Shaping the Intelligent Classroom of the Future

Maria Korozi, Eleni Stefanidi, Georgia Samaritaki, Antonis Prinianakis, Antonis Katzourakis, Asterios Leonidis(✉), and Margherita Antona

Institute of Computer Science (ICS), Foundation for Research and Technology – Hellas (FORTH), Heraklion, Crete, Greece
{korozi,leonidis,antona}@ics.forth.gr

Abstract. This paper explores the general concept of the classroom of the future from a technological perspective, and proposes a set of indicative key facilities that such an environment should incorporate. Over the years, there has been an abundance of related research work aiming to build a "smarter" classroom, initially incorporating distance learning, educational games, and intelligent tutoring systems. More recently, many approaches have revolved around the advancements in the domains of Ambient Intelligence and Internet of Things, resulting in the enhancement of the traditional classroom equipment and furniture with processing power and interaction capabilities (e.g. intelligent desk, smart whiteboard) and the integration of emerging solutions in teaching and learning methods (e.g. AR, VR). The proposed intelligent classroom though is a holistic approach towards a student-centric educational ecosystem, which will incorporate state-of-the-art technologies to support (among others) alternative pedagogies, learning through immersive hands-on experiences and collaboration via flexible class layouts. To that end, this paper reports the various ambient facilities of the classroom and the accompanying software, while a prototype of this environment is currently under development in the AmI Facility of FORTH-ICS.

Keywords: Intelligent Classroom · Smart Classroom · Ambient Intelligence

1 Introduction

Over the past few years, many researchers have investigated the effect of information and communication technologies (ICTs) on the domain of education. Indicatively, when used appropriately, different ICTs are claimed to help students engage in the classroom, increase their involvement in learning, enhance their interest and alleviate boredom [1]. Additionally, it is well established that technology encourages communication, interaction and collaboration amongst students [2], while it allows access to unlimited information, enables teachers to offer a wide and flexible curriculum [19], and permits students to easily share resources. These features help to make learning and teaching an engaging, active process connected to real life [3].

C. Stephanidis and M. Antona (Eds.): HCII 2019, CCIS 1088, pp. 200–212, 2019.
https://doi.org/10.1007/978-3-030-30712-7_27

In the past, learning with the use of ICT was strongly related to concepts such as distance learning [4], educational games [5], intelligent tutoring systems and e-learning applications [6]. However, recent advances in the domain of Ambient Intelligence (AmI) and the Internet of Things (IoT) have led to the emergence of the "Smart Classroom" paradigm. Currently, there are several approaches that foster a variety of ambient facilities and utilize state of the art technologies (e.g., virtual reality, augmented reality) aiming to enhance the educational process. In more details, the hardware infrastructure of a "Smart Classroom" may include both commercial (e.g., touch sensitive interactive whiteboard) and custom-made artifacts (e.g., technologically augmented student desks [7]), which - in some cases - are embedded into traditional classroom equipment and furniture. Finally, the underlying software enhances and augments educational activities through the use of pervasive and mobile computing, sensor networks, artificial intelligence, robotics, multimedia computing and appropriate middleware [8].

2 Related Work

2.1 Immersive Educational Experiences

An immersive environment creates new situations that would be impossible to create solely in a traditional or in a digital environment. To this end, creating immersive experiences inside a classroom would be beneficial for its students, since it could enable interaction with the real world in ways that were not possible before.

There are several research efforts as well as commercial products that focus on creating immersive educational experiences. On the one hand, immersion is achieved either by creating CAVE-like stereoscopic projected environments or with the use of interactive wall displays that surround the users. Hence, the walls in the future classroom, will be a mediator of the interaction between students and educational contents and material, rather than having the traditional "separation role" [9]. On the other hand, state of the art technologies, such as Virtual Reality (VR), Augmented Reality (AR) and X Reality (XR) are employed to create highly compelling and memorable experiences.

Indicatively, the work in [10] reports that the simulation of a rainforest - distributed across several large displays - inside a classroom, engaged students and promoted learning. Similarly, AquaCAVE [11] aims to enhance the swimming experience by immersing students into computer generated environments, such as coral reefs, underwater caves, etc. Furthermore, the Advanced Classroom system uses lights, sounds and video to transform any gym into an engaging, immersive video game [12].

A representative example of using AR in the classroom is SESIL [13], that offers unobtrusive, context - aware student assistance by performing recognition of book pages and of specific elements of interest within a page, and by perceiving interaction with actual books and pens/pencils, without requiring any special interaction device. Additionally, the work in [14] tries to overcome barriers in distance learning by proposing a 3D user avatar in an augmented classroom, so that the teacher can interact with the remote students just like interacting with the local students. Finally, in [15] the author suggests that VR can provide unparalleled educative experiences to students e.g. in biology and astronomy. For instance, The Body VR [16] is an educational virtual reality experience that takes the user inside the human body to travel through the bloodstream and discover how blood cells work to spread oxygen throughout the body.

2.2 Technologically-Enhanced Furniture

An agile and highly flexible classroom layout allows its users (i.e. teachers, students) to modify the arrangement according to their needs, so as to form groups, collaborate, share and create new knowledge [17], and can accommodate different learning goals. For that to be achieved, the furniture and any technologically-enhanced artifacts should be able to easily adapt to support learning activities of varying degrees of collaboration (i.e. individual tasks, small-group activities, class-wide activities), while their appearance and affordances should minimize the effort needed by the students to access their enhanced functionality.

A number of research attempts concern intelligent desks that aspire to enhance the learner's experience in the classroom. In particular, in [18] a system is proposed which is embedded in a smart desk and identifies probable connections between learner behavior and task performance, with the aim to improve student performance and aid the learning process by unobtrusively observing and determining specific needs. Similarly, the work in [19] presents an Augmented School Desk that accommodates numerous educational applications in order to support learning activities.

Another topic that has attracted the researchers' attention over the years and has been extensively used in thousands of educational setups is the Interactive Whiteboard. It constitutes a giant sensitive whiteboard that is connected to a computer and a digital projector, which reflects the computer's image onto a big touch-enabled computer screen controlled by an electronic pen, a finger or other kinds of physical objects (e.g. sponge). Research has confirmed that using smart boards increases students' engagement and the interactions among the students, the teacher and the educational content [20], with specific examples showcasing their benefits. In particular, [21] and [22] have demonstrated that the use of an IWB had a positive result on students' motivation, interest, participation and even performance in certain cases.

Finally, with respect to the educator, [23] introduces an advanced teacher's workstation that relies on an intelligent multi-agent infrastructure to unobtrusively monitor the students' activities in order identify potential learning weaknesses and pitfalls that need to be addressed, either at an individual or at a classroom level.

2.3 Robots and Other Technologies

Robots have been actively used as an innovative educational tool or even as teaching assistants. A robot called Elias, which was used for language and math learning provides a typical example. Elias has been programmed to encourage students to dance and sing along with him, based on the fact that having fun is an important element of effective learning. Elias can speak and understand 23 different languages and so far all the experiments showed that students are reacting positively to it [24]. Kindergarten Social Assistive Robotics (KindSAR) robot is another example that illustrates how a novel technological artifact can offer kindergarten staff an innovative tool for achieving their educational aims through social interaction. In a relevant experiment, the robot served as a teaching assistant by telling prerecorded stories to small groups of children, while incorporating songs and motor activities in the process. The experiment's findings showed that children reacted positively to the robot and enjoyed interacting with it [25].

Lego Mindstorms is an easily programmable robot accompanied by a great variety of bricks, motors, sensors and other equipment, which permits students to build small-scale fully functional models of creatures, vehicles, machines and inventions [26]. In an investigation of the effectiveness of Lego Mindstorms as a tool for introducing to students' basic principles of programming through game-play activity, researchers found that the robots had a positive influence on the children's problem-solving skills, creativity, motivation and interest.

Apart from educational robotics, various technological solutions have been deployed in educational environments to enhance students' innovation. Specifically, several publications have shown that the use of 3D printing technology in schools promotes active learning, encourages student's creative and critical thinking and develops problem-solving skills [27–29]. To that end, various general-purpose solutions exist that are also suitable for education, such as Robo C2, Dremel Digilab 3D45 Idea Builder and XYZPrinting da Vinci Jr. Pro 1.0 [30]. These technologies have classroom-friendly features, like enclosed printing area, wide connectivity options and even incorporation of STEAM-based lessons directly from their manufacturers.

Wearables have started to penetrate the classroom as well. In [31], the authors propose the Experience Recorder and an iBand as two ubiquitous devices for an intelligent learning environments. The former is an embedded system that records the paths followed by a student in a classroom and the latter is a wearable device that collects and exchanges information about the students. Finally, given the amount of electronic artifacts in the classroom of the future, a charging solution to successfully power them is needed [32]; to that end, various solutions exist ranging from charging cabinets to charging carts [33, 34].

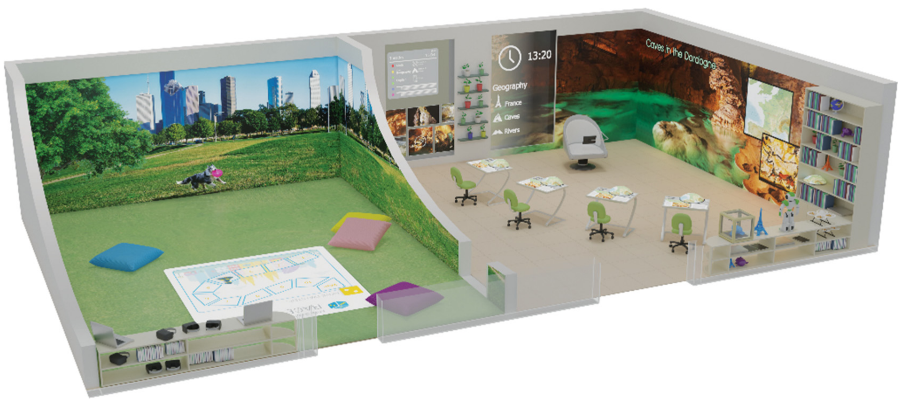


Fig. 1. Overview of (a) an Intelligent Classroom and (b) a special purpose room featuring interactive walls, ceiling, floor, windows and various X-Reality Gadgets

3 The Classroom of the Future

3.1 Ambient Facilities

Intelligent Walls, Windows, Ceiling and Floor. The classroom of the future will have the ability to create immersive experiences (see Fig. 1). Immersion will be achieved through a collaboration between different "devices", such as projectors (e.g. CAVE-like stereoscopic environments) or using the surrounding interactive displays (e.g. interactive walls and ceiling). Additionally, ambient lighting and projection on the ceiling (e.g. showing the sun's position, the sky or the stars) will further enhance the feeling of immersion; that way the students will be able to interact with the real world in ways that were not possible before. The role of the classroom walls will be dual; on the one hand they will act as interactive smart boards (see Fig. 5), where typical educational content (e.g., multimedia, notes, exercises) can be presented, and on the other hand they will be able to immerse the students into any environment relevant to the course's syllabus (e.g., a cave or a rainforest).

Apart from the walls, enhanced glass technology (see Fig. 2) will allow natural sunlight to be the primary source of light in the classroom - since it reduces headaches and improves learning rates - but will also control the amount of light entering the classroom based on the context of use (e.g. minimize light when watching an educational video). Such technology will be able to transform the windows into secondary displays presenting supplementary content (e.g. classroom's schedule, multimedia, announcements, notes) according to the context of use. Additionally, the windows will also have the ability to be a part of the immersion mechanism by either displaying the same environment as the surrounding wall, or by creating the illusion that the classroom is being transferred to another location.

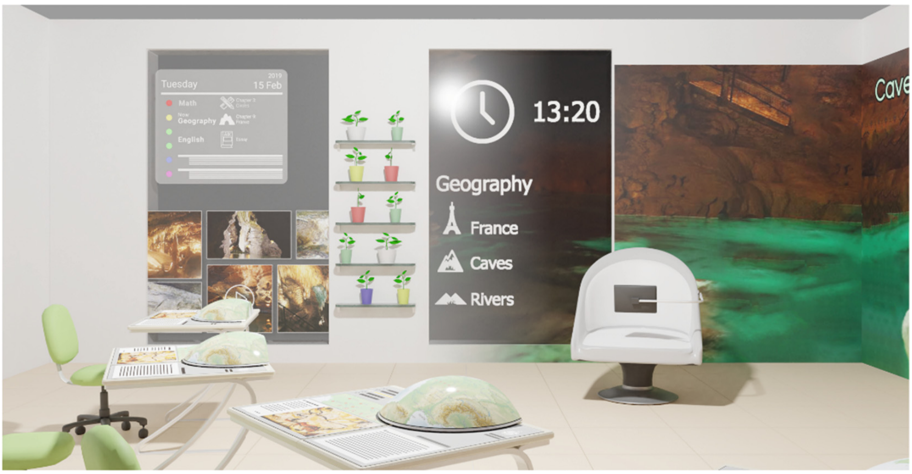


Fig. 2. View of the classroom's intelligent windows and the intelligent garden

Finally, special purpose rooms (see Fig. 3) with two or three interactive walls, ceilings and floors will be available to the students not only for educational purposes, but also for creating playful, fun and also calming environments (e.g. a student playing frisbee with a dog inside a park). The interactive floor will contribute to the sense of immersion, but it will also offer the opportunity to dynamically create playgrounds anywhere in the room aiming to support collaboration and full-body interaction.

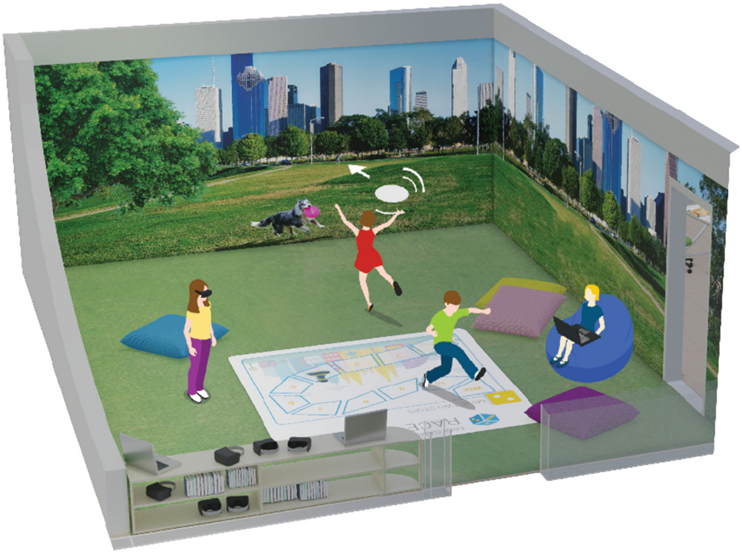


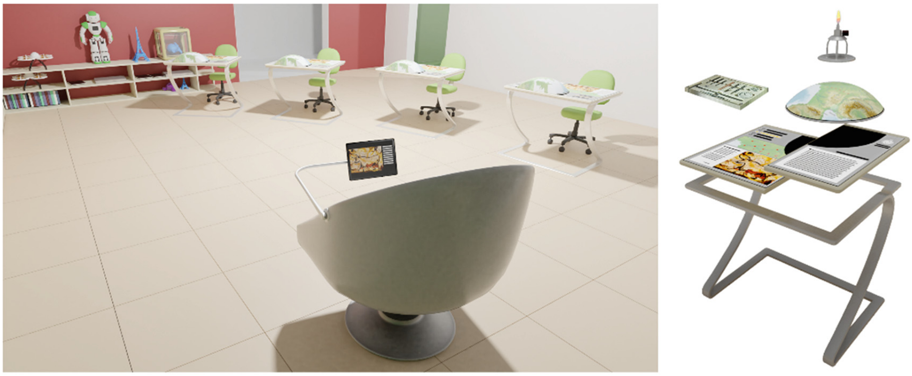
Fig. 3. A special purpose room will dynamically create playgrounds anywhere aiming to support collaboration and full-body interaction, and offer players memorable experiences

Intelligent Desk and Teacher's Workstation. The student desk (see Fig. 4b) will feature a modular design where customizable surfaces can be added or removed on demand in order to support the needs of different courses. Such desks will further enhance students' engagement and motivation, offering hands-on experience and providing personal study spaces with specialized equipment.
Indicative dedicated surfaces are:

- **Geography:** featuring a globe dome, a compass and multiple secondary display
- **Chemistry:** featuring smart flasks, test tubes, scales, a Bunsen burner and basic accessories
- **Physics:** featuring equipment to accommodate experiments and secondary displays
- **Geometry:** featuring a calculator and a set of smart mathematical instruments such as a ruler, protractor etc.

The surfaces will be designed in such a way that the cables, chargers, electronics and microprocessors will be hidden from the students. This will not only make the desks safe for use by young children, but it will also reduce distractions. In order to facilitate rearrangement of classroom desks - addressing the changing demands of different teaching scenarios (e.g. two adjacent desks can be connected to create a larger interactive workspace and promote teamwork) - desks will be designed for single use.

The teacher on the other hand will be able to monitor and manipulate every aspect of the intelligent classroom (e.g. ambient facilities, educational software, intelligent behavior, automations) from a comfortable workstation (see Fig. 4a) (e.g. an armchair with an embedded tablet). Additionally, the future intelligent classroom will be able to interoperate with commercial wearables (e.g. smartwatch) in order inform the teacher regarding important events that occur during a lesson (e.g., a watch vibrates to alert the teacher that the student's do not pay attention).



a. b.

Fig. 4. (a) A comfortable workstation for the teacher with an embedded tablet, and (b) the student desk will feature a modular design with customisable surfaces

Intelligent Garden. Each student will be responsible for a smart pot (see Fig. 2) that will track the plant's progress (measure humidity, soil richness, growth information). Such stem tools aspire to strengthen the student's feeling of responsibility, motivation to learn, teach them action and accountability and other relevant 21st century skills by granting them exclusive rewards when their plants thrive.

Intelligent Bookcase. Physical books will still be present in the classroom of the future due to their indisputable educational value. However, selection and retrieval will become a much more sophisticated and entertaining processes via robotics, AI and AR technologies. Students for example, will be able to search for a specific book or a category via an interactive screen and then moving mechanical parts of the bookcase will fetch the desired books or place them on a designated shelf of the bookcase (see Fig. 5).

Educational Robots. Robots have been used and will continue to be a part of in-class activities (see Fig. 6). Robots can take on the role of the personal assistant for the students, monitoring their actions and supporting them according to their needs and weaknesses. Additionally, they can function as a teaching assistant or be themselves a subject of interest (e.g. robotics class).

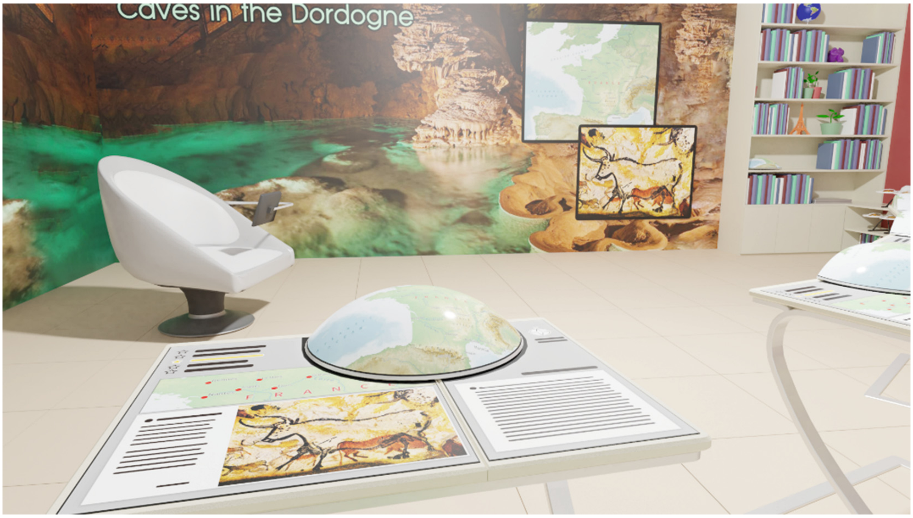


Fig. 5. View of the Classroom Board and the Intelligent Bookcase

Prototyping Facilities. Students in the classroom of the future will be able to design and manufacture their own ideas as well as objects and tools needed for the lesson, aided by advanced 3d-printing technologies (see Fig. 6). Those technologies will enable students to give shape to their wildest ideas and direct their own learning, thus contributing to the development of their creativity and sense of accomplishment.

X-Reality Gadgets. Advanced X-Reality technologies (see Fig. 7) will be employed and be available to students in order to change the way students learn. In conjunction with the immersive environment of the classroom, those technologies will be used to create highly compelling experiences, through which students can improve and explore different skills and practices.

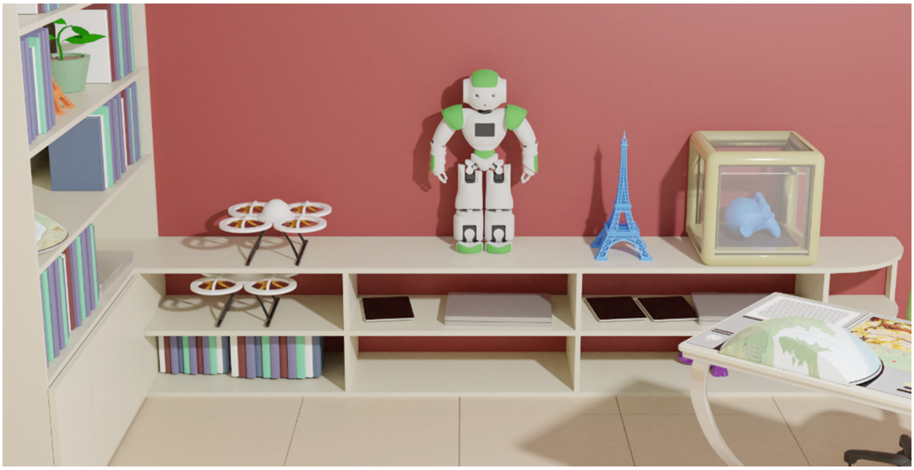


Fig. 6. The corner of Robotics and Prototyping Facilities

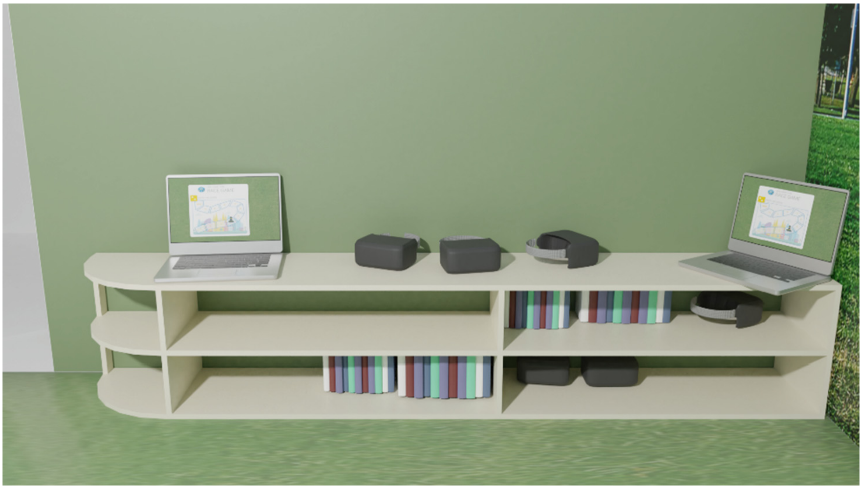


Fig. 7. The corner of X-Reality Gadgets

3.2 Intelligent Educational-Oriented Software

The future Intelligent Classroom should heavily depend on contextual information in order to make informed decisions (e.g., course, topic, syllabus). Since a typical classroom consists of different students with varying backgrounds, personalities, behaviors, needs and learning patterns [35], a solid profiling mechanism would be of utmost importance, since it would permit the delivery of personalized material and assistance to each individual.

Since a wide range of technologically augmented artifacts will equip the Intelligent Classroom of the future, a mechanism that transforms the classroom into a unified working environment rather than a group of isolated units is required [36]. In more details, an application host respecting the concepts of Composition, Consistency and Continuity [37], will eliminate the interaction challenges that stem from the cross-device migration of the available educational applications.

As passive listeners, people generally find it difficult to maintain a constant level of attention over extended periods of time, while pedagogical research reveals that attention lapses are inevitable during a lecture; according to [38], student attention will drift during a passive lecture. Ideally, the future Intelligent Classroom should be able to keep students engaged in the educational process. To this end, a mechanism that detects inattentive behaviors and selects appropriate interventions in order to help or support students throughout the educational process seems as an essential feature [39]. In such context, interventions are system-guided actions that subtly interrupt a course's flow so as to (i) draw the educator's attention in problematic situations, and (ii) re-engage distracted, unmotivated or tired students in the educational process (e.g., instantiate a quiz with appropriate content). A suitable mechanism is also required in order to present the selected interventions appropriately.

As far as the end-user applications are concerned, the students should have access to an inventory of educational applications (e.g., calculator, dictionary, multimedia viewer), as well as the digital representations of physical books and exercises. That way, they will be able to (i) get personalized assistance on exercises, (ii) retrieve additional resources about something interesting (e.g., an image displayed on the book), (iii) have access to assistive applications (e.g., calculator, dictionary, etc.), (iv) have access to multimedia, (v) maintain a personal area with access to board's history, homework's history, electronic materials, etc. Additionally, a suite of educational games should not be absent from the classroom of the future; that is because through games students become engaged with the learning process while developing a variety of important skills such as creative thinking, problem-solving and teamwork.

Special software should be available for the teachers so as to support complete classroom overview, automation of trivial tasks and suggestion of engaging activities [23, 40]. Additionally, a sophisticated mechanism that collects learning analytics and statistics of students interacting with the educational applications would enable teachers to easily monitor their performance and detect learning difficulties [41].

Finally, a Classroom Operating System (ClassroomOS) would be invaluable for the Intelligent Classroom of the future. Such a middleware will handle fundamental issues such as heterogeneous interoperability of intelligent artifacts and services, synchronous and asynchronous communication, resilience, security and context aware orchestration [42].

4 Future Work

The above systems are currently under development and deployment in the "Intelligent Classroom" simulation space at the AmI Facility (http://ami.ics.forth.gr/) of FORTH-ICS. The process towards its realization comprises the following steps: requirement analysis to identify state of the art and future trends, design and evaluation of interactive prototypes, implementation, integration and evaluation with users of the solutions in the educational environment. Such process will be followed iteratively for each individual space, component and service. Specifically, the requirements elicitation will be conducted using multiple methods such as interviews, brainstorming, focus groups, storyboards and journey maps, which will be carried out along with various stakeholders, including industrial designers, engineers, interaction designers, UX experts, educators and students. Afterwards, a feasibility analysis of the identified solutions and prototyping will take place during the design phase. Subsequently, a formative expert-based evaluation of the prototypes will be carried out in context to assess their usability and usefulness. Thereafter, the revised solutions will be implemented and deployed in the classroom simulation space, where finally, a summative, user-based evaluation with educators and students will be conducted in vitro, in order to assess the effectiveness of each system, as well as the classroom environment as a whole.

Currently, prototypes of the smart desk have been developed and the infrastructure of the immersive environment (e.g. interactive wall displays, X-Reality gadgets) is in place, while the first interactive demos have already been deployed. The immediate next steps include the construction a dozen of intelligent desks that will host the table tops accommodating the classes of physics, geometry and robotics, the intelligent board and the prototype design of the teacher's workstation.

Acknowledgements. This work is supported by the FORTH-ICS internal RTD Program "Ambient Intelligence and Smart Environments". Moreover, the authors would like to thank Emmanouil Apostolakis, Antonis Chatziantoniou, Antonis Dimopoulos, Thodoris Evdaimon, Spiros Paparoulis, Nikolaos Stivaktakis, Emmanouil Stamatakis and Emmanouil Zidianakis for their valuable contribution.

References

1. Kurtz, G., Tsimerman, A., Steiner-Lavi, O.: The flipped-classroom approach: the answer to future learning? Eur. J. Open Distance E-Learn. **17**, 172–182 (2014)
2. Business tools: how technology can help with team collaboration. https://www.turbinehq.com/blog/tech-team-collaboration
3. Tinio, V.L.: UNDP Asia-Pacific Development Information Programme, E-ASEAN Task Force: ICT in Education. E-ASEAN Task Force; UNDP-APDIP, Manila; Kuala Lumpur (2003)
4. Bates, A.T.: Technology, E-learning and Distance Education. Routledge, New York (2005)
5. Cross, N., Roy, R.: Engineering Design Methods. Wiley, New York (1989)
6. Brooks, C., Greer, J., Melis, E., Ullrich, C.: Combining ITS and e-learning technologies: opportunities and challenges. In: Ikeda, M., Ashley, K.D., Chan, T.-W. (eds.) ITS 2006. LNCS, vol. 4053, pp. 278–287. Springer, Heidelberg (2006). https://doi.org/10.1007/11774303_28
7. Savvaki, C., Leonidis, A., Paparoulis, G., Antona, M., Stephanidis, C.: Designing a technology-augmented school desk for the future classroom. In: Stephanidis, C. (ed.) HCI 2013. CCIS, vol. 374, pp. 681–685. Springer, Heidelberg (2013). https://doi.org/10.1007/978-3-642-39476-8_137
8. Cook, D.J., Das, S.K.: How smart are our environments? An updated look at the state of the art. Pervasive Mob. Comput. **3**, 53–73 (2007)
9. The Classroom of the Future: A New Phygital Space | Acer for Education. https://eu-acerforeducation.acer.com/innovative-technologies/the-classroom-of-the-future-a-new-phygital-space/
10. Lui, M., Slotta, J.D.: Immersive simulations for smart classrooms: exploring evolutionary concepts in secondary science. Technol. Pedagogy Educ. **23**, 57–80 (2014)
11. Aquacave: Augmented swimming environment with immersive surround-screen virtual reality. In: Proceedings of the 29th Annual Symposium on User Interface Software and Technology, pp. 183–184. ACM (2016)
12. Lü Interactive Playground—Advanced Classroom Technologies. https://advclasstech.com/lu-interactive-playground
13. Margetis, G., Zabulis, X., Koutlemanis, P., Antona, M., Stephanidis, C.: Augmented interaction with physical books in an ambient intelligence learning environment. Multimed. Tools Appl. **67**, 473–495 (2013). https://doi.org/10.1007/s11042-011-0976-x
14. Shi, Y., Qin, W., Suo, Y., Xiao, X.: Smart classroom: bringing pervasive computing into distance learning. In: Nakashima, H., Aghajan, H., Augusto, J.C. (eds.) Handbook of Ambient Intelligence and Smart Environments, pp. 881–910. Springer, Boston (2010)
15. Virtual and Augmented Reality in the Classroom | Saturday Academy. https://www.saturdayacademy.org/about/news/virtual-augmented-reality

16. The Body VR: The Body VR: Journey Inside a Cell - HTC Vive Trailer (2016)
17. Mäkitalo-Siegl, K., Zottmann, J., Kaplan, F., Fischer, F.: Classroom of the Future: Orchestrating Collaborative Spaces. Sense Publishers, Rotterdam (2010)
18. Hernández-Calderón, J.-G., Benítez-Guerrero, E., Rojano, R.: Towards an intelligent desk matching behaviors and performance of learners. In: Proceedings of the XVIII International Conference on Human Computer Interaction, pp. 29:1–29:6. ACM, New York (2017)
19. Antona, M., et al.: Ambient intelligence in the classroom: an augmented school desk. In: Khalid, H., Hedge, A., Ahram, T. (eds.) Advances in Ergonomics Modeling and Usability Evaluation, pp. 609–619. CRC Press, Boca Raton (2010)
20. Al-Sharhan, S.: 14 smart classrooms in the context of technology-enhanced learning (TEL) environments. In: Transforming Education in the Gulf Region: Emerging Learning Technologies and Innovative Pedagogy for the 21st Century, p. 188 (2016)
21. Using an Interactive Whiteboard in Vocabulary Teaching – ScienceDirect. https://www.sciencedirect.com/science/article/pii/S187704281400295X
22. Interactive whiteboard and virtual learning environment combined: effects on mathematics education - Heemskerk - 2014 - Journal of Computer Assisted Learning - Wiley Online Library. https://onlinelibrary.wiley.com/doi/full/10.1111/jcal.12060
23. Mathioudakis, G., et al.: Real-time teacher assistance in technologically-augmented smart classrooms. Int. J. Adv. Life Sci. **6**, 62–73 (2014)
24. How to use robots in education. https://www.lasserouhiainen.com/how-to-use-robots-in-education/
25. Fridin, M.: Storytelling by a kindergarten social assistive robot: a tool for constructive learning in preschool education. Comput. Educ. **70**, 53–64 (2014). https://doi.org/10.1016/j.compedu.2013.07.043
26. Atmatzidou, S., Markelis, I., Demetriadis, S.: The use of LEGO Mindstorms in elementary and secondary education: game as a way of triggering learning, 9 p. (2008)
27. 4 Benefits of 3D Printing for Schools | The Educator K/12. https://www.theeducatoronline.com/k12/technology/e-learning/4-benefits-of-3d-printing-for-schools/245670
28. 5 Benefits of 3D Printing in Education. https://www.makerbot.com/stories/education/5-benefits-of-3d-printing/
29. Trust, T., Maloy, R.W.: Why 3D print? The 21st-century skills students develop while engaging in 3D printing projects. Comput. Sch. **34**, 253–266 (2017). https://doi.org/10.1080/07380569.2017.1384684
30. 12 Best 3D Printers for Schools and Education in 2019. https://all3dp.com/1/best-3d-printer-for-school-education/
31. Winters, N., Walker, K., Roussos, G.: Facilitating learning in an intelligent environment. Presented at the IEE Seminar on Intelligent Building Environments (2005)
32. 7 EdTech Tools Every Smart Classroom Needs. http://www.aver.com/AVerExpert/7-edtech-tools-every-smart-classroom-needs
33. AVer Charging Carts and Sync Carts | AVer Global. http://presentation.aver.com/lines/tablet-storage-and-charging?_ga=2.176573093.1868001760.1562405843-1184187599.1561463407
34. Charging Solutions. http://rise-edu.com/charging-solutions/
35. Felder, R.M., Brent, R.: Understanding student differences. J. Eng. Educ. **94**, 57–72 (2005)
36. Ntagianta, A., Korozi, M., Leonidis, A., Stephanidis, C.: A unified working environment for the attention-aware intelligent classroom. In: EDULEARN 2018 Proceedings, pp. 4377–4387 (2018)

37. Wäljas, M., Segerståhl, K., Väänänen-Vainio-Mattila, K., Oinas-Kukkonen, H.: Cross-platform service user experience: a field study and an initial framework. In: Proceedings of the 12th International Conference on Human Computer Interaction with Mobile Devices and Services, pp. 219–228. ACM (2010)
38. McKeachie, W., Svinicki, M.: McKeachie's Teaching Tips. Cengage Learning, Boston (2013)
39. Korozi, M., Leonidis, A., Antona, M., Stephanidis, C.: LECTOR: towards reengaging students in the educational process inside smart classrooms. In: Horain, P., Achard, C., Mallem, M. (eds.) IHCI 2017. LNCS, vol. 10688, pp. 137–149. Springer, Cham (2017). https://doi.org/10.1007/978-3-319-72038-8_11
40. Stefanidi, E., Korozi, M., Leonidis, A., Doulgeraki, M., Antona, M.: Educator-oriented tools for managing the attention-aware intelligent classroom (2018)
41. Rigaki, A., et al.: Learning analytics for AmI educational games targeting children with cognitive disabilities. https://www.researchgate.net/publication/332287424_LEARNING_ANALYTICS_FOR_AMI_EDUCATIONAL_GAMES_TARGETING_CHILDREN_WITH_COGNITIVE_DISABILITIES
42. Leonidis, A., Arampatzis, D., Louloudakis, N., Stephanidis, C.: The AmI-Solertis system: creating user experiences in smart environments. In: 2017 IEEE 13th International Conference on Wireless and Mobile Computing, Networking and Communications (WiMob), pp. 151–158. IEEE (2017)