its relationship to sustainable development.
- Knowledge and application of "precision agriculture", saving of resources and greater efficiency.
- Teaching in the field.

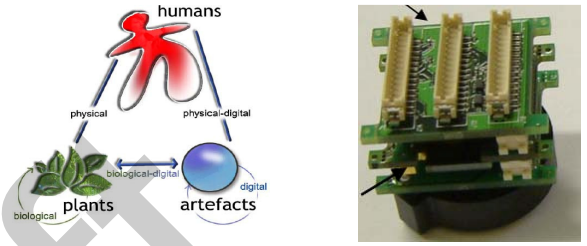

Figure 4. Schematic ePlamts approach and one precision agriculture mote

As for the Environmental Education:

- Theory and implementation of the principles of Environmental Education, which require the active involvement of students in environmental activities through the planting of school yards.
- Development of new Environmental Education programs in high school.
- Development of educational material.

Specifically regarding the creation of educational material for the environment:

- Creation of an interactive web node with educational content related to the environmental education. Specifically:
- Systematic collection and presentation of information about the plants that can be used for the planting of school yards.
- Each reaction of plants that students have planted will enrich this broader educational material for the plants.
- Creation of an environmental education school network around the specific application aiming at exchanging views and information on the design process of the school yard, the evaluation of the output, the selection and development of planted plants.

V. IMPACT ON LEARNING

The impact of the project extends over five interrelated educational fields:

A. Environmental Education

The project is based on the concept of carrying out environmental education programs within the framework of the elective course of High School B: "Principles of Environmental Sciences', as suggested by the authors of the related schoolbook.

In the foreword note of the book from the editor (Hellenic Schoolbooks Publishing Organisation) it is stated: '... the structure and function of these teaching chapters aspires to convert this book to activities guide... .... These activities, when they are integrated **programs of Environmental Education and Training**, in collaboration with professors from different disciplines are the best experience to build the concepts and principles of Environmental Science ... '[1]

The experience of such applications in the 1rst General High School of Agios Dimitrios showed that the project has also practical advantages, such as but not limited to: the **time** of two hours a week is enough to approximate a variety of objectives and activities, ecological **knowledge** that is given through the schoolbook, and the possibility of applying **pedagogical methods** that are considered necessary in Environmental Education and that are thus incorporated into the formal mode of education, which is a challenge for the Greek educational reality.

It should be noted that this project meets the objectives of Environmental Education (apart from awareness and knowledge which are the usual targets of such programs) such as: the acquisition of **incentives** to create in students a desire to actively participate in improving and protecting the environment, the **skills** to identify and resolve environmental problems, and mainly to give students the opportunity to **participate actively at all levels** of solving environmental problems.

Finally, we should mention that although the course 'Principles of Environmental Science" is the ideal framework for the proposed project, this could also be realized within the framework of **other courses** or through **interdisciplinary works**, with the results reported above. This may be the goal of a future implementation and expansion of the program.

B. School yard (design and planting)

The school yard is re-designed by the students in collaboration with architects and agriculturalists. Green spaces are defined, sitting spaces where pergolas are created. Proposed by the architecture team are shadings of maximum shade relatively to the sun trajectory. Issues of aesthetics, economy, technique in space design and planting arose. The choice of plants is related to the "background" of planting (flower gardens, pergolas, rock gardens, vegetable gardens, trees, living walls, etc.) on the basis of their role in the courtyard and the "economy" of planting and maintenance. Lectures within the framework of the course help students to choose alternative layouts and plants.

The intention is to react to contemporary **planting** approaches such as the use of low maintenance vegetation and of adaptive and native plantings.

The aim of the project is to help the students to create custom planting designs that use plant types of the local area. The scope is to incorporate the natural system of the school site and work with the existing ecologies to produce a sustainable environment. The integration of adaptive planting in the design produced would improve the ecological function of the site.

New plantings are working with specific environmental urban conditions and microclimates, build upon the existing landscape character revealing new emergent and adaptive dynamics. [2]

The educational scope of the design is the use of appropriate plants for site conditions (soil moisture range, soil pH requirements, heat tolerance, salt tolerance, watering requirements, maintenance requirements). The selection of native plants or adequate species would be crucial for the results obtained. The local ecosystem has to be protected and for that reason invasive species should be avoided. The selected plants should adapt and thrive in the climate and conditions of the specific site.

"Appropriate plant species are plants adapted to site conditions, climate, and design intent. The following attributes should be considered in determining whether plants are appropriate for the site: cold hardiness, heat tolerance, salt tolerance, soil moisture range, plant water use requirements, soil volume requirements, soil pH requirements, sun/shade requirements, pest susceptibility, and maintenance requirements. Native and non-native plants are appropriate if they meet the above criteria.

Invasive species are species that are not native to the ecosystem under consideration and that cause or are likely to cause economic or environmental harm or harm to human, animal, or plant health.

Native plant communities are plant species, composition, and structure typical of communities native to the specific place."[3]

In general, a rationale is developed concerning the **parametric design** of the courtyard and of the elements / backgrounds planting which can be useful for all schools in the country.

Nowadays most of the contemporary architectural design software is limited to information management during design and construction phases, while interaction design remains an autonomous research field that meets application in building structures that either are realized or their fundamental design has already been decided. Therefore parametric design concerns the design team and interaction design regards the users. The integration of these distinct topics will drive the progress of the research and the connection of parametric design with interaction design in a uniform total.

At a theoretical level, the production of concepts that combine the relation between parametric design and interaction design will be developed. While concerning the software development, a total model will be produced on the subject of the design of integrated components in modeling structures. Specifically there will be produced parametric models for particular component sequences of the built elements created (i.e. shadings or sitting places). [4]

"Currently industry attention is on systems in which a designed artifact is represented parametrically, that is, the representation admits rapid change of design dimensions and structure. Parameterization increases complexity of both designer task and interface as designers must model not only the artifact being designed, but a conceptual structure that guides variation. Parameterization has both positive and negative task, outcome and perceptual consequences for designers. Positively, parameterization can enhance search for designs better adapted to context, can facilitate discovery of new forms and kinds of form-making, can reduce the time and effort required for change and reuse, and can yield better understandings of the conceptual structure of the artifact being designed. Negatively, parameterization may require additional effort, may increase complexity of local design decisions and increases the number of items to which attention must be paid in task completion."[5]

C. Informatics: Ecology and Green Development

Concepts that are developed are the interaction with the environment, the information collection on environmental data and processing so as to acquire a picture of their condition which after its assessment leads to actions. The reason is the planting and the ongoing monitoring of its state. However, educationally, the program extends to the broader need for gathering environmental data and in the ecological production process of "precision agriculture", which refers to major cultivation and the possibility of interventions in it with the aid of sensors that detect problems and suggest local interventions resulting in resources savings and disaster prevention.

As all the activities and monitoring of plant are communicated to students through SMS and Internet posting on the website of the school, links and social networks are created that transcend the boundaries of the specific school, to a network of schools, introducing students to the concept of common productive action through networks.

D. Study of positive influence and change of students' behavior

The presented project aims at raising awareness and changing attitudes and behavior of students towards plants before and after their involvement in the program.

Specifically, it will study and measure:

- The interest that students will show to plants
- The incentives to attract the students' interest to the plants
- How and whether their behavior will change in that school year in relation to the following: a) degree of peace - violence (delinquency) b) energy or fatigue c) the need to protect plants or indifference d) desire to diffuse to other schools in neighborhood in the municipality, etc.
- If and how their interest will increase in the subjects of their expertise to engage them in this profession since it is one of the most interesting and viable solutions for our country.

E. Technological Education

The project involves the students of the B class of 4th EPAL of Patra specifically the Department of Agriculture, Food Agriculture and Environment specialization in conjunction with the Department of Health, Early Childhood specialization, and is part of the following courses under the curriculum:
1) For a sector of Agriculture) Agriculture and Development b) Introduction to Agricultural Production c) Environment and Agriculture d) Agricultural Economics.
2) For the health sector: a) Methods of children's creative occupation b) Elements of genetic and evolutionary psychology c) Organization of children's environment

VI. FUTURE RESEARCH DEVELOPMENTS: COMMON TECHNO – PLANTS (CTP), FROM PRIVATE AND PUBLIC TO THE COMMON.

The development at the School of Agios Dimitrios is seen as a test bed application permitting the conceptualization of interlinked installations of “common” interactive plants at an urban scale.

In cities, we have:

- Public green spaces, owned, managed, supported by public or local authorities
- Private gardens disseminated on private verandas and terraces.

The current effort and politics to multiply and strengthen separately both private and public initiatives meets the following constraints:

- For the public green spaces, a need to find more public owned space and a budget limit.
- For the private green spaces, an obvious limit to the available open space.
- For both, public and private, a dissemination of green “spots” (bigger for the public spaces, smaller for the private spaces), with no apparent global strategy over the city.

Yet, private green spaces seem to be more dynamic (relatively low cost, everybody grows some plants in his apartment), but of minor impact on the city as they are small, isolated and constrained by the available private space, they are in fact, isolated green spots

We propose to start linking all those isolated private green spots, each one trying to be extended, on light constructions, towards its neighbors, to the adjacent terraces, to the green spots across the street, down the road to a small public place, all of them towards.

As those domestic plants will be *e-plants* [7], exchanging information with users, we propose the possibility of interlinking users to form local communities that could discuss and take decisions on:

- The possible spaces of plants extensions (between the properties and towards public spaces)
- The ways this extension could improve the micro climate of the neighborhood.
- The provision with water (possible grey water) and management of the plants.

The above will be supported by a site hosting info about the e-plants, decision making tools, parametric space designing tools, energy evaluation s/w, grey water – public water management s/w.

REFERENCES

[1] Athanasakis A., Kousouris T. and Kontaratos S., Principles of Environmental Sciences, OEDB, Athens, 2008

[2] Sustainable Planting Strategies and Cultivated Ecologies, http://www.asla.org/uploadedFiles/CMS/Meetings_and_Events/2010_Annual_Meeting_Handouts/Mon-C6%20Sustainable%20Planting%20Strategies%20and%20Cultivated%20Ecologies.pdf

[3] The Sustainable Sites Initiative: Guidelines and Performance Benchmarks 2009, http://sustainablesites.org/report/Guidelines%20and%20Performance%20Benchmarks_2009.pdf

[4] D. Papalexopoulos, A. Stavridou, A. Kouveli, Y. Orfanos, S. Tzimopoulou,. et al., IBC Intelligent Building Components, Research Report, NTUA, 2010

[5] R. Aish, R. Woodbury, Multi-level interaction in parametric design, Smart Graphics, 5th International Symposium, Proceedings, Springer, Munich, 2005, p. 151-162

[6] C. Goumopoulos, A. Kameas and A. Cassells, An Ontology-Driven System Architecture for Precision Agriculture Applications. International Journal of Metadata, Semantics and Ontologies (IJMSO), 4, 2009, Inderscience, pp 72-84.

[7] C. Goumopoulos, A. Kameas and B. O'Flynn, Proactive Agriculture: An Integrated Framework for Developing Distributed Hybrid Systems. Proceedings of the 4th International Conference on Ubiquitous Intelligence and Computing (UIC-07), Hong Kong, China, July 11-13, 2007, Springer-Verlag, LNCS 4611, pp 214-224.

[8] G. J. Hwang and S. J. Yang, Criteria, strategies and research issues of context-aware ubiquitous learning. Educational Technology and Society, 11(2), 2008, pp 81-91.

[9] R. Gagne, L. Briggs and W. Wager. Principles of Instructional Design (4th Ed.). Fort Worth, TX: HBJ College Publishers, 1992.