The AmI Classroom from a Technological Perspective

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***Abstract*—The use of technology within an educational setting is well documented and notoriously recognized within the academic community. The application of ambient intelligence to a classroom setting offers novel and intrinsically distinctive outcomes that require meticulous investigation and thorough analysis. We ground the concept of an ambient intelligent classroom upon established learning theories as we propose an academic framework to accurately and systematically position such a technology within a pedagogical neutral environment. The focus is mainly on the technological aspect as one of a number of dimensions that form part of our conceptual framework. The article investigates how technology-enhanced learning embellishes higher education, as we present and discuss a number of requirements that every technological aspect within the middleware is required to abide with. We employ these guidelines and best practices within a three-dimensional model based on a social, educational and technological aspect, that collectively contribute to the successful implementation of our ambient intelligent classroom. We also discuss future directions as we ground our work on the adaptive learning theory together with the adoption of learner profiling techniques. These enabled us to identify areas of interest and focus to pose recommendations that could potentially characterize the future of ambient intelligent classrooms.**

***Index Terms*—ambient intelligence, technology-enhanced education, smart classrooms**

I. Introduction

Technology has been employed within educational institution as a teaching aid for as long as it has been available to the general public. Educators and schools adopt all kind of resources to facilitate the teaching process and ensure that their learners are provided by the best possible medium to achieve their potential. Technology and its application is another resource that lends itself very well to educational scenarios not just in schools but also within industry like automotive [1] and flight industries [2], military [3], [4], and other professions. As soon as computers were available on the market, educational institutions started making good use of them [5], that triggered the educational game industry to play its crucial role in enhancing the motivational and engagement levels of school children [6].

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Technology within the higher education domain has also significantly contributed to the changing needs of learners and educators over the years. The department of education in USA points out that technology positively transforms formal and informal pedagogies in a number of ways [7]. The report lists a number of ways of how technology-enhanced learning embellishes higher education, namely:

"1. Technology enables students to access learning opportunities apart from the traditional barriers of time and place.

2. Technology lets students access learning opportunities outside of formal higher education institutions, such as at their workplace or in community settings.

3. Technology allows students to access high-quality learning resources, regardless of their institution's geographical location or funding.

4. Technology enables enhanced learning experiences through blended learning models.

5. Technology supports students in their learning based on individual academic and non-academic needs through personalization.

6. Technology can ensure that students with disabilities participate in and benefit from educational programs and activities." (p. 17-21)

However, this does not come without its challenges. Elmes [8] argues that improving digital literacies is a major challenge that higher education institutions are encountering, together with integrating formal and informal learning. Other challenges include an achievement gap between students from different backgrounds, digital equity, knowledge obsolescence, and re-training of the academic staff themselves. Another advantage provided through the application of technology that is independent of human intervention is the collection of data and its implication to learning analytics. Brown [9], Falvin [10], Weimer [11] and the US DoE [7] endorse the value and potential of fruitfully employing learning analytics to further enhance and strengthen the use of technology. Such data can be collected through the learners' interaction with devices, software, interfaces and through feedback given. An unobtrusive system that can collect data through the surrounding environment and employ this data to further adjust the setting and accommodate the user is possible through Ambient Intelligence (AmI). AmI is a technology that renders an environment artificially intelligent. The automated

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system at the background is sensitive and receptive to the user's actions, personalising the surroundings in an effort to adjust to the same user. Within an educational setting AmI is applied to a classroom setting to respond and adjust to the academic needs of a learner.

The rest of this article is organized as follows. Related work will be presented in the next section before delving into the theoretical learning theory and artificial intelligent techniques involved in Section III. The main focus of this article follows in the next section as the technological aspect of AmI is thoroughly discussed as we present our conceptual model. Final conclusions and recommendation bring a close to this article.

II. Related Work

A number of projects have been documented related to the application of ambient intelligence to the school environment. These research projects have investigated different aspects within a variety of scenarios which renders a proper and uniform comparison hard to perform. However, each of the findings offer a possible source of inspiration that sheds light on the future of this promising research area.

Winer and Cooperstock [12] present an intelligent classroom whereby a team of computer scientists and educational specialist attempt to achieve three goals. The first objective was to automate the presentation process and facilitate the educator's task through a series of control structures that adjust the lighting, set specific projector in motion, and activate screens or displays. Another objective was to maintain a log of all the sessions and make them available to the students so they could review material, access sessions they missed, and interact with the educator about any particular issue. In this case recording devices where employed and sessions uploaded on virtual learning environment that both students and teachers automatically had access to on registration. Finally, the third objective was to allow students submit their presentations over the same learning environment as an alternative mode of assessment. Even though the final system seems to encompass a number of essential functionalities very few of them are intelligent in any way. For the purpose of this article Artificial Intelligence (AI) constitutes that automated functionality that otherwise require human intelligence to perform. The automatic setting up of the presentation environment described in the first objective does not constitute or require an intelligent human behavior, but simply a support structure that requires no skill or training.

In another project, documented by Ramadan, *et al.*, [13], an architectural setup of another intelligent classroom, called iClass, is presented as it is based on a number of technologies. A number of embedded sensors and actuators are employed to control a number devices like lighting, air conditioning, presentation devices, and monitors. Additionally, the use of Radio Frequency IDs (RFID) readers [14] is extensively made to track learners and teacher within the classroom, as a result of which performs a number of useful processes like attendance, information sharing, and setting up the relevant material associated with the current class. iClass also makes use of basic speech interaction with the learners together with the integration of intelligent agents to learn and adapt to the same learners' behavior. Although this proposal seems interesting and promising it leaves much to be desired as all the components mentioned require further testing and tweaking to ensure their combined contribution to AmI in a classroom is tangible and verified.

A final related work is a very good effort from Greece by a number of researchers who proposed an augmented school desk [15], and an integrated framework called ClassMATE [16]. A year later they presented the combination of both proposals within a student-centric [17] ambient intelligent classroom [18]. The augmented school desk in itself does not constitute an intelligent environment but is a valid contribution as a possible piece of supporting furniture within the AmI classroom. An array of hardware devices networked through purposely developed software were incorporated within a purposely designed student desk. The system incorporated a personal computer in the background interfaced with the learner through a flat screen that had two mini projectors, two cameras and four infrared projectors behind it. An additional camera and a smart pen transmitter completed the setup that was employed in an empirical study to investigate how AmI technologies can contribute to the teaching process and enrich the learning experience. The authors concluded that through a carefully designed and tested setup the experience positively affected the learners who welcomed the use of technology. This was further investigated as part of the integrated architecture ClassMATE to enable pervasive interaction within a context-aware classroom. The proposed framework was made up of five core components that controlled all the operations within the pervasive and ubiquitous computing environment. The first and overarching component is the context manager that is in charge of coordinating the other four components while orchestrating all the operations within ClassMATE. As soon as the context manager senses the user, through some interaction, is requesting a specific operation, it triggers off a set of purposely designated reasoning schemes that control the decision-making process required to achieve the operation requested by the user. Consider the scenario whereby the teacher decides to show a video clip to the students. As soon as the video file is highlighted the context aware component recognizes the file type as well as the intention of the educator. This puts in motion a process workflow that launches the presentation software, loads the clip, powers the projector, and displays the video clip, as it temporary places all other students' processes and devices on pause to ensure that all the students can focus their full attention to the activity at hand. All this is possible through the coordinated effort of the four other ClassMATE components, namely, the security service component, the user profile, the device manager, and the data space component. The security service component takes care and manages all authorizations required by the different users, devices and applications. The user profile component ensures that the services and applications are respectively associated with the individual behavioral patterns of all the users. The device manager controls and coordinates all the hardware devices through the context aware component thereby facilitating the smooth running of all the process workflows. Finally, the data space component ensures that both the content is classified accordingly, as well as implementing a centralized content repository. To do so, the data space component collects material from four possible sources. These sources are meta-data accumulated from the different applications, users, classes and lessons, are semantically correlated offline by the educator and saved within a content relational database to serve as educational material through the context-aware AmI system and address diverse needs within the same environment. This theoretical framework brings together a number of AmI components that can be applied to education that closely relate to the framework proposed in this article. We investigate the key elements and the crucial factors that are involved within an AmI academic context grounded within conventional learning theories.

III. Adaptive Learning & Learner Profiling

The concept of employing learner profiling techniques with the sole reason to customize and adapt the learning experience as well as tailoring the educational resources to accommodate the specific and unique needs of each learner is referred to as adaptive learning [19]. Artificially intelligent techniques from the computer science domain can be employed to generate the learner profile that will then be employed to adjust the entire educational process to that same profile. The process of personalizing the learning process and content to each individual student is also supported by a specific learning theory from the education research domain. The ideology behind the adaptive learning theory has long been followed [20] as educational psychologists [21] and learning theorists [22] have long argued in favour of personalized one-to-one instruction that the educator can optimally customize and adapt to the needs, interests and benefits of the learner. Students do possess their own learning approaches that work better for them [23] and that such an adaptation process potentially enhances their motivation [24] and satisfaction [25]. Studies [26] have shown that higher education bodies have embraced the concept as they have realized that the academic benefits can assist in the overall success of the institution. The authors distinguish three models, namely, content, learner, and instruction that contribute to the fruitful application of adaptive learning. These models ensure that the content is favorably structured to be easily indexed, accessed and compiled; the student profiles are consistently defined to embody different student abilities; and the instructional body is advantageously designed to bring the content and student models effectively together. Other researchers [27] argue in favour of personalizing not only the educational resources but also academic processes and pedagogical strategies. Similarly, Salehi, *et al*., [28] argue that a learner profile, based on interests and academic characteristics, evolves and refines itself over time, and is subject to some important influences. The authors point out that a truly adaptive learning environment needs to take into consideration the fluidity of learners' interests and preferences, together with the intricate and compound nature of educational resources. The positive effect of adaptive learning was also documented within an e-learning environment [29] as improved effectiveness was reported. The authors argue that personalized learning pathways enabled healthy lifelong scholarship, and which could be achieved through a variety of ways like machine learning techniques [30], dynamic adaptive processes [31], and other automatic learner profiling procedures [32].

Learner profiling aims to capture the uniquely specific and individual characteristics of each learner in a way that a generic educational programme can be customized and adapted to the academic needs encapsulated within the same profile [33]. In the results reported in their study, the authors explain how such an adaptive process that employed a learner profile relieved specific learning difficulties that the same learners reported. Such a conclusion has massive implications that other researchers [34] have confirmed over time. Apart from the academic achievements and positive results documented, it was also reported that additional psychological effects assisted students in feeling proud of their achievements, autonomous to do more and achieve more, and determined to pursue further their studies [35].

IV. Technological Aspect

The research related to ambient intelligence within a classroom is very much restricted and still in its infancy, however the literature available seems to focus mainly on the technological aspects from a physical devices point of view. AmI itself very well documented in its application in everyday life [36], assisted-living [37], and other smart environments [38] like boats, cars and airplanes. The sensitivity of such research that deals with human environments becomes even more susceptible to detail and attention when dealing with the education of people. The interfacing middleware component between the human factor and technology applied within a smart AmI environment thereby becomes decisive in the overall successful realization of such technology-enhanced environments. The European Information Society Technologies [39] insists on the crucial role of the middleware as it needs to ensure not only the successful interoperable coordination between multiple devices [40], but also to ethically and delicately interact with human subjects. In fact, the European commission's advisory group [39] on AmI identifies five requirements to ensure the reliability and a robustness of such middleware.

The first technological requirement specifies unobtrusive hardware that in no way will interfere with the educational process or with the social or educational aspects of the AmI classroom. The technology is required not only to be miniaturized but eventually disappears completely from human sight similar to all other indispensable amenities that society cannot do without. Unobtrusive also suggests that the data generated from such devices is automated as smart and nano devices have permeated the domestic industry. Such low-powered devices should form part of the Internet of things to efficiently and productively accumulate data from diverse learners to ensure that that the generated added-value is directed towards the specific learner.

This brings in the second requirement as the devices need to effectively interoperate and seamlessly share information about the learners. The communication infrastructure connecting all these technologies needs to be robust, safe, and fast to ensure real-time acquisition of data as well as instantaneous delivery of any information to individual learners. Additionally, it requires a secure, dynamic and distributed network to maintain such communication infrastructure and support multiple devices that are concurrently operating and servicing numerous learners within the same environment. This device network constitutes the third technological requirement, and probably one of the most important components that sustains all the other technological requirements including a comprehensive database system at the backbone of the entire AmI classroom.

The fourth requirement related to an intuitive and user-friendly interface between the learners and the underlying system that controls the AmI classroom. Such an interface does not need to be tangibly visible but naturally accessible by the learners in any way possible as they communicate with the devices, software agents, and other applications that enable the smooth running of the same environment. Artificial intelligent techniques play an important role in this requirements as smooth and effective handshaking between learners and technologies are essential and instrumental in the overall success of the AmI environment. Some capabilities include context sensitivity, alternating multi-media, and multi-recognition functionalities that include pattern, speech and gesture.

Finally, learners need to trust the entire setup for it to be effective and successful. This technological requirement is gained rather than enforced as learners tend to depend and trust the ongoing process that have proved over and over again that they are reliable, safe, and robust enough. The learner profiles will also evolve over time that will cyclically refine the customized outcome that the AmI systems provides. This will further build a much-needed reassurance that the learners will seek from the AmI classroom that should, in our opinion, still make use of an educator to coordinate, supervise and facilitate the entire process. Such an academic facilitator will champion the AmI classroom especially within the scope of the technological aspect. This might involve interfacing directly with computerized devices or with technical people who can provide the assistance in extreme cases. Realistically the inevitable requirement to fine-tune and adjust technologies will not cease to exist and thereby to be expected. The human facilitator is required to not only tend to the educational and social needs of the learners in the classroom, but also justify, trouble-shoot and support the occasional inconsistencies, software glitches, and artificially generated suggestions and recommendations. We subscribe to the notion that technology in isolation does not suffice and thereby an AmI classroom based solely of technological concepts with no human educator will be incomplete and academically curtailed and incomplete. A learning environment that does not take into consideration the social and educational aspect, and without the involvement of a professional human intervention, then the AmI classroom is bound to fail. No amount of technology will replace the role of an educator turned facilitator or moderator, with expert skills and competencies provided by a trained educator. Numerous studies [41] have shown that a classrooms eco system depends and is positively conditioned by the benchmarks and ethics of the educator. Such social interactions and educational skills are passed on from educator to learners on a regular day-to-day basis through simple and continuous interaction establishing a heathy social and emotional atmosphere [42].

It is also for this reason that our AmI classroom framework is based upon three fundamental aspects, one of which is the technological. The other two dimensions to our framework are the social and educational aspects that are in turn are grounded in respective learning theories. The social aspect of our AmI classroom accounts for the human aspect within the educational environment that subscribes to the Connectivism learning theory, while the educational dimension accounts for all the academic aspects that are based on a reflexive rather than didactic pedagogic approach. The combination of the three aspects gives a much more thorough and realistic insight into the realization of a smart classroom that, apart from lacking within the literature, is still far from successfully and tangibly becoming a reality.

V. Conclusions

In this article, we have investigated the use of technology within an educational setting with particular focus to the application of ambient intelligence within a classroom setting. A number of projects related to smart classroom were investigated and discussed before presenting the established adaptive learning theory that stands at the base of our technological dimension. Additionally, the application and employment of learner profiling techniques from the artificial intelligence domain also form an essential part of this particular technological aspect.

We argue that five requirements needs to be meticulously and thoroughly investigation to properly and realistically analyze and realize our conceptual ambient intelligent classroom framework. These requirements included unobtrusive hardware, seamless and wireless communications, intuitive and friendly user interface, safe and trusting environment to reassure learners, and dynamically distributed network to sustain all the other requirements. Through such a technological analysis, as part of three-dimensional model, we have managed to design a complete and realistic AmI classroom model that can characterise the way we envisage future classrooms.

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