iCE: An Intelligent Classroom Environment to Enhance Education in Higher Educational Institutions

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Abstract. The intelligent Classroom Environment (**iCE**) promises to convey a rich and complex environment with the aim to achieve educational excellence and to provide world-class education in the university classroom environment. The classroom, the keystone for educational environments, is our first informational computer: a long-serving, complex, physical environment that embodies the education of human-minds; yet, classrooms are becoming an inadequate environment for tech-savvy generations. The **iCE** is a novel creative environment with the objective of enhancing education by embedding IT, Robotics, and Interactive Physical systems into the very fabric of the classroom's design. The **iCE** communicates a unique and flexible setting that allows for a better educational environment. The **iCE** will be developed to reconfigure and retune six basic scenarios of the different tasks needed in contemporary classroom environments, calling them: the Exploration, Collaboration, Meeting, Lecturing, Lounging, and Presentation configurations. In this paper, we will present **iCE**'s concept, design, and **iCE**'s kinetic wall explorations, as scaled prototypes.

Keywords: Design · Interactive systems · Cyber-physical platform Classroom configurations, and education

1 Introduction

One of the greatest challenges facing education is the ever-growing need for the use of different learning tools, techniques and environments that enhance lifelong learning in academic institutions. Peter Lippman's research, an Associate AIA and architect, shows that there is a growing need to think of the connections between 21st century's learning tools and techniques in the ever-changing world and the "classroom," the physical environment. Additionally, a growing scholarship has emphasized the need to change our "classrooms and furniture to adapt to student's learning style[s]," [4, 3, 11]. Thus, the planning and construction of new classrooms should be undertaken with an awareness of the different teaching techniques and configurations [8–11].

On "Bridging Down the Wall," David Raths describes that, "the classroom setup does indeed have an effect on instructors' habits as well as student participation and

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collaboration" [2]. Moreover, in a 2011 comprehensive study conducted by Marko Kuuskorpi *et al.*, comparing a "traditional classroom environment" versus a "dynamic teaching environment," the researchers conclude by the need to have adaptable furniture to the different learning configurations with respect to the different working methods: formal teaching, informal learning, social, and individual learning [4]. "By using mobile tables and chairs, a learner can create the proper setting for the activity being performed," as stated by Hassel [3]. *Therefore, rethinking of the current traditional classroom-design comprised of the static petrified skins (i.e., walls and ceilings) and furniture, is becoming essential in developing teaching and learning experiences in our Higher Educational (HE) institutions.*

As our pedagogical approaches are getting more complex and dynamic; i.e., there is a *paradigm shift from passive learning to participatory learning*, using new technologies and new teaching methods and techniques, such as: game-storming, focus grouping, brainstorming, social and individual learning, multisensory stimulation, among others [1, 11]. Yet, if the classroom continues to communicate to and educate us, what is a classroom for the ever-changing Informational World? In today's Informational World, however, architects are largely under-prepared to design state-of-the-art electronic-based intelligent systems; and the classroom is likewise, today, an inadequate information technology environment.

Today, however, with our powerful electronic devices and gadgets, the use of architectural spaces as the physical interface to our educational interactions may seem quaint [5, 6]. **iCE** seeks to fill this gap by focusing on how a robotic environment on a room scale can respond and adapt to our different pedagogical needs.

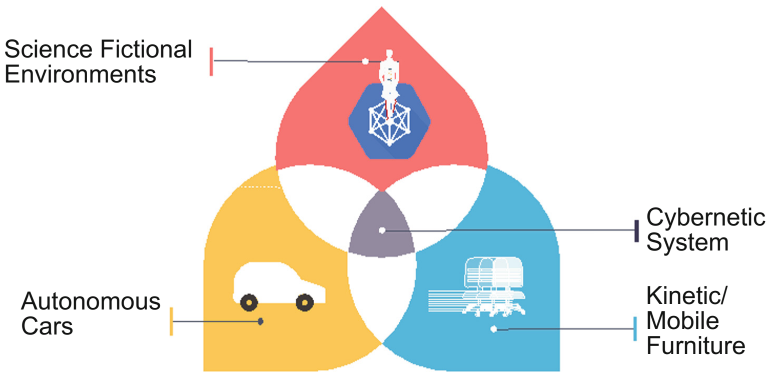

Fig. 1. iCE's motivation and concept.

2 iCE's Motivation and Concept

iCE is an architectural-robotic environment that adapts to the continuously changing needs of its users. The design of **iCE** is motived by the technological advancements of the autonomous physical movements of mobile furniture and autonomous vehicles. The **iCE**'s walls and ceilings are reconfigurable like a person who dreams that (s)he can change the surroundings based on his/her preferences, as in the bending city of the 2010 award-winning film "Inception" – Science Fictional Environment. We imagine that the chairs and tables autonomously move to set different configurations based on the different pedagogical and educational needs of its users, as described in **iCE**'s design. Literally, **iCE** is designed as a *cybernetic system that adapts to the continuous needs of its users* (Fig. 1).

3 Research Methodology

The design of **iCE**'s six different configurations is based on *iterative-design processes and prototyping techniques* (scaled and full-scale prototypes). A set of design guidelines for **iCE** informed by focus groups and brainstorming activities, informing the design of alternatives, and total virtual (i.e., computer generated models and videos) concepts for **iCE**. Finally, *a quasi-experimental research method* will be used to test and validate the effectiveness of such a system on real users, i.e., students and professors.

Our design of **iCE** is based on a human-centered design (HCD) approach, in which we use *personas and storytelling* as a research design approach to better understand the targeted users. For achieving this goal, we designed three different personas as described in the following section, Fig. 2.

Fig. 2. **iCE**'s three Personas employing the use of Storytelling technique

3.1 iCE's Personas

Personas and Storytelling techniques can help bringing to life the various users' needs and challenges. Accordingly, the research team had learned from creating these personas certain design drivers, which helped us in adopting the technologies that meet such needs. We had also taken a *design-driven technology* approach by getting immersed in the social life within the different classroom settings so as to create an evolutionary classroom environment. Not only from the understanding of the university's society and culture, but also from the ever changing needs and the evolution of the society, to *create new meanings* for all the classroom's stakeholders; *an autonomous classroom that can interact with us*.

Three different personas were developed for this research on the intelligent Classroom Environment, i.e., Andrew, Kate, and Prof. Adams.

1. *Andrew John* is an architectural student at Harvard University, he represents art students or what we called the "*creativity model*," who is interested in design and art modeling, see Fig. 2.
2. *Kate Hogan* is a freshman electrical engineering student at Harvard, she is a tech savvy student representing a "*classical engineering student*".
3. While Prof. *Annmarie Adams*, is in her 40s, researcher and professor of Mathematics at Yale University, prefers to use a mixed method in teaching. She uses the classical white board to show students *hands-on* the solution of complex math problems. She also prefers to use smart boards and tablets as new means in mixing the use of pen and paper method with the use of advanced software to solve such problems. Thus, representing a "*postmodernist model*".

As presented in Fig. 2, our personas had been the characters of storytelling graphical formats that best describe the needs and the challenges for the three different models. Following the social immersion exercises and observing the targeted users, we came with the following design drivers to best fulfill the needs of the targeted users.

The Design Drivers for iCE, after creating the personas and storytelling, *should include:*

1- Minimal time for organizing space elements.
2- Physical and Digital tools.
3- New classroom arrangements for the ever-changing savvy tech users.
4- More than a place to sit and listen, it should embody social interactions.
5- Spatial and sensorial dimensions (sound, light, colors and texture), which are essential for the different user profiles, personas.
6- Open/reconfigurable environment.
7- User-friendly performance and system feedback.

3.2 iCE's Iterative Design Activities

Based on the above design drivers, the research team had identified three main challenges for the design of iCE, a. wall and ceiling robotic movements; b. table and chair design components; c. the centralized vs the distributed network of the system. The design team had employed the use of the iterative design approach in two studio-based design courses, semester-long projects for second and third year architectural students, to design physical kinetic walls and ceilings; and for interior design students to develop movable kinetic tables and chairs, Fig. 3. These iterative design activities led to the selected design of iCE.

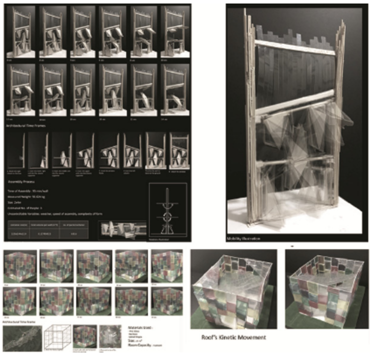

Fig. 3. iCE's interactive wall and roof panels while reconfiguring.

4 The Intelligent Classroom Environment (iCE)'s Design

4.1 iCE's Main Components

What we call "**iCE**" reflects the dynamic and inclusive character of our time. **iCE** is a robotic interactive physical-digital system for students and professors to connect with their classroom through the different components of the room; and, to reconfigure and retune it to the needed configuration, described below.

iCE is comprised of the following artifacts, a-self-organizing robotic desk; b-self-organizing robotic chairs; c-interactive wall panels; d- autonomous ceiling; e-auto-adjustable projector; and f-auto-adjustable sound and light systems, as in Fig. 4.

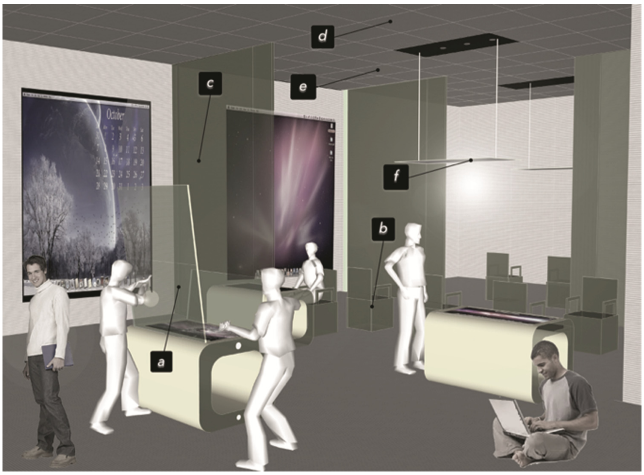

Fig. 4. **iCE**'s different robotic and interactive components.

4.2 iCE's Architecture

iCE is a hybrid physical-digital system comprised of the above six elements, as in Fig. 4. The chairs, tables, walls, and ceiling are to be designed as architectural-robotic systems capable to reconfigure based on the six different configurations, more details in the following section. In achieving this goal, we incorporate the use of three robotic technologies: a. sensors that can help in detecting proximity to people and objects, and distances between **iCE**'s different elements, i.e., ultrasonic sensors; b. Linear actuators, motorized wheels system, and servomotors to move the objects and components of the system; and, c. microcontrollers that work as the brains to process the inputs and the outputs, and to communicate wirelessly with a centralized computer/server.

As we envision **iCE's** table and chair designs, following the iterative design activities, the table is comprised of two movable on-track screens driven by linear actuators, LCD touch screen, ultrasonic sensors, three-wheel motorized systems, battery, and microcontroller, as in Fig. 5 (left). The chair is comprised of a movable back and two sides driven by linear actuators, ultrasonic sensors, two motorized wheel systems, battery, and microcontroller, see Fig. 5 (right).

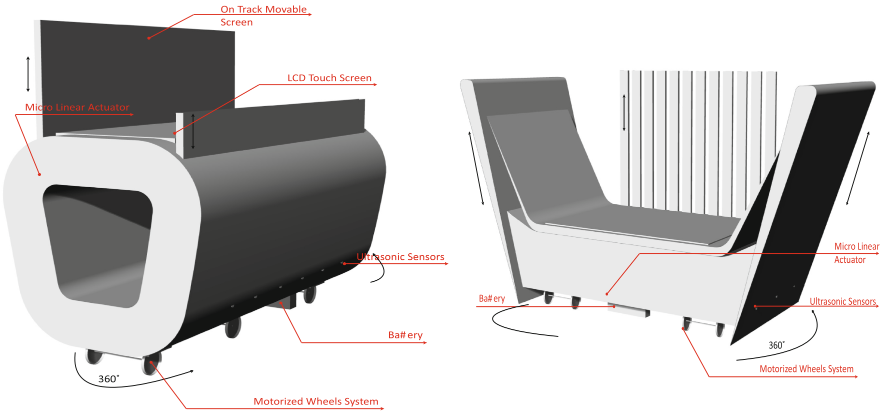

Fig. 5. **iCE**'s Table (Left) and Chair Designs (Right).

For the walls and ceilings, the walls are comprised of foldable structures moving on motorized wheels, embedded in wall pockets when needed.

4.3 iCE's Network System

iCE involves the use of centralized and distributed network elements for module autonomy and independence. **iCE** incorporates the use of self-organization factors evaluated under metrics of speed (i.e., time for convergence to desired layout/configuration), energy, and safety [7].

The modular design approach also requires the development of reliable control schemes. Towards that end, a control algorithm will be created for each module with its own embedded system microcontroller, in addition to a centralized controller that coordinates the actions of the different modules. A hierarchical centralized control scheme must be developed for the different scenarios with reliability as one of its main design objectives, as in Fig. 6. In addition, an interfacing module is required and it will be programmed with a visual interface.

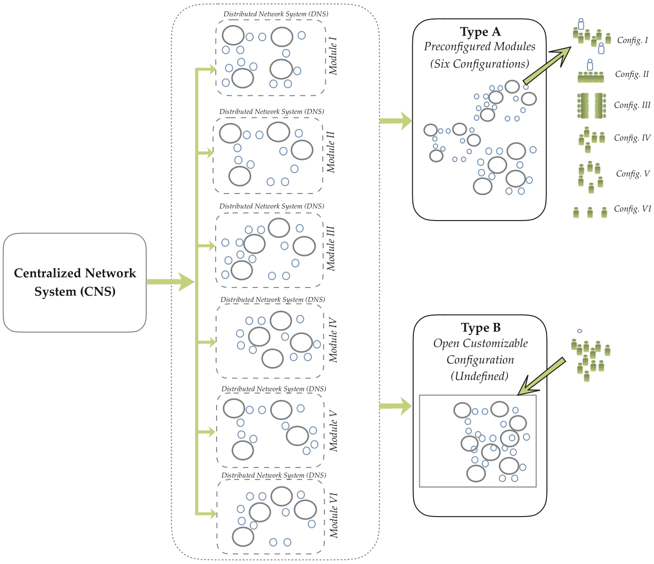

Fig. 6. **iCE**'s centralized network system and distributed network systems

5 iCE's Configurations

As we envision the intelligent classroom of tomorrow, we conducted many design related exercises through the HCD methods and studio activities. This leads to understanding the different kinematics of the movable/mobile furniture and reconfigurable space elements. Based on the literature review on the different teaching methods, and on the brainstorming activities conducted by five professors from social and natural sciences, iCE's six basic configurations have been selected as, a. Exploration; b. Collaboration; c. Meeting; d. Lecturing; e. Lounging; and, f. Presentation configurations; in addition to the open customizable configuration that can be set by user's preferences, see Fig. 7.

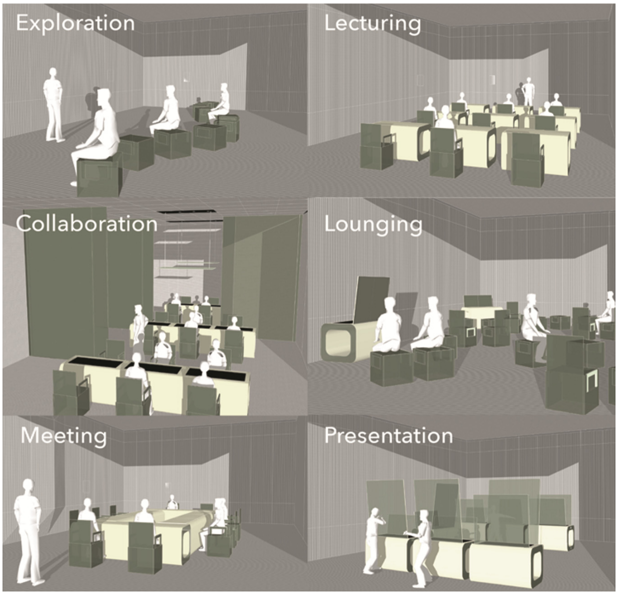

Fig. 7. **iCE**'s Six Different Configurations, i.e., a. Exploration; b. Collaboration; c. Meeting; d. Lecturing; e. Lounging; and, f. Presentation.

6 Conclusions

While the use of the hybrid physical-digital platform in enhancing the classroom environment is not yet fully experimented, the vision of the hybrid reconfigurable environment is to open the possibilities for more explorations on the use of this system in universities and cultural centers to enhance human-space interactions. **iCE**'s system suggests a novel research for designing social interactive systems for the classroom environment, and for enhancing both the human-hybrid interactions and our educational systems. The work has the potential for full-scale realization and evaluation on real users.

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