Studies in Computational Intelligence 840

Matthew Montebello

The Ambient Intelligent Classroom

Beyond the Indispensable Educator

Springer

Studies in Computational Intelligence

Volume 840

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ISSN 1860-949X ISSN 1860-9503 (electronic)
Studies in Computational Intelligence
ISBN 978-3-030-21881-2 ISBN 978-3-030-21882-9 (eBook)
https://doi.org/10.1007/978-3-030-21882-9

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

I dedicate this work to all my family
who have supported me unconditionally
in every step and in every decision I took.

Foreword

Machine and Human Intelligence

In this important and innovative contribution to thinking about the future of education, Matthew Montebello explores the potentials of ambient intelligence to support learning. Ambient intelligence, he explains, is an application of artificial intelligence through a range of sensors and the coordinated collection of data from these sensors. In an educational context, the most obvious of these sensors are in computing devices: a desktop computer, a laptop, a tablet or a phone. Such devices are capable of tracking learner activity as they view videos, navigate simulations, read texts, follow hyperlinks, write, record speech and videos, calculate, answer questions and interact in discussion boards, to name some of the learning interactions using digital devices. This might be supplemented by cameras and microphones tracking sound and movement. There are also the "seeing" and navigational devices of virtual and augmented reality.

Such activities generate huge amounts of digital data, in varied data types. These are to be found in characteristic file types of text, image, video and audio. Patterns of reception and production by learners can also be traced in log files, keystroke records and clickstreams. While students are working more and more in digital media, many of these data go to waste. They are not used to evaluate learning or support learning. If these are the raw materials of learning, asks the author, how can they be put to work as "ambient intelligence?"

To begin to answer this question, we need to develop a notion of machine intelligence. In what ways can machines be intelligent? How is machine intelligence different from human intelligence? How can machine intelligence work in complementary tandem with human intelligence?

"Can machines think?" asked Alan Turing in his celebrated 1950 article, "Computer Machinery and Intelligence" [3]. After playing a central role in breaking enemy code during the Second World War, Turing moved to the University of Manchester where he and colleagues started to build an electronic computer using seven tons of surplus parts from the scrapped codebreaking machines. “Manchester 1” had 1024 bits of random access memory.

By 1949, announced The Times, “the mechanical brain” in Manchester had done something that was practically impossible to achieve in the paper. It had found some previously undiscovered, extremely large prime numbers. This was the kind of thinking computing machines could do—enormously large calculations, producing results that would come as a surprise because they were too laborious for humans to do. In this way, they are smarter than humans, though in a different way. The difference can be used to supplement human intelligence, making calculations that no human in their right mind would attempt.

Then another step in Turing’s argument: a universal logical computing machine would be able to do more than calculate according to instructions; it would also be able to apply the answers it came up with as new instructions to itself. “Whenever the content of [the machine’s] storage was altered by the internal operations of the machine, one would naturally speak of the machine ‘modifying itself’” [2]. Today, these processes are called “machine learning” and “artificial intelligence”.

As for ambient intelligence, said Turing (though of course, he would not have used this term), “the electrical circuits which are used in electronic computing machinery seem to have the essential properties of nerves”. Without having to go through the cumbersome process of creating a body, an electronic brain could be given organs of sight (television cameras), speech (loudspeakers) and hearing (microphones), by means of which it could learn games, languages, translation of languages and mathematics [2].

For the time, some of this was too far fetched. Today, a good deal of Turing’s imaginings have become the realities of digital media and computation—the fantastically large quantities of zeros and ones, and their calculation, that today record and render text, image and sound. And the “electronic brain” can apply its own forms of intelligence to itself, supplementing the human brain in teaching and learning. Matt Montebello shows us how this vision can be turned into reality.

Teachable Moments: A Repertoire of Machine-Mediated Meanings

What kinds of meaning can be captured in digital learning environments, and how can these be turned into teachable moments? Matthew Montebello addresses both these questions. We would summarize his objects of analysis into three macro-genres of data:

1. Unstructured data, incidental to learner activity: keystroke patterns, edit histories, clickstream and navigation paths, social interaction patterns. We might also have dedicated devices and sensors to collect unstructured data in the form of text recording, video capture, eye trackers and movement detectors. To develop artificial intelligence, these require training models involving either supervised

learning (identifying and naming patterns so the machine can locate similar patterns) or unsupervised learning (where the machines find areas of statistical significance, and humans interpret its meaning).
2. Structured data or immediately legible learning moves emerging from intelligent tutors, games, e-textbooks, video access and student work.
3. Machine assessments, including select response assessments, quizzes and semantic analysis using natural language processing.

The most salient features of these data are their range and extent—so broad and so wide, that in an environment of ambient intelligence, we need a machine to make sense of them [1].

The most significant feature of these data, as Matt Montebello so clearly points out in this book, is how they are used. Here, the challenge is not simply to judge learning processes and outcomes, but to contribute them. The purpose of ambient intelligence is not just to record learning; it is to contribute to learning. The challenge now is to create just-in-time feedback loops that are just-enough and just-right.

To reframe this as a question, how, in an incremental way, can ambient intelligence offer teachable moments, many more in their quantity than the teacher in the traditional classroom could feasibly offer, and more appropriate in their range by being adaptive to the differences between learners? Here, we wholeheartedly agree that the answer must be to develop a new pedagogy for the digital era: a reflexive pedagogy supported by machine-mediated, recursive feedback.

Here, we are referring to machines offering a complementary relationship to humans. At no point are we substituting machine intelligence for human intelligence or even mimicking human intelligence. We are supplementing human intelligence with a fundamentally different kind of intelligence—dealing with massive data, applying that data to itself using the algorithmic methods of machine learning and coordinating human complexity.

New Learning Requires New Teaching

This leads us into our final major takeaway from this path-breaking book. In no way does ambient intelligence displace the teacher. However, it does change the professional roles and responsibilities of the teacher in a fundamental way.

Formerly, teaching was the talking profession. Now it has become a profession in which the teacher's central role is to curate digital resources and to design and implement machine-mediated learner interaction. Formerly, the teacher was a test implementer, in a linear process where assessment came after learning. Now the teacher is a data analyst, where they need to be on top of the constant stream of data, using it as a source to adapt their instruction and differentiate their interventions for learners in their diversity.

We cannot say this better than the author does in his conclusions: "Contrary to popular belief that a smart classroom would eliminate the need of a human educator, the AmI classroom requires the expertise, dedication and sensitivity of an educator who is required to professionally switch roles according to the educational and social needs of the individual learners as well as of the entire class".

Matthew Montebello not only provides clear expositions of the technical aspects that underpin learning with ambient intelligent machines, but he takes the reader on a staged journey outlining and demonstrating through vivid examples the components and development processes of ambient intelligent spaces—be they classrooms, civic spaces or living rooms.

In so doing he correctly emphasizes the interplay between technology, the social and educational features of ambient intelligent ecosystems. The complex ideas presented are well laid out clearly and make a compelling case for the pervasive, ubiquitous impact and the optimizing potential that new technology has brought both to formal and informal educational and both physical and virtual learning environments.

Urbana, IL, USA Prof. Mary Kalantzis
Urbana, IL, USA Prof. Bill Cope
April 2019

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Preface

Ambient intelligence has been an area of personal research interest for close to twenty years as numerous undergraduate projects and research initiatives focussed on its application within the home. As my personal research interests within the artificial intelligence domain started shifting towards its application to Higher Education, it was only a matter of time to shift my focus and attention to the application of ambient intelligence to Higher Education. The feedback received following the first book was overwhelming as numerous readers from academia and otherwise easily related to the content. Non-technical readers particularly appreciated the comfortable and relaxed narration of technical details that required no special expertise to comprehend and put into context. This provided further incentive to pursue the next initiative and embark on an amazing journey and a second book.

This project started similar to other budding research interests with a number of undergraduate students at the ICT faculty working on minor components of a bigger picture, but which all shed light on the final goal of deploying a fully fledged ambient intelligent classroom. The concept of integrating so much technology within a classroom and perform an empirical study with students in attendance was going to create ethical issues right from the start. However, as soon as a group of university undergraduate students heard about the project they wanted to participate in a proof-of-concept set-up and volunteer as participants. The project dominated their activities during the AI in an education programme that turned out to be a vibrant and exciting experience during which the students overachieved the set objectives as they performed extensive research, experimentation and development. The three aspects upon which the AmI classroom is grounded, the social, technological and educational, proved to be perfectly suitable in practice as the students have been together for over two years and thereby function as a cohesive group who collaborate and cooperated very well. Additionally, their vibrant enthusiasm for novel technologies and social media provided a perfect fit that encapsulates the digital learner for whom the AmI classroom has been envisaged. Furthermore, the educational backdrop provided the required application content and context to bring all three concepts together and realize this one-off empirical study.

The requirements of the physical classroom and the online learning environment were based on research work performed over the last two years as a series of experimentations with different smart environment set-ups and innovative learning platforms were performed. However, the drive and eagerness provided by the students themselves facilitated the laborious process of dealing with teething every day challenges in the knowledge that no project of this type has been attempted and documented. The book will hopefully inspire other educational technologists to consider the application of AI to education through ambient intelligence and take the ideas and concepts recorded to the next level.

Each aspect has been solely investigated and researched through numerous publications while being presented in various international conferences. This turned out to be of tremendous help as colleagues, friends and other interested academics provided additional insights and valuable suggestions on how to improve and enrich the conceptual ideas. The project brought together a number of research interests as the application of AI to e-learning in combination with the applicability of ambient intelligence to specific environments provided an engaging and rewarding concept that researchers are always in search of. This provided me for yet another time the possibility to switch from an educator role to a narrator while employing my communication skills to pitch the content at the right level to equally appeal as much as possible to technologist, educators and computational AI researchers.

Msida, Malta Matthew Montebello
March 2018

Acknowledgements

My research work and the collaborations I developed at the University of Illinois in Urbana-Champaign have been at the basis of this work as the beauty of this place and the work ethic of my colleagues here have been inspirational and memorable. This has also been possible due to the invaluable support that the University of Malta gives to its academics during the sabbatical period to further pursue our research and develop our professional career. Family and friends have been instrumental in supporting me in every step along the way, to which I am forever grateful.

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About the Author

Matthew Montebello is an associate professor at the Department of Artificial Intelligence at the Faculty of ICT, University of Malta. Before joining the University in 1999 with a PhD in Computer Science, he was already heavily involved in Education in secondary schools after graduating in 1990 at the University of Malta with a B.Ed. (Hons) degree. Having obtained an extensive teaching experience and having been involved with the introduction of computer laboratories through the Ministry of Education, he proceeded to follow the Computer Science domain when he pursued his postgraduate studies obtaining a Masters and a Doctorate at the Cardiff University in Wales in 1996 and 1998, respectively. Furthermore in 2009 and 2016, he also completed an M.A. and an Ed. D. (Higher Education) specializing in the application of artificial intelligence to e-learning. In 2017–18, he was offered a visiting academic status at the University of Illinois in Urbana-Champaign where he collaborated with the Computer Science department and College of Education on numerous projects and research initiatives. In May 2018, he was appointed Adjunct Professor at the University of Illinois, Urbana-Champaign.

Acronyms

AAL	Ambient Assisted Living
AI	Artificial Intelligence
AmI	Ambient Intelligence
AmILE	Ambient Intelligent Learning Environment
AmI-PLE	Ambient Intelligent Personal Learning Environment
AR	Augmented Reality
CGI	Common Gateway Interface
DTD	Document Type Definition
F2F	Face-to-Face
FTP	File Transfer Protocol
HTML	HyperText Mark-up Language
IAL	Intelligent Adaptive Learning
IoT	Internet of Things
IST	Information Society Technologies
ITS	Intelligent Tutoring System
LAN	Local Area Network
LCS	Learning Companion System
LMS	Learning Management System
MOOC	Massive Open Online Course
MR	Mixed Reality
OER	Open Educational Resources
OSI	Open-Source Initiative
PAN	Personal Area Network
PLE	Personal Learning Environment
PLN	Personal Learning Network
PLP	Personal Learning Portfolio
RAT	Replacement, Amplification and Transformation
RDF	Resource Description Framework
RFID	Radio-Frequency IDentification
SmE	Smart Environment

TCP/IP	Transmission Control Protocol/Internet Protocol
TIP	Technology Integration Planning
TPCK	Technological Pedagogical Content Knowledge
UDL	Universal Design for Learning
VR	Virtual Reality
W3C	World Wide Web Consortium
WAN	Wide Area Network
Web 2.0	Second-generation Web technologies
WIFI	WIreless FIdelity
WWW	World Wide Web

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Chapter 1
Introduction

Arriving at one goal
is the starting point
to another.

John Dewey

1.1 Introduction

The classroom is the typical environment we think about, visualise, and contextually assume when we talk about education or mention students and teachers. In reality education and teaching happens all around us and at any moment of the day as we live our lives. Whether the learning has formally or informally occurred and whether the learning objectives are controlled by an educator or the learner, intentional or incidental, the process of knowledge acquisition has taken place. This fortuitous and opportune characteristic of learning conveys an important and fundamental message, that learning is not only a complex and multifaceted entity, but at the same time, it is incredibly versatile and amazingly polymorphic. Do we take full advantage of these qualities? I believe we do, especially when we consciously and intentionally teach someone a lesson, or explain a concept or a technique to our children, or post an update on social media or a clarification about a topical subject we have some expertise in. So what happens within the classrooms of our schools, colleges, and universities? Are we taking advantage of these same favourable characteristics of learning and education? I still believe that we do, but a deliberate and well-thought endeavour to formalise and configure the entire process, in an attempt to amplify and optimise its effect. What has happened over the years is that education and teaching have not been left to chance or occur by coincidence, but have been meticulously scrutinised and systematically structured and controlled in a way we have experienced them in our schooling days. The plethora of learning theories, together with the variety of numerous education reforms and proposed methodologies, are testament to the

M. Montebello, *The Ambient Intelligent Classroom*, Studies in Computational Intelligence 840, https://doi.org/10.1007/978-3-030-21882-9_1

Fig. 1.1 Medieval classroom [1]

attempt and resolve of civilised societies to formalise and institutionalise teaching and learning. The systematic management of educational practices within purposely designated learning spaces were initially not business oriented in nature, and thereby their primary and sole objective was purely academic. Even though lecture rooms have evolved since the mid-fourteenth century learning spaces depicted in Fig. 1.1, the concept remains fundamentally the same, where the educator dictates, and in a non-reflexive manner, has full control of the classroom, as well as initiating, controlling, sequencing, and completing all of the activities occurring within it.

1.2 Teacher-Centred Pedagogy

This teacher-centred philosophy was predominant in the initial stages of establishing the classroom to be the dedicated space whose sole objective was for education to take placec. Essentialists, like Bagley [2], strongly argued in favour of such a philosophy whereby the teacher instilled order and set down regulations, while enforcing discipline and passing on a common culture of knowledge. Even though the educator, in such cases, has the reassurance that all the students did not miss any essential topic, there is no guarantee that any learning actually happened. One thing

Fig. 1.2 First classrooms [3]

is for certain, that students are encouraged to independently think for themselves in order to succeed. However, this may also lead to weaknesses in students' communication skills as they are encouraged to work alone and not to collaborate and share efforts. Some teachers prefer such a practice, as it helps maintain order in class, with a hassle-free and quiet progression, that seems to benefit more the teachers' tranquillity rather than the students' academic improvement. This may work for the best and highly-motivated students, but it could easily lead to other students who get bored and wander away, missing the educational content altogether.

Similarly, perennialists, like Robert Hutchins and Mortimer Adler, believe that the teacher should guide and control the educational process, heading every activity and ensuring that the learners are acquiring the foundational and relevant human knowledge required to become model citizens. Even in this case, students are not given enough space to externalise their unique qualities, to freely express themselves, liberally query any subject matter, and healthily direct and control their own learning process. Such philosophies led to the configurative arrangement of the classroom as we know it, as shown in this early nineteenth century classroom (Fig. 1.2).

This does not mean that informal learning ceased to exist or was not possible, as the need to survive and the vigour that humans accumulate in difficult and struggling situations, leads to a natural learning process that no classroom can contain. Still, a need to formalise and organise the educational process within the higher education arena, especially where professional skills and domain expertise are required to be instilled, was deemed necessary. Such a scenario involves adults, and even though the philosophical underlining is educator-centred, the mature learners are psychology old enough to think for themselves, express themselves, and direct their own learning processes. The role of the educator changes and adapts to the needs of the learners, from a facilitator to a knowledge bearer, from a challenge provocateur to a career advisor, and from a tutor to a colleague. Higher education classrooms and auditoria

Fig. 1.3 Classic classroom setup [4]

configurations still reflect the traditional teacher-centric philosophy as seen in this mid-nineteenth century lecture room (Fig. 1.3). Once again, learners are discouraged from interacting as they have their backs to others behind them, and where the 'sage on the stage' literally meant that very often platforms were purposely used, and still are, to epitomise authority and knowledge. Sitting in front or at the back has social and academic connotations and ramifications, but from a physical point of view, the closer a student is to the teacher, the greater the chances of interaction and engagement.

Educators within higher education are much more independent and autonomous to decide on which venue and which configuration to adopt according to their philosophical outlook and type of physical stance they would like to convey to their students. The subject matter at hand can occasionally impose and constrict an educator to employ a particular configuration or a specific venue. However, what is interesting is that whereas modern schools with liberal space designs are moving away from such traditional and restricted configurations at primary and secondary level (Fig. 1.4), higher education institutions are strongly sticking to and endorsing the traditional educator-centric philosophy.

These observations become even more interesting when we introduce the use of smart technologies and personal devices by the students within the classroom. Whereas higher education institutions and teaching academics seem to allow and trust their learners' mature judgement, schools at an earlier stage are still not embracing the use of such smart technologies as they strictly filter and restrict their use or prohibit altogether (Fig. 1.5). So, should we ban use of smart devices in classrooms?

Fig. 1.4 Modern classroom configuration [4]

Fig. 1.5 Use of smart devices at university [5]

Should we be rethinking classroom configurations? How can we integrate the use of such devices, that can be fruitfully employed as learning resources, within dedicated learning spaces? This book attempts to bring these realities together while answering or referring to these questions as guiding indicators towards the goal of optimising the learning process by employing any of the available software, physical and human resources.

1.3 Student-Centred and Reflexive Methodologies

The main concept is to move away from the traditional didactic teacher-centred methodology of teaching to an inclusive and student-centred reflexive one, where the focus shifts from the educator onto the learner. This does not mean in any way that teachers are not required within the classroom, or lose their leading role, but that they share the focus, and have the opportunity to equally interact individually or as a collaborating group are working on a task together. Such a philosophy fosters and helps to build confident learners who are encouraged and inspired to communicate, share, collaborate, form opinions, direct their attention and learning, query and pose questions, as well as work independently and with other learners. The classroom might seem or sound out of order or out of sync a lot of the times, but as long as formative learning, exciting creativity and motivating innovation can potentially occur through such a conducive environment, then the academic motives and intensions are sound and appropriate. This does not exclude that at any point the educator calls all to the attention to communicate or report about an important or essential issue. In this way the class can conveniently re-group ensuring that everyone is conscious about some basic facts and requirements, while also confirming that all the learners are on board.

The use of technology, like any other learning aid, is to be embraced, controlled and put to good and appropriate use. Cope and Kalantzis [6] make it clear that technology is pedagogically neutral, even though it is highly influenced by it. The advent of Web 2.0 and the proliferation of the World-Wide Web, enabled networked technologies that not only changed the way web users interact within the online environment and amongst themselves, but also the way research is performed and the way we look at education. Networked technologies have unleashed a plethora of possibilities that enabled learning affordances that learners and educators can bank on and benefit from. Furthermore, the classroom will still remain the dedicated learning space that it has been in the past, as it serves its purpose, but needs to be intelligently and purposely restructured to accommodate numerous learning modalities that we as learners and as educators need and make use of, to truly provide a holistic educational environment that is inspiring, nurturing, and conducive to creativity, innovation and collaboration.

1.4 Learning Modalities and Affordances

Two lines of thought or models have influenced this work and that have strongly contributed to the inception, design and development of the ambient intelligent classroom project. The first is the work by Nair and Fielding [7] who analysed and thoroughly investigated school design. Of particular interest are the different learning modalities, listed in Table 1.1, that the authors identify and argue that such modalities are required to be supported within a comprehensive learning space. They go on to propose different design patterns of classrooms to house four realms of human experience within purview of planning and designing learning spaces, namely, spatial, psychological, physiological, and behavioural. The second work is by Cope and Kalantzis [6] who identify seven new learning affordances (Fig. 1.6) that have been made possible through the emergence of Web 2.0 networked technologies and based upon Bloom' s theoretical recommendations [8] on how to aim towards mastery learning. The authors refer to this new ecology as an eco-system, consisting of the complex interaction between human, textual, discursive and spatial dynamics. In a somewhat very similar manner McIntosh [9] identifies seven spaces within a physical learning space environment whereby learners can interact in a variety of ways. The author argues that new technological developments have enabled classroom designers to embrace the learning modalities identified earlier by Nair and Fielding [7]. The seven spaces, originally six [10] and incremented to seven by McIntosh, are enti-

Table 1.1 Learning modalities [7]

1. Independent study
2. Peer tutoring
3. Team collaborative work in small and mid-size groups
4. One-on-one learning with the teacher
5. Lecture format with the teacher or outside expert at center stage
6. Project-based learning
7. Technology-based learning with mobile computers
8. Distance learning
9. Research via the Internet with wireless networking
10. Student presentations
11. Performance and music-based learning
12. Seminar-style instruction
13. Community service learning
14. Naturalist learning
15. Social/emotional learning
16. Art-based learning
17. Storytelling (floor seating)
18. Learning by building—hands on learning

Fig. 1.6 Eight affordance of new learning [6]

tled secret, group, publishing, performing, participation, watching, and data spaces respectively, turn out to be closely overlapping with the seven affordances identified by Cope and Kalantzis [6]. This overlap has enabled the convenient mapping of the seven Cope and Kalantzis's affordances to the Nair and Fielding's modalities, connecting the two lines of thought, from new learning approaches in this digital age to physical learning spaces within the present classroom. This is the scaffold upon which the book is structured around.

1.5 Conclusion

The theoretical models by Nair and Fielding, Cope and Kalantzis have inspired and are at the base of the rest of the book as each chapter incrementally and sequentially builds on the previous towards the inception of the ambient intelligent classroom. The application of Artificial Intelligence to a physical environment is encapsulated within the Ambient Intelligence research domain and applying this to one of the most important environments in developed societies is of utmost importance and interest. Chapter 2 gives an in-depth analysis of this young yet thriving research domain that, apart from education, has been applied to numerous other environments inhabited by humans. Chapter 3 through to 5 tackle different aspects that contribute and are critical to the multi-dimensional nature of the topic at hand. The social, technological, and educational dimensions of an ambient intelligent classroom are separately investigated bringing into discussion numerous related works, learning theories and fundamental concepts that have previously been individually investigated, but never brought compatibly together. All this leads to the ambient intelligent classroom, in Chap. 6, whereby all the previous chapters come together to justify the concept, the empirical study, as well as the findings over these last two years. The book comes to a close with a final chapter to extrapolate this research and its findings in an attempt to optimise the proposed model and offer recommendations for future research into what promises to be the future of our ideal and preferred learning space.

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Chapter 2
Ambient Intelligence

The environment
is everything
that isn't me.

Albert Einstein

2.1 Introduction

The notion of personalisation through artificial intelligent techniques has been applied to various domains, especially when the goal is to enhance a service or a product that closely fits the corresponding requirements of a human user. This reflects the natural tendency of humans to seek attention as they draw pleasure when distinguished from the rest [1], especially when their unique characteristics are accurately matched to specific service attributes or product specifications. When the target service or product are the environment or the ambient itself that surrounds the user, then an Ambient Intelligent (AmI) setting has been established. The surroundings become sensitive and perceptive to the user's characteristics, needs, interests and actions to an extent that they accommodate the same user and transform, modify or adjust the environment itself. The idea that was originally conceived by Weiser [2] was that the technology was around us and everywhere to the extent that we do not even realise that we are surrounded, and that the same technology is tracking each person and every movement. The AmI research area has flourished and developed into numerous sub-fields as evidenced in the yearly European conferences [3] and high impact journals [4], while the media still consider AmI as the next upcoming digital technology wave that will revolutionise the world around us [5]. What has changed and improved since the early days of AmI is the technology itself that is employed to collect information and generate greater amounts of data or big data. This exponential assemblage of data also resulted as a consequence of the inception of the Semantic web, Web 2.0 apps, the mass diffusion of embedded device in all aspects of our everyday devices at home and at work, as well as the wide acceptance of technology around us in the form of an Internet of Things (IoT). The data

M. Montebello, *The Ambient Intelligent Classroom*, Studies in Computational Intelligence 840, https://doi.org/10.1007/978-3-030-21882-9_2

generated by all these devices and supported by the networks around us serves as training sets for the artificial intelligent techniques at the background that get trained, and eventually will be capable to predict, perceive and infer useful and informed assistance to people within the environment within which they are deployed. AmI is much more accepted and understood nowadays as pervasive technologies are even more common, seamless connections are taken for granted, and trust together with confidence in digital technologies is reaching unprecedented terminal heights. This chapter attempts to comprehensively cover all aspects of ambient intelligence before immersing into the deeper details of the AmI classroom. The next section triggers off this AmI overview with its short history, from its recent beginnings to the multiple domains that branched off or alternate approaches that evolved into research domains in their own right. The different technologies, techniques, instrumentation and potential setups are covered in the second section, while a number of AmI case studies are presented and examined in the third section, as they assist the reader in forming a better picture of such environments. Finally, the case for the classroom in light of all the previous sections, is presented, expounded and explicated. Worth closing this chapter introduction with Weiser's opening statement in his iconic paper that set the scene for the next twenty-five years of research and development within the AmI domain.

> The most profound technologies are those that disappear.
> They weave themselves into the fabric of everyday life
> until they are indistinguishable from it.
>
> [2, p. 94]

2.2 Historical Background

The term 'Ambient Intelligence' has gone through a number of transformations and interpretations, and thereby it is important that a formal definition of what is meant by Ambient Intelligence (AmI) in this book is given. All definitions agree that AmI is only possible through the application of Artificial Intelligence (AI) techniques, that is, the use software development programs that are purposely programmed to perform tasks that usually require the intelligence of a human person to accomplish. Just for the sake of clarification, not all computer programs perform tasks that under normal circumstances would require human intelligence to complete. For example, an electronic alarm clock performs no intelligent task that an analogue clock or even a human person can execute. On the other hand, if the electronic alarm has been programmed to keep track of the person's brain activity during the night, as well as the previous week's schedule, and the next day's schedule, allowing the same person to rest for a full six hours of mental tranquillity, then such a task can be said to be intelligent. It would take a human person, a partner or a guardian to really know the person who is sleeping and infer that it is fine not to wake him or her up just yet. As a matter of fact, as humans we do not have the ability to keep track of brain activity, and therefore the AI application, through the use of some sensors like a watch or otherwise, is performing a useful operation that goes beyond human capabilities. Another example that requires some extent of human intelligence is when we recommend or suggest a service, a product, or even a website to another person, on the basis of our knowledge of their interests, needs or requirements. We are making inferences and drawing conclusions on our long-term memory about the characteristics of another person, like a partner, a close friend or a family member, to the extent that we can match and identify the connection between the item, service or whatever we came across with the same knowledge we have of another person. If a computerised program or application has been purposely programmed to perform such a task, like suggesting, recommending, matching or proposing a product or a service to a person based on that same person's unique profile, then that application can be considered to be an artificially intelligent piece of software. Additional examples and far more detailed situations where the application of AI in different everyday scenarios are given in Sect. 2.4.

When we apply the same AI within software to act upon the environment around us in a way that, through the surrounding sensory data collected, adjusts the same environment to accommodate us as persons, then we can formally define what Ambient Intelligence (AmI) stands for in this book. The AmI program unobtrusively monitors the surrounding ambient, be it a car, a boat, a plane, a room, or even a house or a building, to provide a service to the human user. The automated system that is woven within the ambient environment is receptive and highly sensitive to the user's actions, gestures, needs and requirements, thereby adjusting and personalising the same environment to accommodate the unique user. Users tend to enjoy such a personalised experience as the underlying AmI systems is continuously attempting to optimise and heighten their experience within the targeted environment. Such a personalisation is possible through the identification of the specific user through technological sensors or otherwise and adjusting the provided functionalities within the ambient to reflect the profile of the specific user. Postma and Brokke [1] maintain that we as humans positively react to personalised services while valuing and appreciating products that in some way or other have been specifically customised to our unique personality. AmI applies such personalisation to the surrounding environment thereby raising the quality and value of the provided services as they are uniquely adapted to the dynamic profile of the user within the same environment. Such practices have been and still are being widely employed by commercial entities who quickly took advantage and capitalised on extracted benefits of tailoring services and products to the exact needs and interests of clients. Starbucks [6] incorporated user customisation capabilities within their downloadable mobile app to maintain their client retention rate as high as possible as each customer is uniquely and individually identified and serviced, keeping track of consumption patterns, menu choices, and personal preferences. These capabilities trigger off an innate human psychological need in all of us as we seek to be unique and distinct from all the rest. The concept is to instil a sense of control and prominence that prompts a person or a client to request further differentiated treatment. Psychologists [7] confirm that targeted advertising are grounded on the assumption that such practices have a positive and captivating effect on an individual's ego and psyche as they set a positive mind-set and inject confidence and self-assurance. This phenomenon has also been corroborated by brain researchers [8] who specify that addressing a person by their first name triggers higher levels of activity within the left hemisphere of the human brain, thereby justifying the reason behind sales persons and marketing departments revert to the use of potential clients' first name within their advertising and sales pitch. The emotional responses resultant from personalising a service, a product, or simply information, have been taken full advantage of and employed by numerous other commercial entities [9] in an effort to maximise engagement levels and eventually sales. Tailored advertising and focussed pitching builds a strong and lasting customer base while establishing fruitful and healthy client rapport.

Within the education realm personalisation has also been embraced and adopted by a number of projects [10, 11] whereby the differentiating process proved critical in tailoring and adapting the standard academic material to address the individual and unique needs of each learner. Similarly, other researchers [12–14] acknowledged the beneficial effects of personalising educational material and services as learners reported no progress when employing standard course material. The online education equivalent was even more effective as the customisation process was possible through personal learning environments and in real-time [15, 16]. Such environments manage to instil a sense of belonging and comfort within learners who can call the learning environment theirs [17, 18], triggering off a string sense of self-esteem, pride and rising levels of motivation and empowerment [19]. These same personalisation techniques, attributes and capabilities can be fruitfully adopted and employed within the environment around us through ambient intelligence. In Sect. 2.5 the case for an ambient intelligent classroom is made as the personalisation process within a classroom environment would inadvertently detect students and teachers within, with the help of AmI, and act accordingly [20]. Learners and people in general are accustomed to the use of technologies in their life rendering the AmI concept easy to integrate within the schools and classroom. Such a scenario also includes the devices and apps that students and teachers make use of, as they provide further knowledge and data that can be collected, processed and applied by the underlying AI techniques to further improve the background services rendered by the AmI technologies. AmI is heavily dependent on the technology behind it that makes it possible, but technology is not the only dimension to consider, as discussed further in Sect. 2.5. However, technology and research surrounding AmI has evolved over the years influencing the domain itself and the way we investigate, deal with, and study how to productively make use of such a powerful and promising technology. The next three subsections offer an overview of how AmI has progressed and developed over the years as numerous researchers and developers from all over the world contributed into the technology as we know it today.

2.2.1 Ubiquitous and Pervasive

Ambient intelligence is commonly referred to and synonymous used with ubiquity and pervasiveness, as these terms are interchangeably used to refer to omnipresence. It would be beneficial to precisely define both terms, together with the way they are interpreted within this book. Something, an object, a service, or even a intangible thing like a feeling or an effect, has an ubiquitous attribute when it can be found or manifested all over the place. The ever-present characteristic of such a thing that appears to be found in every location, and in every circumstance, is a powerful and overwhelming featuring trait that is acceptable to society at large, but also indispensably necessary and desirable by the same society. In this context one can say that the effect of information technology in modern society if ubiquitous as people have become increasingly dependent on the automation and convenience of employing such technologies. This has been made possible and facilitated by the introduction and integration of digital devices within every aspect of our lives. Pervasiveness on the other hand refers to the physical and conceptual penetration of the use or dependency of a technology, a concept, or even a tangible object. A pervasive attribute, more than a ubiquitous one, instils a concrete and perceptible manifestation that is spreading widely throughout and in all aspects of society. Pervasive computing [21] is a perfect example to epitomise how computers as physical machines made their appearance at the end of the twentieth century and literally swarmed the workplace, industry, schools and houses within a relatively short period. This includes the integration of micro-chips and computerisation into every day appliances, cars, and hand-held devices. The ever-diminishing and low-cost of embedded and integrated devices are still pervading all facets of developed society to enable the use and fruition of ubiquitous information and communications technologies.

The generic and prevalent focus when dealing with AmI is mainly on the sensory technologies and embedded devices involved due to a number of circumstances. Apart from the obvious tangible nature of such devices planned to disappear behind the scenes, their early availability and popularisation before the actual inception of AmI itself, tend to represent the whole notion behind the AmI concept. Gilder [22] identifies this early era as the *microcosm* within the technological evolution whereby an abundance of silicon-based microelectronics characterised the 80s and which were unfortunately limited due to their bandwidth (speed) connectivity (see Table 2.1). The author argues that the next technological era, which he calls *telecosm*, resolved such limitations as optic technologies in the 90s enabled fast and wireless communications, however encountered storage issues. As technology further evolved nano technologies alleviated such limitations after the millennium according to Privat and Streitz [23], who refer to this era as *ambicosm* that is only limited due to human capabilities as the previous technological eras resolved the speed and space concerns. This places us in an ideal situation where the technology and the application need are mature enough to extract the best benefits in a coordinated effort.

Table 2.1 Eras of technology evolution [23]

Era	Timescale	Defining technology	Defining abundance	Defining limitation
Microcosm	1980s onwards	Microelectronics	Silicon-based processing power	Bandwidth
Telecosm	1990s onwards	Optics	Wireless and wireline bandwidth	Storewidth
Ambicosm	2000 onwards	MEMS and nanotechnologies	Physical interaction capabilities	Eyewidth

The availability, adaptability and opportunistic prospects of these ubiquitous and pervasive technologies enabled AmI to mature and develop into a research domain in its own right while their commercial application and viability was also successful transitioning to industry. The evolution of the web and networked technologies, as will be expanded in the next subsection, have further facilitated and enabled the adoption of AmI environments, coupled with the escalation in communication speeds and the decline in cost and size of these same devices. When considering the transition of pervasive and ubiquitous technologies to education a disappointing outcome to an expected adoption boils down to the difficulties encountered in making changes within academic circles. The bureaucratic restrictions, regimented educational programmes, adherence to strict syllabi, and socially unjust assessment procedures are just a few reasons why resistance and slow adoption of technologies that can potentially assist educators and enhance learning effectiveness. Numerous researchers [24, 25] have documented their disappointment at such a paradox as learners, who are easily and increasingly employing and enjoying the multi-functionality of such technologies, are forced to *power-down* and suppress the urge to engage with fruitful technologies when they arrive at school. Educational researchers [26, 27] at primary, secondary and higher levels have shown and empirically recorded the benefits of embracing rather than rejecting the supportive and inclusive nature of such digital educational technologies [28, 29]. A well-planned and researched educational reform is required whereby educators are trained and allowed to liberally integrate technologiesv that learners are already comfortable with and good at, while still attaining their educational goals.

2.2.2 Internet of Things

The Internet of Things (IoT) is a network that connects not only computers in the sense when we refer to a local area network (LAN) or a wide area network (WAN), but to all other devices, objects and things that are capable to communicate in some way within the same environment. Reference to the IoT is commonly made when referring to ambient intelligence. The simple reason behind such an association is that in an ideal AmI environment every item, object, person, or resource within that environment is identifiable and connected onto one network. One would argue that since a small network within a specific environment is being considered, where everything is tagged and can be referenced, then it should be referred to as an Intranet of Things rather than an Internet. However, when a private Intranet is open to and connected to the resourceful World-Wide Web (WWW), then it turns into a bigger and inclusive Internet of Things. The massive knowledge-base over the WWW together with the crowdsourcing wisdom from social media play an important and crucial role within AmI scenarios as will be mentioned in Sect. 2.4, but also in the AmI classroom study documented in Chap. 6. Non-technical persons or AmI environment users often query the definition of IoT as given at the start of this subsection, and wonder how inanimate objects like tables, bulbs and furniture, or even devices that have no communication functionality like projectors, washing machines and toasters, can ever be identifiable or communicating over a network in any way. Starting with the obvious, powered devices can easily connect via a wireless network like WIFI or even with the assistance of some embedded micro-chipped device, while other non-powered objects can be detected and uniquely identified through other wireless technologies like RFID (Radio-Frequency IDentification). Details of how RFID functions are given in Sect. 2.3 but at this point it suffices to clarify that even a non-powered object like a chair or a bottle can have a tag attached to its side that will enable a special electronic reader to detect it and recognise it while distinguishing from all others in the process. The concept of the IoT was first coined by Gershenfeld et al. [30] in 2004 as they justify how such an inclusive communications network employing numerous sensors can easily combine with the environment around those occupying it in an effort to share all the available information. This information travelling through wireless means provides the required input for a surrounding system that brings together the digital and physical world. The output services the users providing useful functionalities and intelligent capabilities.

How will the user connect to the IoT within an AmI environment? The users are a source of information, not only through their presence, but also through their actions, contributions, and reactions. Users can be easily be identified through a person identification chipped-card or even through their wireless mobile phone connection. Another wireless technology, that will also be expanded in Sect. 2.3, is Near Field Communication (NFC) that identifies a hand-held device as soon as the device is close enough to sensory surface, and thereby identifies the specific user. The use of mobile devices form part and parcel of the IoT as the user can easily access services and information off the device, while the device wirelessly connects to the communications network accessing all the available functionality. The combination of the wireless mobile device and mobile services together with the physical characteristics of sensors and embedded devices provides an ideal environment for AmI. Figure 2.1 depicts a topic map to distinguish the fundamental application area differences between mobile computing, embedded computing, and pervasive computing as they come together within an AmI environment. However, each of these domains, taken at the extremities of their application spectrum, provide distinct and significant application areas.

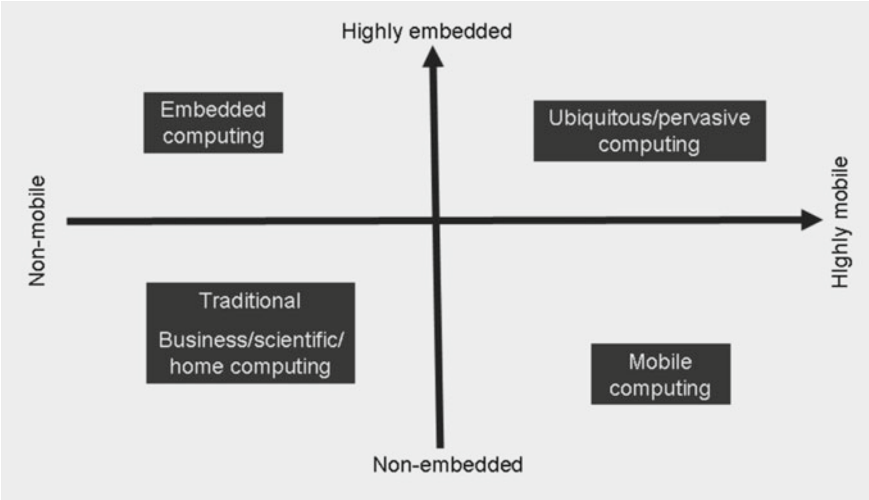


Fig. 2.1 Topic map for embedded and mobile computing [23]

2.2.3 Smart and Calm Computing

An environment that is technologically upgraded with added-value capabilities intrinsically included is also referred to as a smart environment. Smart computing involves software that has been developed to execute a set of instructions (a program) based on a particular methodology (an algorithm) to perform specific functionality (in this case Artificially Intelligent techniques). As mentioned earlier, AI programs have no particular intrinsic magical alien attributes within, but simply techniques and procedures coded by human developers following some reasoning that scholars and researchers have been proposed, tested, and improved over the years within a rigorous, highly-researched and peer-reviewed academic community. Some of these techniques are typically modelled on human reasoning patterns or network arrangement of neural cells within a human brain, however optimization efforts and alternate proposals are always ongoing within the vibrant AI community. Smart techniques within an AmI environment have been purposely programmed and developed to grab information from the surrounding sensors and automatically adapt their output and actions according to the input. The main difference between smart computing and normal applications we use every day is that they recycle their output as input to the next processing round similar to what humans do through their learning process of experience. Another important difference is that such computing style evidenced within AmI environments is automatically triggered and independently executed without the intervention of the users and invisibly secluded behind the scenes. It is due to this specific attribute that such technologies are referred to as calm computing. Users are not required to direct their attention and focus to the technology or the computer program within their surrounding AmI environment. A technology is designed to be a *calm computing technology*, as originally introduced by Weiser and Brown [31], when it manifests itself out of the users' centre of attention, on the periphery of their focal concentration in a way that it eliminates or at least diminish as much as possible the perceptive invasion of computerised devices and technologies. This does not mean that there will be no control over the AmI environment, but simply that users shift their attention and focus to the technologies only when required and absolutely necessary, otherwise the smart computing systems can maintain their peripheral data collection, processing, and cyclic execution. In this way the unburdened AmI users can calmly interact with the technologies surrounding them in a confident, familiar and calm way fully aware that the smart technology is continuously alert to their future needs and interests as well as of their current surrounding and past choices and decisions.

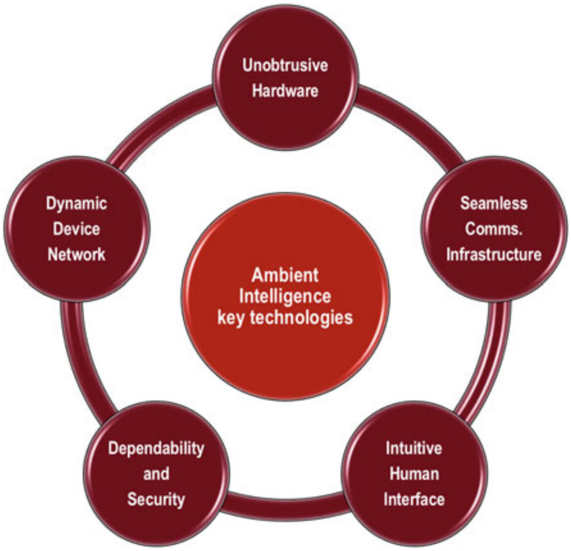
2.3 Enabling Technologies

The technological dimension of ambient intelligence is as important as the other dimensions, which will emerge later on, and essential as it physically enables and supports all other processes without which the entire AmI functionality fails to deliver. On the other hand, the technology in isolation is not enough and requires well-thought and proven techniques to ensure the tools are being efficiently employed to maximise their use and optimise the eventual outcome. An in-depth and technical detail of how to deploy these technologies is beyond the scope of this book, but the methodology employed, the techniques adopted, the sensors operated, and the setup configurations applied, will help set the scene and assist in understanding the concepts behind AmI classrooms. In the next subsections all these issues will be expanded in details to offer a better understanding of all the different aspects before making the case for the classroom. The techniques are important as they set the strategy to be adopted, a methodological plan that enables a structured approach rather than simply pushing sensors and equipment within a room and expecting to obtain meaningful results or a positive outcome. Once the procedural organisation is set and justified then the right tools need to be identified and selected for the specific job they are required to do and the specific data they are meant to sense, collect and act upon. Finally, the ideal setup, based on previous case studies and different rationales, is proposed and drawn, before being tested and eventually adjusted according to outcomes and evolving requirements. As a guideline to these three pillars of the enabling technologies it is worth considering the recommendations offered by the European Commission's Information Societies Technology (IST) Advisory Group, known as ISTAG, regarding the key technologies required to make AmI feasible and realistic. The five technological requirement areas depicted in Fig. 2.2 are:

i. Very unobtrusive hardware

ii. A seamless mobile/fixed web-based communications infrastructure

Fig. 2.2 AmI key technologies adapted from [32]



iii. Dynamic and massively distributed device networks
iv. A natural feeling human interface
v. Dependability and security

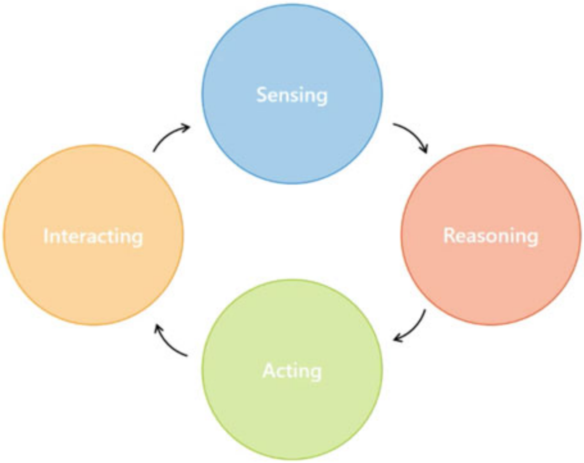
[32, pp. 18–19]

These key enablers will assist in the rest of the book as they provide indicative and essential guidelines to the techniques, sensors and setups that will be expanded in the following sub-sections. However, it is worth elaborating a bit further on each of the five above mentioned underpinning technologies required to construct the AmI landscape. The disappearing hardware that Weiser [2] anticipated is expedited by the evolution of hardware that continues in its unobtrusive drive, as micro and nano technologies pursue their goals of miniaturising, self-powering, integrating and interoperating devices that can intelligently and efficiently communicate and collaborate. Additionally, if this same hardware is easy to plug-and-play in a seamless and trouble-free manner then it would further facilitate its adoption and the establishment of AmI environments. To do so a reliable, fast and secure network is required that sustains the transport of multi-modal resources as well as ensuring the ease, intuitiveness and practicality of employing such networks. This can also be attained through an appropriate human-computer interface as a convenient and trustworthy way to communicate, be it verbal, gesture, intelligently through repetitive patterns, or through the traditional manual interaction interface employing a mouse, touch-pad, pen, joystick or keyboard.

2.3.1 Techniques

Ambient intelligence interaction with the environment perceives the state of the environment and users within it with the use of sensors, as data is collected and a variety of AI techniques are employed to analyse it. Once the data is processed and productively employed to rationally deduce what action to perform, the AmI system acts upon the environment using controllers in such a way that the algorithm achieves its intended goal. The cyclic process of an AmI system, depicted in Fig. 2.3 justifies why special focus on techniques that assist with sensing, reasoning, and acting are crucial in the overall success of the system. Ambient Intelligence falls under the umbrella of Artificial Intelligence and thereby it stands to reason that AI techniques are employed fruitfully within AmI environments. The whole process initiates by the actual interaction of human users with the environment that is purposely and strategically sensory-loaded to capture such interactions as required and indispensable input to the rest of the AmI process. The sensing component can be compared to an invisible entrapment mechanism that captures the user's actions, feedback, and status, to acquire data about the same user. This data is eventually employed and processed at the next reasoning phase of this cyclic process. The different sensors that can be employed together with their domain of application and variety of data they can acquire will be covered in the next section, however it suffices to keep in mind that all forms of data captured by an assortment of sensors will move to the next phase, be it user's position, hand gesture, sound, language, text, choice, post, eye movement, preference, bookmark, or any other output perceived from the user. Reasoning based on the data acquired from the previous sensing phase encapsulates the real and existent link between the computerised programs working at the back of the system and the user's real world. These software programs are, simply-put, a set of instructions, also known as algorithms, that a human developer has written, or coded, to process the data in an intelligent way. The computer program runs through the data in specifically instructed ways to extract information that is not explicitly stated or overtly captured. Fast and repetitive instructions, called iterations, are required to process massive masses of data, referred to as big data, at such speeds that is humanly impossible to achieve. This reasoning promptness and efficacy of hundreds of thousands of processes in a millisecond is what distinguishes an impressively powerful and formidably rapid computerised system from a human reasoning mechanism. The crux of this reasoning phase is not only to be fleetingly swift and instantaneous, but also to be adequately responsive to the situation, adaptive to different users, and beneficial to the specific situation within a particular environment. Computer scientists over the years have theorised, proposed and developed numerous reasoning techniques that have been tested, argued about, counter argued, adjusted, improved, discarded, regenerated following some new discovery, and applied to different situations. Such an academic and research-oriented process is how AI techniques have developed over the years and scientist have been able and managed to build on previous techniques to further refine and optimise such processes. Modelling the user, supporting or making decisions, reasoning within a spatial-temporal environment

Fig. 2.3 AmI cyclic system [33]



(meaning/defining/explaining) and predicting or recognising activities are just a few reasoning techniques that have over the years gained popularity due to their successful and operational effectiveness when applied to computerised situations that required some level of intelligence.

User-modelling is a different category of computer programming distinct from the generic algorithms used in traditional computing, simply because its goal is to capture the characteristic features of a user's behaviour and employ them as a model. In this case the model is used to adjust and adapt the environment around the user within a dynamic ambient. Furthermore, the model is not static, but is able to change and evolve in an attempt to further refine the model potentially as close as possible to the user. To keep in mind that the user's behaviour is also dynamic in nature and thereby it is of utmost importance that the generated baseline model is sensitive and receptive to minor variances and specific changes to truly digitally replicate an individual user. User models are highly dependant on which particular data and information is being collected about the same user, and this is functionally subjective upon the type or structural model the software developer is aiming to build. This means that the success or failure of a user-modelling technique still hinges on the choice of programming technique employed by the software developer. Which data is contributing to the model? What type of model or data structure is being employed to store the model itself? Is the model being generated using a supervised or unsupervised methodology? These questions characterise the work of numerous artificial intelligence researchers over the last century in their quest to discover and develop the optimal user-modelling technique.

Decision-making techniques that support or assist a user within an environment are commonly related to safety whereby surrounding sensors recognise a hazardous setting and make amends to ensure it is safe for human users to make use of. Techniques employed in such cases could be as simple as rule-based systems that require satisfaction of specific constraints in order not to raise an alarm or trigger off some remedial process. Similarly, planning systems are considered artificially intelligent techniques as they strategically and automatically execute a series of actions, or software commands, once the data provided has been processed and results that an issue needs to be resolved. Such a discovery is extracted from the state of the environment that the system is supervising and controlling. In such a case the system is programmed to seek and continuously strive to return to the original safe state to satisfy the original conditions that have been set. To do so one needs to keep in mind that a particular problem could have numerous dimensions and conditions that require attention. Decision-making techniques are based on questions that AI developers attempt to codify and control as the system or environment could potentially have specific states, or continuously varying states, or even ambiguous that are not observable. This makes the situation even more complex and not easy to recognise, determine and resolve.

Spatial and temporal reasoning techniques are particularly suited to AmI intelligent environments a temporal) that the user is within the environment are crucial and deterministic to the reaction and eventual success of the underlying AmI software. The combination of both time and space variables provide the contextual dimension a human would equivalently require to resolve a similar situation. Techniques in this domain mainly focus on specific relations between objects that occur within a specific environment at a particular time. To give an instance of such spatio-temporal techniques it is worth mentioning the work presented by Allen and Ferguson [34] where they explain how Allen's temporal logic techniques employs time intervals to capture the changes in the relations between specific objects. Differences in the states within these intervals trigger off particular processes once the particular relations satisfy, or not, certain conditions.

Finally, another technique widely used during the reasoning stage is the prediction and recognition of activities especially within ambient intelligent environments. These techniques are purposely deployed to identify patterns in the activities of the user to the extent that future activities can be predicted. Needless to say that the assumption here is that the same user is subject to behavioural patterns, and this is what AmI researchers who work employing these particular techniques hope and base their work on. Predictive techniques are possible for more than one user within the same environment and this will be a very important detail later on in the book as the AmI Classroom is proposed in Chap. 6.

The next and final phase within the cyclic AmI system is the acting phase that enables any outcomes from the AmI system to be effectively executed once the sensing phase has collected the data and the reasoning phase processed it. Cook et al. [35] also point out that such a phase together with the sensing phase ties the reasoning stage to the real world, thereby proving a mechanism by which AmI systems actively execute and affect the lives of users. The manifestation of these acts can take multiple shapes and come in different forms or media. The most obvious and explicit outcome derived from this acting phase is the physical materialisation that is visually, audibly or tactually experienced. Changes in the environment or the interface, as well as audio messages or music, together with motor actuators within devices, can potentially produce the processed output from the reasoning phase following the interacting and sensing phases. Such outputs are easily discernible as they are obvious and unambiguously evident to the user, whereas other implicit and imperceptible output could still be happening in the background within the user modelling process. Numerous authors and researchers refer to robotics as another way of how automated devices can act on behalf of the underlying system to explicitly illustrate the output to the user. Intelligent robots are beyond the scope of this book and do not feature in any way as part of the AmI classroom, however, this area is rapidly evolving in a quest to develop machines that go beyond solely performing specific tasks. Robots that are flexible capable to achieve multi-functionality and the ability to simulate complex human activities are still not a reality.

2.3.2 Sensors

In the previous section sensing was identified as one of the four phases within an AmI cycle, and highlighted the fact that this particular phase is crucial in bridging the software and the hardware devices purposely deployed to collect the required data. Without this data that the sensory hardware components assemble and accumulate over time, the reasoning software has no input to its algorithms in the next phase, and thereby the cyclic process generates no change whatsoever within the surrounding environment. Cook et al. [35] point out the vital and effective use of sensors as they provide the required practical aspect of an AmI environment, which link the computational power of software programs to the intelligent and useful physical applications. A variety of sensors, that will be explored in the following sections and subsections, allow the underlying system to capture different aspects or dimensions of the targeted environment, making it possible to perceive the surroundings and actions of the user. Similarly, the setup of these sensors varies from one application to another and from one researcher or developer to another; however, sensors are all encompassing and flexibly employed to achieve the desired and intended intention from their specific functionality. A non-comprehensive list of sensors, shown in Table 2.2, is only indicative of the minute and multi-dimensional data collection possibilities to acquire information about a contextual situation.

Issues related to sensor size, power and scalability have been prevalent within research arenas and industry alike, but the advancements in technology these last decades alleviated these concerns to the point of being negligible. Miniaturised sensors thanks to micro and nano electronics are a reality, self-powering devices are the norm of the day, while long-term data collection from whole arrays of sensor networks is common practice. However, AmI technologist, in their efforts and attempts to capture as much as physically possible a true and complete picture of the ambient environment with users within it, continue in their delicate task of assembling an array of numerous and heterogeneous sensors. These sensors are purposely picked and deployed to execute a specific task of collecting correct, precise and relevant data that needs to be processed on the fly in order for the same AmI system to be effective in real-time. One important and crucial decision is to establish the architectural

Table 2.2 Variety of AmI sensors

Pressure	Position	Temperature
Optical	Current	Voltage
Flow	Chemical	Gas
Torque	Strain	Force
Velocity	Humidity	Motion
Acoustic	Proximity	Infrared
Colour	Brightness	Acceleration
Automotive	Chemical	Moisture

setup of the sensors chosen and the communication methodology adopted. Some AmI systems adopt a centralised architecture whereby all the sensors transmit the intercepted data to a central server that performs the reasoning process. Alternatively, a distributed sensor architecture functions by having individual sensors process the data at source collection and communicate the contributing information down the line to the main reasoning component which can more efficiently process slightly more meaningful data. The choice of employed sensors within an AmI environment is only part of the planning process that still requires meticulous and scientific decision making to ensure that the AmI cycle is successfully productive and effectively operational.

2.3.3 Setups

The previous subsection closed with the critical architectural decision of how AmI environment designers set up the selected sensors to optimise the functionality of the collective sensors as data collectors. Before delving into real examples of AmI in the next section, it is worth establishing a number of typical setup configurations that are most commonly adopted. Figure 2.4 [36] displays the typical components one finds within a smart environment together with their high-level architectural setup. Worth noting that the components and the various inter-connections are initially designed and eventually tested within a prototype that gives ample space to adjust and optimise the setup while also allowing the possibility of inserting additional sensors or removing redundant ones. The services, reasoning engine, database component and different interfaces form part of this proposed setup that assists designers to put together and communicate with developers of the intended AmI system.

In a similar manner, Burzagli and Emiliani [37] propose an architectural setup, shown in Fig. 2.5, that features a controller that contains a reasoning engine and database, similar to the previous setup, and a number of other components that ultimately lead to a natural interaction with the user. The integration of the sensors

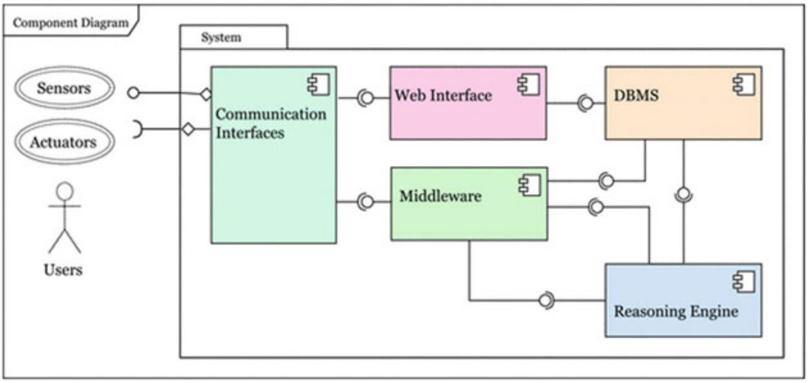
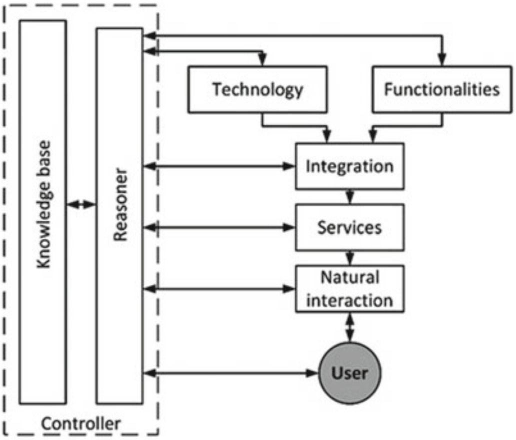


Fig. 2.4 Components setup of a smart environment [36]

Fig. 2.5 AmI architectural setup [37]



with the required functionality through the different services is evident in this case as the user provides a source of input to get the system going.

A deeper investigation into the architectural setup of individual components shows that AmI designers employ similar top-level diagrams to depict the internal components and the interactions between them and the user as well as the environment. Amiribesheli and Bouchachia [36] give a visual breakdown of their reasoning engine structure as it interacts with the smart environment and users within it through the dedicated middleware software. As the processing of the data collected from the top part of the setup presented is performed, the system produces the adequate output and forwards to the same environment through actuators and interfaces. The reasoning engine itself employs triggering of a rule-based AI system that has been initially trained by a domain-specific professional (bottom part of Fig. 2.6).

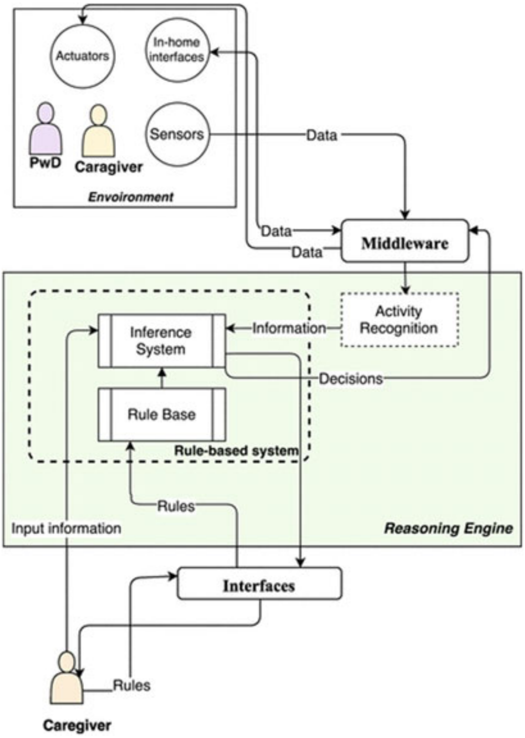


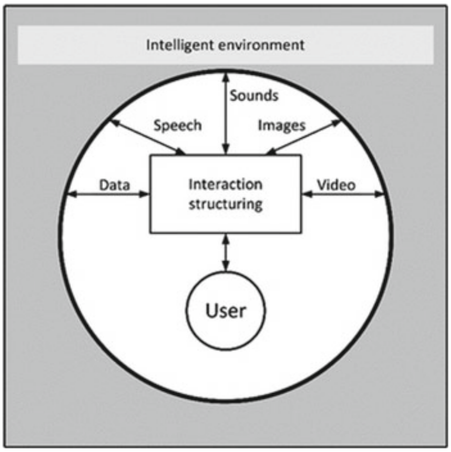
Fig. 2.6 Reasoning engine of a typical AmI environment [36]

In a similar but much detailed manner, Fig. 2.7 shows a typical interaction structure of an AmI real-time interface. The interaction-structuring component is at a high-level and requires further breakdown to better understand how it will function. However, at this stage the AmI designer required to point out and clearly indicate how a distinctive interactive separation between the environment infrastructure and the embedded sensors, as well as services. The user in this case will be presented with what that same person specifically prefers as different media are managed through a centralised interaction component that personalises the communication.

2.4 AmI in Action

A variety of examples and application areas are available to experience an ambient intelligent environment especially as the technology continues to evolve at a rapid pace. This is especially true as the IoT, mentioned earlier in Sect. 2.2.2, is swiftly bridging the gap between household appliances and wireless communication that mobile telephony providers are quickly to invest in and provide to their customers. Inhabited environments provide the ideal setting for AmI to be deployed and opti-

Fig. 2.7 Real-time interface of a typical AmI environment [37]



mally utilised as human users live, work and interact in such locations. These spaces, as we shall see in the next three subsections, include accommodation areas like homes, dormitories, and hospitals, as well as transportation habitats like cars, boats and planes, together with more generic civic environments like shopping malls, office blocks and entire cities. Any of these environments provide the active space whereby wireless and ubiquitous communication enables intelligent processing of the users' activities, actions and status to provide an enhanced and improved way of living. As we go through each of these typical environments it will become obvious that AmI provides an ideal fit to make good use of the ever-pervasive nature of technology as added-value services and personalised products continue to become a reality.

2.4.1 Assisted Living

Living environments are conducive to comfort and leisure, however in some cases, like homes for the elderly or challenged persons, such habitats can make a significant difference between having a roof over your head and a better quality of life. Assisted living does not only apply to elderly persons who require continuous supervision and assistance to be able to function properly within their living quarters, but also to other persons who are challenged in some way or another. Health issues, physical impediments, and visual or auditory challenges present numerous and insurmountable difficulties for some persons that would require assistance and care in order to overcome them. AmI technologies provide the sensors to detect issues or need of assistance, services that intelligently accommodate the individual person, and actuators that can either support or comfort the person in need or recognise the need for external assistance. Apart from the obvious medical sensors to react to a medical situation like temperature, blood pressure, heart rate and sugar levels, other traditional sensors, like cameras, movement detection and audio sensors, can monitor persons requiring assistance from a distance. Additional sensors integrated with clothing, devices and within persons themselves are becoming much more common as to closely and continuously keep track of the user's status and whereabouts. Ambient Assisted Living (AAL) is one of the most notoriously researched AmI areas as its application is both humanitarian in nature and commercially lucrative. Wagner and Hunnerup [38] highlight the rising need of easily available AAL environments as the rise average age across Europe is placing additional pressure on Governments to invest in technological care services. Similar studies in China [39] and the United States [40] outline a number of ways of how AAL improves the quality of life of citizens who require assistance and yet strive for their independent way of life. The prevention, care and support of chronic conditions through physiological sensors embedded within home devices, beds, armchairs and walls. Another AAL aspect helps such citizens not to be socially outcast and thereby maintain their high morale and eventual wellbeing. These aspects can also be supported by actuators to ensure ease of mobility within the living space, as well as, supporting persons in need through daily activities that would otherwise require some kind of human assistance. Finally, AAL enables users to help others by providing them with the possibility to be useful while avoiding periods of isolation. Through the use of technology within their own habitat users can still volunteer to assist others in their same situation or practice their occupation and share their expertise. AAL provides the ideal environment for dependent citizens to pursue their independence as they maintain a high quality of life within a safe living space through use and application of technology. On the other hand this same technology facilitates the life and work of caregivers while enabling family members to live their own lives in the knowledge that their loved ones are fine.

2.4.2 Transportation

The application of AmI technologies and services to a variety of transportation environments is solely and luxuriously intended to enhance and add value to the user's experience while travelling. Ambient intelligent cars, boats and airplanes go beyond the classical and functional modes of transportation as they incorporate additional intelligence through sensors to provide supplementary functionality that can, not only make the journey more enjoyable and gratifying, but even safer and reliable. Weather sensors can provide users with information and alternate route planning to avoid any potential mishaps while ensuring that the travellers are within a protected environment, enjoying personalised entertainment, and comfortably travelling or driving within a customised and adapted ambience. Automated driving systems that respond to numerous sensors are probably the most notorious within intelligent transportation as several commercial entities have invested heavily in such a technology. However, from an AmI point of view, the system is required to accommodate the specific user and modify the way it operates on the characteristics of the user within the transport vehicle.

2.4.3 Civic Environments

Accommodating numerous persons within an environment could potentially create logistic and operational difficulties, however this can be resolved if each individual user within the same civic environment has a personal interface to the background system. Whether it is a public library, a community centre, a shopping mall, a sports facility, a government office block, or an entire city, individual users can still be independently and exclusively attended to and assisted on a personal level. This is possible through individual interfaces that the users employ to access the AmI system working in the background, as for example a tablet, a watch, or a smart phone. A variety of application areas are popping up as individual citizens are provided personalised experiences when accessing public sites as tourists or while visiting cultural heritage sites. Immersive experiences through Virtual Reality (VR) techniques, as well as, through Augmented (AR) or Mixed Reality (MR) enables customised virtual guides that not only add value to the experience, but also provide a much more meaningful and contextual value to individual users. Public AmI technologies provide a civic service that each citizen would appreciate and thereby political figures are looking into such technologies in an attempt to acquire an edge over their direct competitors. Work environments and industry in general is also taking advantage of AmI to maximise their workers' efforts as they attempt to adapt and personalise their tasks through contextual awareness and customised decision making.

2.5 Case for the Classroom

The application areas described in the previous sections have not mentioned the use of AmI in Education or within a classroom. There have been a few research projects that do apply such a technology to an academic environment, as we shall see in the following chapters. However, before expanding in more detail about the rationale behind Ambient Intelligent Classrooms that is the subject of this book, this section will introduce the conceptual ideas behind a systematic and thorough way on how to deploy an AmI classroom through the proper analysis and investigation of three basic aspects or AmI dimensions. The three contextual dimensions, depicted in Fig. 2.8, are social, technological and educational, are duly grounded within educational theories and collectively enable an academic framework as they shed instrumental insights and strategic directions on the future of ambient intelligent classrooms.

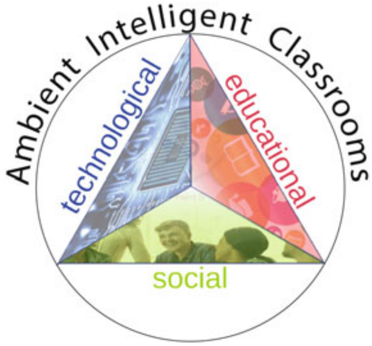


Fig. 2.8 Three-dimensional aspects of AmI classrooms

2.5.1 Social Dimension

The first of the three dimensions that forms an essential part of the proposed AmI paradigm when applied to education is the human aspect as an obvious component of any AmI application due to the fact that the enhanced environment is purposely boosted to add value to people's quality of life. However, the social term is used rather than the human one due to the classroom connotations and the intricately dynamic complexities that occur within a traditional classroom. Chapter 3 will be entirely dedicated to this specific dimension where classroom dynamics are analysed with a social perspective as the Connectivism learning theory proposed in 2005 by Siemens [41] and Downes [42] is associated with this particular aspect of the AmI classroom.

2.5.2 Technological Dimension

The second dimension from the AmI paradigm within a classroom being proposed is the technological aspect that numerous AmI projects have covered over the years and which will be discussed and referenced in detail in Chap. 4. Issues related to wireless communication, learner profile generation, academic portfolios, machine learning techniques, and personalisation will all be expanded further as they contribute to this particular aspect of the AmI classroom. Additionally, the adaptive learning theory is associated and presented within this dimension as it supports the personalisation and customisation of services, information, and products to the specific requirements and profile of each individual user. Adaptation of learning systems is a well-established concept [10] as numerous e-learning researchers predict the intensification of customised learning within all spheres of education.

2.5.3 *Educational Dimension*

The final dimension of the proposed AmI classroom paradigm is the educational aspect. This last aspect has been less explored and investigated by AmI educational researchers then the previous aspect but slightly more than the initial social aspect. Chapter 5 will delve in further detail about this particular dimension as matters related to personal learning environments (PLE) and pedagogical consideration associated to specific learning theories are at the base of the proposed AmI classroom. The model, which is fully expanded in Chap. 6, envisages an AmI classroom whereby a number of learners and an educator interact through electronic and face-to-face interventions. The educator is responsible of setting up the learning environment, providing potential resources, physical and/or electronic, give any required support, while facilitating the entire educational process. The students, on the other hand, have access to their PLE, which acts as an arena for all of them to share resources and experiences, as each of them is individually assisted and supported through the smart environment. This support is manifested through classroom displays, interventions by the educator to a single student or collectively to the class, or through the networked peers themselves. The proposed AmI classroom focuses on the inner motivation of each individual student supported and facilitated by the educator. In this way education becomes an enjoyable and liberal process whereby learners are free to employ what pedagogy they prefer, critically analyse whatever they come across, and evaluate all the information presented through the intelligent environment or the educator while at the same time supported by the AmI classroom environment.

2.6 Conclusion

This chapter comes to a close with a brief look at the three factoring dimensions of the proposed ambient intelligent classroom. The scene is set for the next four chapters that follow where each aspect and the AmI classroom itself are thoroughly investigated and expanded. To get to this point, a comprehensive look into all facets of ambient intelligence was done to ensure that the reader is well acquainted with the basic underlying technology upon which the proposal is based on. The AmI overview and short history enabled the exploration of peripheral issues, like ubiquitous and pervasive computing, IoT, smart and calm computing, enabling technologies, and numerous practical examples, that further helped to make the case of AmI for the classroom.

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Chapter 3
Social Aspect

Coming together is the beginning.
Keeping together is progress.
Working together ... is success.

Henry Ford

3.1 Introduction

The social aspect of the ambient intelligent classroom is one of three dimensions that collectively contribute to the complete analysis, design and implementation of such an intricate and delicate task. The primary reason why the realisation of an AmI classroom is considered convoluted and susceptible to complications is simply because there is a huge and over-bearing component of human element, namely, the learners and the educators themselves. The combination of employing a novel technology within an educational setting where both the learners' receptiveness and the educators' openness to embrace and adopt that technology play a vital and crucial role in the overall and holistic success of the AmI classroom itself. This demonstrates and confirms how much the human aspect needs to be taken into consideration and factored in as it is decisively and imperatively key to the overall proposal. A sound and robust research study in education requires the support and adoption of a relevant learning theory to which the researchers subscribe and associate their philosophical reasoning. In this case the first dimension of the AmI classroom is coupled to an established learning theory, called Connectivism, whose specific characteristics and features lend themselves well and fit perfectly with the social aspect. The benefit of doing so is that the theoretical features assist in the methodological positioning and epistemological reasoning upon which the AmI classroom foundation is partly founded on. The pedagogy adopted at the base of the overall proposal rests on the learning theories which eventually influence decisions, methods, and techniques adopted.

M. Montebello, *The Ambient Intelligent Classroom*, Studies in Computational Intelligence 840, https://doi.org/10.1007/978-3-030-21882-9_3

3.2 Human Aspect of a Classroom

A classroom in itself is a highly complex setting [1], and, according to Walter Doyle [2], the classroom possesses six important features that need to be taken into consideration, namely:

- Multidimensionality;
- Simultaneity;
- Immediacy;
- Unpredictability;
- Publicness;
- History.

All these aspects need to be properly and thoroughly investigated and taken into consideration if Ambient Intelligence is to truly and realistically be employed to assist learners and educators within the classroom. The educators themselves play an important role that is not just academic, to teach, moderate and facilitate, but also an important and decisive role in the overall ecology of the same classroom. Hendrick et al. [3] report to this effect, as they claim that the classroom peer ecology is highly influenced by the educator's modelling behaviour, especially when interacting with individual students. Similar research [4] also pointed out that the overall success of the students, and of the learning process itself, depend on the social and emotional environment that the educator creates and maintains within the classroom. Group dynamics are also part of the social aspect of a class, and as important to the education process of each individual learner. Billson [5] specifically concludes that "deeper awareness of small group processes can enhance the teaching effectiveness of college faculty through improving their ability to raise student participation levels, increase individual and group motivation, stimulate enthusiasm, and facilitate communication in the classroom" (p. 147). This issue requires a deep and clear understanding to further comprehend how the social aspect constitutes a dimensional magnitude when setting up an AmI environment within a classroom. Such group dynamics are also investigated within the dynamics of social networks within the education realm, especially as the dominant method of communication is electronic [6]. The authors conclude that persons and learners form perceptions from their social group communications and use such inferences in their daily task even within the classroom setting. It is thereby important for learners to foster and develop positive and correct perceptions of the other classmates for the class dynamics to properly function and enhance the prospects of a fruitful educational process. Before delving further into the learning theory associated with the social aspect it worth investigating and further analyse the six different features of a classroom. These have been identified earlier, but considering each one of them within an AmI perspective can be insightfully helpful to shed more light on the complex and multifaceted AmI classroom.

3.2.1 Multidimensionality

Numerous educational researchers subscribe to Claxton's [7] claims that classrooms, as well as schools, play an imperative and essential character-forming role as learners experience a variety of social encounters that instil a healthy range of social skills that will be useful in their adult life. Numerous events that are concurrently happening within a classroom are typical of not just the average day but at all times within a standard face-to-face (F2F) classroom. Learners are continuously acting and reacting to the educators' actions, instructions, feedback, and reactions. In a similar manner, educators have the hard, tedious, yet delicate task to ensure they provide the correct and ethical feedback to whatever their students come up with and continuously throw at them. The vast number of events, episodes, and tasks that take place within the classroom are, not only multi-facetted, countless and educationally necessary, but need to be contextually and morally addressed within a relatively small space of a classroom that is crowded by numerous persons. The situation is rendered even more intricate and multifarious when each individual within such a restricted space has personal demands like needs, preferences, abilities, and interests that are affected by the evolving relationships between the learners.

The resources available within a traditional classroom to cater for all these multiple tasks by multiple persons are limited in quantity, medium-specific, and require an amount of learning and creativity to fruitfully employ them within a learning environment. AmI technology within such a multidimensional and scalable matter fits perfectly as the application platform can address and service each and every learner within the same class while acknowledging the educator as a super user within the same environment. Identification sensors can easily identify and distinguish individual persons within the classroom and provide academic services together with additional social capabilities to interact with the other persons that have been identified. Location sensors can detect and pinpoint individual learners within the classroom providing tracking data that the reasoning component of the AmI system can employ to provide addition personalised services or content. Finally, motion sensors can perceptively identify specific movements of learn, like raising a hand to ask a question, or defined gestures by the educator to trigger off a particular process, like switching off lights and switching the projector on. These few practical examples highlighted the applicability and compatibility of AmI within a classroom even though its multidimensional attribute makes it hard to deal with.

3.2.2 Simultaneity

Sensors within an AmI environment are also capable of monitoring, detecting, and capturing multiple actions and conditions that are simultaneously occurring within the same environment. The ability of the technology to collect data concurrently from multiple sensors and systematically organises it to pass it on efficiently to the reasoning module makes it ideal to accommodate numerous users or sources of information. Such simultaneity can easily be compared to the events and activities happening within a classroom. The teacher has the arduous task to oversee and control a number of students in the same classroom who could potentially be doing completely different tasks even though they have been asked to follow the same lesson plan. The different abilities of learners, coupled with their diverse drive to participate in the learning process, and accompanied by their heterogeneous characters and idiosyncrasies, render teachers' task not an easy one which very often goes unnoticed and taken for granted. Individual students require focussed attention that the teacher dedicates short periods of time to address in a round-robin approach, while at the same time monitoring the other students to ensure they have no issues. Additionally, specific students require an occasional push to overcome a minor difficulty, while other interrupting incidents need to be addressed and discouraged, as well as ensure that the class is running on the planned schedule. An AmI classroom could assist the teacher in dealing with a number of these concurrent tasks while ensuring that all of the simultaneous events do not go unnoticed or overlooked as the background system is continuously ensuring that every action and each occurrence that happens within the class is duly addressed or directed straight to the teacher's attention via a visual interface of some kind.

3.2.3 Immediacy

Just as AmI technologies are capable of not just replicating, but enhancing the way they deal with the simultaneous events within a classroom, as we have seen in the previous subsection, they can also optimise the feedback given and response delivered in a quick and efficient way, rendering the whole process seamless and virtually instantaneous. The rapid and copious events that occur within the classroom require instantaneous reactions by the teacher as well as by the learners to the teacher's requests. Educational researchers [8, 9] have pointed out, since the early 60s, that educators had the strenuous responsibility, as part of their daily responsibilities, to interact in one way or another with every student at an elementary level at least five-hundred times a day.

The vastness of such a task, and the required detail of all these exchanges, yet once more goes to show the amazing yet belittled work that educators perform in class. As digital tool and electronic devices permeated through the educational system and into the classroom, both as teaching aids and as educational facilitators, the amount of sourced interactions have multiplied and eventually escalated the number of exchanges between learner and educator. In a recent white paper [10] about the evolution of data and the rocketing intensity of data interaction that every person experiences, predict that by the year 2025 the number of interactions per day for a connected person will reach 5000 exchanges, from a current overbearing 600 interruptions. This means that an average learner and educator within a university lecture room could potentially be bombarded with a packet of information and a prospective interaction or interruption every fifteen (15) seconds.

3.2.4 Unpredictability

This feature that educators very often encounter within the classroom ensures they are continuously on the alert and vigilant to events and situations that are, not only unexpected, but potentially the cause of major confusion and undesirable commotion. Classroom events tend to be community activities and therefore it is not always easy or straightforward to predict exactly how they will turn out, or what issues could pop up on the day. The unpredictable nature of such occurrences are characterised by the educator's ability and experience to deal with typical developing situations, characteristic students' behaviour, and effectively anticipate the problem solving technique to employ, ensuring that it all leads to a learning experience.

AmI technologies have the advantage of being programmed to purposely deal with unpredictable behaviours while ensuring to have the adequate knowledge base to address all perceivable situations that the AmI developers have taken into consideration. What if some other unpredictable behaviour occurs that the underlying system was not expecting? AmI designers can factor in just those behaviours they want to monitor as well as any contextual situations they plan to react to. Any other events, unpredictable as they may be, that are of no interest or of no importance to the current educational situation can be simply intentionally not detected and ignored.

3.2.5 Publicness

The pressure exerted on students when feeling exposed within a classroom is so real that they feel overwhelmed with all the public attention they attract even if only within the boundaries of the same classroom. Speaking out in class, giving a presentation in front of peers, receiving feedback or scorned by the teacher, as well as being made fun of in front of all the class is a challenging situation for a lot of learners as the public exposure is considered a treat to the safety of the self and the shelter of the home environment. Every individual learner is visible and exposed to all the others in class as everyone is witnessing everyone else including the educator. The educator above all is continuously scrutinised by the learners as well as by the parents and the educational institution. Whatever the educator says, does, reacts to and performs are highly subjective to the interpretation and assessment of all. Lortie [11] justly points out that "Teachers act in fishbowls; each child normally can see how the others are treated" (p. 70).

Within an AmI environment the publicness is not reduced in any way but potentially echoed further and stronger as the classroom technology continuously and relentlessly captures the occupants' activities, including those that might have gone unnoticed or those that would have potentially been uneventful. This may sound undesirable or excessive to some educators or educational institutions, however on the other hand, this same enhanced feature may have been an intentional pedagogical tool to assist or even alleviate this specific educational process. The classroom situational circumstances and the specific academic requirement provide a unique context whereby AmI can be supportive or not, in which case the educator should have the option of disabling it.

3.2.6 History

Just as the AmI technology complemented, or even more transformed, the previous five different features of a classroom, the accumulating history of the classroom is eventually positively affected and transformed in a number of aspects. The historical feature of a classroom refers to the collective activities, routines, norms, together with amassed sets of experiences of all the learners and the educator/s within a specific classroom during a particular academic year. This historical record of a class [12] provides the underpinning narrative that is required to direct the same classroom occupiers seek and require to conduct their actions and behaviours for the rest of the academic year.

Will AmI be adopted as another variable within the classroom and seamlessly form part of the chronicle that will guide the educational process? Similar to other technologies that in the past were portrayed as disruptive and non-traditional, AmI within the classroom will provide a different and enriched experience that will not only become accepted, but eventually indispensable as it weaves itself as a necessary teaching aid to optimise the educational process.

3.3 Connectivism Learning Theory

The Connectivism learning theory that was proposed in 2005 by Siemens [13] and Downes [14] is frequently associated with the use of social networks for educational purposes as it justifies how learners employ networked resources, as potentially those within an AmI classroom, to form connections and links to learn and share knowledge and ideas. Termed as the learning theory for the digital age it has been extensively adopted as a network theory for teaching and learning in a connected classroom environment [15]. The social aspect of an AmI classroom can be supported and substantiated by the connectivism learning theory delivering education relevance from other application areas where the theory has been thoroughly researched and investigated in relation to its academic relevance but most of all to social network and tools to develop novel and effective learning processes [16]. This learning theory has been assimilated to social constructivism within the digital age by Kop and Hill

[17] as they argue that students in today's reality are independently able to develop educational processes from their surrounding environment which also includes their peers and the educator as a facilitator.

This brings into perspective the relevance of the connectivism learning theory to Ambient Intelligence within the class as it incorporates the fruitful use of networked resources with the academic importance of social connections between the learners. What George Siemens and Stephen Downes foresaw was the social role within the context of education as learners interact amongst themselves within a healthy environment that generates resource sharing, knowledge generation, and collective learning. The function of social networks within the education realm, as argued by numerous connectivism researchers [18] is that such an environment encourages engagement and fosters motivation amongst learners. Junco et al. [19] conclude that through the process of synchronous posting, contributing and sharing of information, student participation within the educational process exceeded that of a traditional educational environment. Another study [20] verified the high correlations that other researchers [21] had shown to exist between academic use of social media within a connected environment and learner engagement, motivation and academic accomplishment. Bell [15] also makes the case that connected learning environments positively influence and enhance the educational process from both the aspects of teaching and learning.

Pettenati and Cigognini [16] propose four stages of learning experience grounded within the connectivism learning theory. The authors argue that these stages can be employed to model, design and develop learning activities and academic environments similar to AmI scenarios.

i The first stage involves *awareness and receptivity* in the first instance, whereby learners experience challenges to understand and handle the amount of knowledge available that the environment can provide them. They need to appreciate its value and able to take full advantage by employing it to their benefit.

ii This can be performed through the second stage that is related to *connection forming and selection filtering*. Learners will employ tools and understanding to form their own learning networks with a clear understanding of which sources and connections are most beneficial to their academic needs.

iii The next stage involves *contribution and involvement* as students start to play an important role within the networked environment by actively participating, collaborating and transforming themselves into a source of information.

iv Finally, the fourth stage refers to *reflection and metacognition* whereby learners have to think and allow all that occurred in the previous three stages to sink in. This might lead to the establishment of new links, as well as inception of new ones as students reflect, assess and evaluate previous interactions and experiences.

The connectivism learning theory has enabled and justified the academic relevance not just of the use social media and Web 2.0 applications but has highlighted the educational benefits that can be extracted from the social interactions of learners. An

AmI classroom will tend to augment and magnify such social interactions which in turn generate further networking and a healthier educational environment. The extent of how much a smart educational environment is grounded around the connectivism learning theory needs to be investigated as part of the social aspect that is expected to develop within an AmI classroom.

3.4 Related Work

The literature related to ambient intelligence within smart classrooms is mainly focussed on the technological aspect, partly on the educational aspect, but barely any mention regarding the social aspect. However, a number of educational researchers have contributed to the social dimension that can shed light on the AmI classroom proposal and proof-of-concept. The following documented research initiatives have a common theme of investigating the social influences that have some kind of effect on the classroom environment and learning in general. Conclusions drawn and recommendations made will further assist in providing implications of the social aspect to the AmI classroom in the next section.

Creemers and Tillema [4] edited an entire journal issue more than thirty years ago regarding the specific aspect of social-emotional factors within the classroom. The editors document numerous studies that in their opinion classroom research uncovers crucial factors and variables related to the social aspect within the learning environment that had been neglected. They conclude that within a classroom environment three issues are of great importance, namely:

- i *Classroom management and dynamics* within a social aspect are highly dependable on the behaviour of educators;
- ii *Effective instructional behaviour* is instrumental within a classroom social environment;
- iii *Classroom processes* are decidedly conditioned by the social relationships between learners themselves as well as with the educators.

Ryan and Patrick [22] contributed numerous research findings related to learners' motivation and engagement levels as indicators of the classroom social environment. The authors argue that the perceptions of learners within a classroom significantly enhanced these indicators especially within a higher-order classroom social environment. Along the years the same authors [23] identified four distinct dimensions within a classroom social environment that justify the boost in motivation and engagement of learners, namely:

a. *Teacher Support* has already been identified as indispensable and essential, yet in this context it has been highlighted as a primary dimension within a classroom social environment. Educators plays a decisive role within the social group as learners look up to them and seek their support giving a lot of value to the perceived respectable relationship between them. Numerous researchers [24–27] have reported that supportive educators provide learners with achievement motivation as well as elevated levels of interest and enjoyment within the classroom environment. Furthermore, learners experience a positive academic self-concept [28] and good prospects of accomplishment [24] as a direct result of the fruitful support of educators.

b. *Promoting Interaction* amongst learners during classroom sessions, group tasks, informal peer assistance and during leisure periods helps create a healthy social setting especially if the classroom arrangement encourages it. An environment that supports and stimulates learners to engage with each other is inductive to a beneficial and academically advantageous social setting. Researchers [29, 30] have reported an elevated learner efficacy to learn and accomplish tasks due to the accessibility of resources, ideas and different points of view. Furthermore, other documented research [31] suggests that a strong social setting within a classroom fosters an increased propensity for taking into consideration other learners' standpoints, consider different options, be reflectively active, ponder about alternatives, as well as providing learners with excellent possibilities to justify their own position while being open to that of others.

c. *Promoting Mutual Respect* is the highest prosocial attribute that any healthy community embraces and practices. A cooperative and respectful perception within a classroom contributes to a positive feeling amongst learners and educators that engender a constructive psychological influence like safety, easiness, comfort, and a subdued anxiety. Some researchers [32, 33] claim that some of this anxiety within an uncomfortable social setting creates stressed learners that are prone to make mistakes, reduced effort and strategy to engage in academic work, and a rise in non-academic distractions that only help in diminishing learners' cognitive capacities due to an overloaded working memory. On the contrary, a classroom social environment that focusses on respect propagates a positive communication atmosphere amongst learners themselves as well as with educators providing an efficaciously good feeling about their social relationships.

d. *Promoting Performance Goals* provides a particular competitive focus that even though it is a social process as it involves all participants, it is not the best exercise to promote collaboration, cooperation and social bonding. Educational researchers are in disarray about this aspect of the classroom social environment as some [34] argue that goal theory practices are detrimental to the educational process. Additionally, some research [35] shows that educators promoting performance goals could have a negative effect on some of the learners motivation and academic efficacy while undermining harmonious social relations within the same classroom.

Becker [36] argues that social influences within the classroom contribute to the learning process through inquiry-oriented techniques that positively reflect on normative aspects of social interaction. The author makes extensive reference and use of social norms that were adapted from previous work [37] and that involve routine social interactions within a community. A classroom is considered a social setting and all forms of group interaction that occur or are encouraged by the educator are deemed to be good exemplars of social norms. Numerous studies [38, 39] have employed these methodologies to investigate the set norms of a microculture within a classroom. Becker employs four social norms that all refer to the general expectations for learners to participate in a particular classroom environment. Namely:

- Instructor validating student responses;
- Learners making sense of reasoning put forward by their peers;
- Group of learners negotiating a consensus;
- Group of learners negotiating the meaning of terminology, conventions and symbols.

Stewart [40] also investigated the classroom social environment through the perspective of the learners' perceptions in regards to their motivation and engagement. The author concluded that the social aspect had an impact on the learners' adjustment as they settled from one education institution to another. Such findings corroborate previous findings [41, 42] that documented how learners not only adjusted quickly and effectively, but the classroom environment provided the learners with the ideal opportunities to improve their educational and social skills.

Hendrickx et al. [43] investigated the social dynamics of the classroom as they take into consideration how the peer ecology evolves through interaction with the educator. The authors, similar to numerous other researchers [44, 45], consider the social environment where learners' interact together as one of the main tenets of learners' social development. Over and above this, the educator is considered an essential and significant catalyst in affecting the nature of the peer ecology within the classroom setting. This research concludes with a number of recommendations related to the social aspect of a classroom, namely:

- Educators are crucial in supporting the peer ecology within a class as it characterises the social dynamics between learners;
- Problematic learners require more attention from the educator and within a delicate social environment it would be much more beneficial to the peer ecology to reprimand in private and provide supportive comments in public/class;
- Social dynamics and student development are highly correlated and crucial to the fruitful accomplishment of the classroom social/emotional environment.

3.5 Implications to the AmI Classroom

Following the numerous revelations identified in the previous section the implications that these related research initiatives have towards the AmI classroom are valuable especially when the requirements are drawn further on in Chap. 6. A common theme that emerged was the need for the classroom social environment to impart a positive ambiance in which learners and educator harmoniously work together. This is not only beneficial to the classroom smooth running but also creates a peer ecology that constructively provides a nurturing social environment to the learners' character formation. Another generic premise that has already been established is the importance and indispensability of the educator within the classroom. Numerous related works have shown that the educator is a role model, supports the peer ecology, sets the social norms, promotes mutual respect, and is instrumental in the classroom management and dynamics. The educator cannot be replaced with no amount of technology or artificially intelligent software as the social aspect of a classroom fully justifies and necessitates the human factor. Other implications to the AmI classroom include:

- Promoting social interaction within the AmI classroom can be achieved through the setting up of group tasks that learners have to collaborate together to accomplish. The classroom will provide the adequate space together with the online social collaboration learning environment;
- Another strategy to encourage learners to embrace and contribute to a healthy peer ecology is to promote interesting and investigative tasks that compel the learners' sense of inquisition. The task could help build a sense of community as members work on separate parts that can be performed online or in class. Such activities promote communication, problem-solving, how to lead, how to form part of a team, and how to listen to others;
- Setting up classroom rules and norms help establish a modus operandi that learners can follow and that they usually seek to comply with as an expected social behaviour. Such an approach generates a safe and healthy social environment that is predictable with established boundaries while at the same time ideal to support a strong peer ecology;
- Establishing peer relationships is essential within a classroom social environment and thereby it is of essence that introvert learners are provided assistance and ample opportunity to rectify such a situation. The AmI classroom underlying system should easily figure out which learners require attention and duly notify the educator;
- Group and class meetings provide ideal settings to bring the social aspect in practice as the classroom setting itself supports and facilitates such activities. Use of anonymous electronic boards can be employed to provide all learners the opportunity and the safety to contribute to the discussion as well as respect the opinions and ideas of others;

- Personalisation helps learners feel special and unique, thereby automatic identification can facilitate such a process as it nurtures positive social relationships. Educators, even through software assistance, can customise the attention given to each individual learner as user profiles are generated and employed;
- Providing a sense of community by ensuring that each learner is given regular attention either through periodic activities that focus on whatever each learner decides to talk, show or inform the class about. The classroom setting should provide an adequate space for such activities that embolden a communal feeling in a way that learners belong to a social group.

3.6 Conclusion

The contribution of the social aspect to the AmI classroom has been shown to be indispensable as this chapter drew parallels with traditional classroom settings and revealed the extent of the social experienced in classroom. The chapter started out with the human aspect of the classroom as a number of characteristics were expanded to ensure that each dimensional aspect of the classroom is scrutinised. This led to the adopted learning theory that supports the social aspect within an educational context. The Connectivism learning theory was expounded and justified as it was put into context of the AmI classroom especially considering there is a strong element of networked learners as will be detailed in the technological aspect. Finally, a number of related works were presented and discussed providing ample food for thought as listed in the last section dedicated to the implication of the social aspect to the AmI classroom. One of the most important implication is that the educator is part and parcel of the AmI classroom setting that helps ensure the successful realisation of the other implications like a healthy peer ecology, a functional community setting, a safe environment, and other dynamics involved that all form part of a well-planned and successful learning environment. To achieve such a goal the project will obviously also require the contributions of the two other aspects that will now follow in the next two chapters.

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Chapter 4
Technological Aspect

Technology is just a tool.
In terms of getting the kids
working together and motivating them,
the teacher is the most important.

Bill Gates

4.1 Introduction

The second dimension of the ambient intelligent classroom is the technological aspect that follows the social aspect discussed in the previous chapter and precedes the educational aspect in the next chapter. The case for the three dimensions was made at the end of Chap. 2 when the rationale for the classroom within an AmI context was presented and justified. The inclusion of technology within an educational setting is highly researched, widely practiced and frequently documented within the education research community. The application of ambient intelligence to a classroom setting offers novel and intrinsically distinctive technological outcomes that require meticulous investigation and thorough analysis. In this chapter the role of technology within the educational domain is presented to set the scene for a deeper analysis of the technological aspect or dimension of the proposed AmI classroom. Additionally, the integration and use of AI techniques in the form of machine learning functionality introduces a supplementary layer of technology as part of the same AmI environment. The use of machine learning techniques, grounded upon another learning theory, create a perfect fit within the proposed academic framework to accurately and systematically position the AmI technology within a pedagogical neutral environment. The chapter also looks into established technical requirements that highlight best practices that the middleware within the AmI classroom ought to abide to. Numerous AmI projects that have mainly focussed on technology over the years are also presented and put into context as they shed light on the adoption of the

M. Montebello, *The Ambient Intelligent Classroom*, Studies in Computational Intelligence 840, https://doi.org/10.1007/978-3-030-21882-9_4

same technologies. Finally, the chapter closes with the implications of all the issues that have been covered through the chapter in relation to this particular technological dimension of the proposed AmI classroom as we prepare to investigate the third and final dimension related to the educational aspect.

4.2 Technology in Education

The use of technology as a teaching and learning aid has been recorded ever since some kind of a formal educational process has been planned and practised. Educational institutions have throughout the years accepted and adopted a plethora of technological tools, instruments, gadgets and devices, apart from software packages, games, and applications. Educators and schools adopt all kind of commercially available resources to facilitate the teaching process and ensure that learners are provided with the best possible medium to achieve their potential. Industries were quick to take advantage as they realised from a very early stage that the education domain is a good source of revenue. Commercial entities rapidly and wisely directed their attentions, marketing campaigns and sales pitches to swiftly profit from such a potential. Education and training within industry also provided scope for technological application as domains like automotive [1], aeronautics [2], and military [3, 4]. Amongst the adopted technologies employed as teaching/learning aids one can certainly point out the use of computers that infiltrated the classroom as soon as they hit the market. Individual educators together with educational institutions welcomed the flexibility, speed and suitability of these electronic devices as part of the learning process [5]. Educational games and an associated industry took off at even a faster pace as the allure of this medium played a crucial role in enhancing the motivational and engagement levels of school children [6].

The impact of technology within the class has also had a major impact on the educators and the pedagogies they employ as they seek to optimise such methodologies. Departments of education around the civilised world seek to adopt new technologies and encourage educators through in-service training, finance resources, adapted syllabi to ensure that the technologies employed assist and facilitate the educational process. The American education technology plan [7] points out that technology positively transforms formal and informal pedagogies in a number of ways. The report lists a number of ways of how technology-enhanced learning embellishes higher education, namely:

i. Technology enables students to access learning opportunities apart from the traditional barriers of time and place;
ii. Technology lets students access learning opportunities outside of formal higher education institutions, such as at their workplace or in community settings;

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

iv. Technology enables enhanced learning experiences through blended learning models;

v. Technology supports students in their learning based on individual academic and non-academic needs through personalisation;

vi. Technology can ensure that students with disabilities participate in and benefit from educational programs and activities.

(p. 17)

The use of technology provides novel and diverse educational affordances that potentially offer alternate pedagogical alternatives that would otherwise would not be possible. Such opportunities create prospective channels of comprehension that naturally increase the chances of a successful educational process. The availability of the same technology outside a classroom or school environment is also an additional avenue for the educational process, even though informal, to happen and successfully reach its pedagogical goals. Such availability, irrespective of geographical location, empowers learners even more and distinctively marks a considerable improvement in technological learning aids over other traditional ones. The multimodality provided by the miscellaneous technologies supply a rich source of alternate media that accommodate the unique learning styles and preferences of individual students. Customisation does not only accommodate individual learner needs but addresses dynamic issues as well as evolving interests that traditional and static resources and techniques are incapable of ever achieving. The added value and elevated functionality that technology is able to offer and afford if enabled and applied wisely can assist challenged learners in novel ways that were not even possible before. For all these reasons, and more, the adoption and assistance of technology in education is considered to be a supporting asset and a beneficial aid when employed within a planned and meticulously thought-out pedagogical process. However, this does not come without its challenges. Higher education institutions are encountering numerous challenges to integrate formal and informal learning while raising and maintaining adequate levels of digital literacies of their own learners [8]. These challenges are further magnified as other issues tend to exacerbate what otherwise, under normal circumstances, would be a challenge for the educator to address. The learners' background, their family' s financial situation, digital equity and knowledge obsolescence are just a few examples of how the use of technology can highlight and proliferate matters that have a strong disposition to influence and characterise the educational process.

The use of technology within an AmI classroom has another major advantage due to the numerous sensory devices strategically planned and arranged. Continuous collection of learner data and educationally interesting generated information contributes to a massive volume of data that can efficiently be employed towards learning analytics. Such analytics have generated academic interest and numerous researchers

[9–11] have endorsed the value and investigated the potential of fruitfully employing learning analytics to further enhance and strengthen the use of technology. Sensors and software applications can continuously collect learners' interaction with multiple devices, educational software, user interfaces and directly through learner provided feedback and artefacts. Before closing this section and delving into the theoretical learning theory associated with the use of technology in education and personalisation, it is worth underlining the four threshold concepts that Meyer and Land [12] propose to justify the use of technology in education.

a. The authors characterise the application of a novel technology within a learning environment as *transformational* as it introduces a novel and exciting medium. The learner-centric approach that supports the adoption of multimodal content instils a game-changing rationale and encourages networking functionalities between peers and educators. In this regard educators are considered facilitators rather than knowledge providers as they expedite and enable the effective use of the technology;

b. Learners and educators who are inclined to and receptive to the adoption of new technologies tend to be open to new creative possibilities and increased productivity. The *integrative* threshold concept of emerging technologies embolden students and teachers alike to courageously experiment and embrace change not only to create new content but also to adjust and refresh the environment as well as the tools they employ. This can only be achieved through deeper understanding of the educational process as to enable such integration with the changes induced by the use of the same emerging technologies and practices;

c. Meyer and Land consider the use of technology as *irreversible* due to its implicit characteristic of leading educators and learners out of their comfort zone and across threshold concepts. This is mainly due to the need and necessity to relearn, rethink different ways of doing tasks, re-conceptualise established beliefs and approaches, while abandoning obsolete practices and well-established methodologies;

d. Change is not desirable by all and potentially a source of stress and uneasiness for those who find comfort in routine, tried-and-tested procedures and practices. Technologies within an educational aspect are considered *troublesome* as they challenge the serenity and contentment of established techniques while introducing novel and substantive changes that are often considered as a threat to the vested interests of learners, instructors, and institutions. However, similar to any other change, the successful adoption of technology is highly dependent on the attitude adopted of embracing the challenge and seeking ways of taking full advantage rather than consider it disruptive and troublesome.

4.3 Adaptive Learning Theory

The technology aspect within the AmI classroom is not only the array of instrumentation, displays and sensors that are typically documented in similar research projects as will be mentioned in the next section. Another technological aspect that needs to be referred to in this book is the use of artificially intelligent techniques that employ machine learning technologies to generate learner profiles. The data collected through the physical type of technologies contribute to the learning analytics that provide the required input to the AI techniques. The outcome contributes to further adjust the environment, both physical and educational, to the specific learner, under the guidance of an educator. Adaptive learning, in the context of the AmI classroom, is meant as the process of employing learner profiling techniques in an attempt to tailor and adapt the entire learning experience to the specific and unique characteristics and needs of each learner [13]. Furthermore, the learning experience incorporates learning resources, educational content, experiences, feedback given and received, as well as the environment where the educational process is taking place. Intelligent Adaptive Learning (IAL) employs AI techniques and technologies from the computing research domain to process academic information to put together a profile for each learner and tailor the educational experience in the process. A white paper by Dreambox Learning [14] endorse and practice IAL within their products as they argue that this next generation technology immerses learners in modular learning environment similar to what is being proposed with the AmI classroom. The authors argue, as shown in Fig. 4.1, that three phenomena are converging for the first time ever, namely affordable and sophisticated devices, learning analytics, and learning trends, to truly and tangibly unleash IAL systems that are affordable real-time virtual personal tutors.

IAL is capable of capturing every learner action, within the context of sound learning theory, and employ intelligent techniques to assist and guide learners in

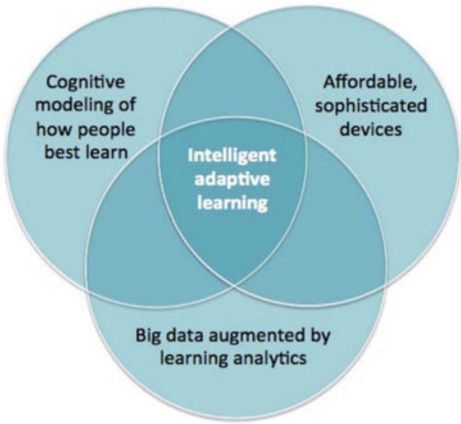


Fig. 4.1 Phenomenon converging in support of intelligent adaptive learning [14]

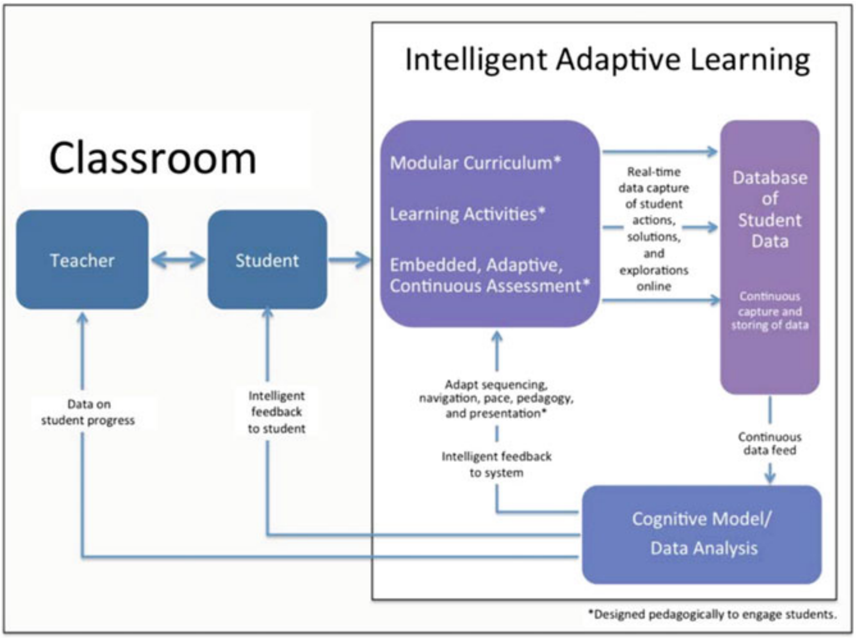


Fig. 4.2 Classroom environment leveraging an intelligent adaptive learning system [14]

their individual learning experience. The classroom environment shown in Fig. 4.2 can potentially leverage an IAL system by providing formative and summative information from data collected during the interaction of each learner. In this way every learner can be guided accordingly with a unique academic plan, personal learning pace, and individual needs based on current understandings and evolving interests.

The educational research community refer to the adaptive learning theory as the theory that subscribes to the notion of personalisation and an ideology that customisation is possible through the use of technology [15]. The technology aspect of the AmI classroom is grounded within this learning theory that has been strongly supported by educational psychologists [16] and endorsed by learning theorists [17]. Adaptive learning acknowledges the individual traits and characteristics of every learner within an educational process [18] as each person has a unique approach and pace. The reason why personalisation is required within the AmI classroom is mainly because it has proved to be highly effective in raising motivational levels [19], but also because it provides a distinctive satisfaction [20] to the entire learning process. Higher education institutions have been documented [21] to promote personalisation due to the exceptional benefits that learners enjoy which in turn contribute to the overall success of the same institutions. Oxman and Wong [21] clearly distinguish between three models upon which an adaptive learning ideology is to be based and deployed. The necessity of the three models, *learner*, *content*, and *instruction*, to support an adaptive learning space are also required as part of the AmI classroom whereby the technological dimension brings them all together. The learner is the first of the three models as the other two are dependent on the profile generated and refined through continuous interaction with the adaptive environment. The profile encompasses data that has been collected through the various sensors and learning analytics in time to be processed and employed reflecting a real representation of each individual learner. The second model ensures that the content is adequately and purposely structured in an efficient way to be easily accessed, indexed, adapted, compiled, and eventually presented to the learner. Finally, the third instructional model for a personalised learning environment brings the other two models together to ensure that the content is designed in an advantageous and pedagogically sound way addressed uniquely to the specific profile of the learner. The processes and strategies employed are also subject to customisation [22] as adaptation of instructional methodologies and pedagogies potentially contribute to further characterise the academic needs and interests of learners. On the same lines other researchers [23] argue in favour of the benefits of personalisation especially when the learner profile is not static but actively evolving around the fluid learner interests and shifting needs, as well as irregular academic requirements that are highly subjective to the specific learner. Research projects like the one reported by Morales, Garrido and Serina [24] put the theory to the test in an empirical study whereby an adaptable e-learning environment proved to improve effectiveness. Similar studies [25–27] that employed a variety of artificially intelligent technologies also concluded that personalised learning techniques are highly effective and that they enabled sound lifelong learning. In all cases the specific profile of a learner is being generated in some away as it encapsulates what a personal educator would need to know about the learner in order to academically guide in the most fruitful way [28]. The learner profile has not only been reported to adapt content, feedback and learning experience, but has been also successfully documented to address specific learning difficulties that learners encountered [29], as well as empowering learners psychologically when given distinctive personal attention making them feel much more inspired, accomplished, emboldened and determined to pursue their education [30].

4.4 Related Work

In this section we investigate in some detail a few research projects that have employed technology within an educational environment, but specifically these particular projects focussed on the technological aspect of an ambient intelligent environment. Their relevance to the topic at hand is not just imperatively relevant but essential to apprehend how others attempted to develop and test an AmI classroom. It will become clear as each project is highlighted that the technology was at the centre of the research and occasional it was the only thing the researchers focussed on. Additionally, the heterogeneity of these projects does not permit a consistent comparative study to be performed. Nevertheless, previous studies enable future research to follow their recommendations, avoid their concerns, and get inspired from their outcomes.

4.4.1 *The 'Intelligent Classroom'*

This project [31] at McGill University in USA had three distinctive objectives which brought together a team of engineers, educators and learners to develop an automated system to capture and store in-class content that included hand-written notes during class, apart from audio, video and other media employed as teaching aids. The functional system, shown in Fig. 4.3, was purposely deployed and tested with engineering students and professors to perform these tasks:

i. To automate the educator' s task when employing teaching aids in class through different media. A number of control structures were programmed to adjust the lighting, activate particular projectors, and power-up the respective display screens. A typical example would be when a professor logs-in onto the university network and the background system has been programmed to take this as a trigger to activate a series of events to appropriately prepare the lecture room to use the audio-visual medium. This task is usually performed by a technical person or the professor who ideally should be focusing on the academic aspect rather than the technology employed;

ii. To maintain an indexed database of all the recorded sessions together with the respective educational materials employed and any lecture notes that have been captured during the same session. Such an electronic pool of class sessions enables students to access any session to annotate their own notes, revise, review any gaps, as well as interact offline with the professor regarding queries arising

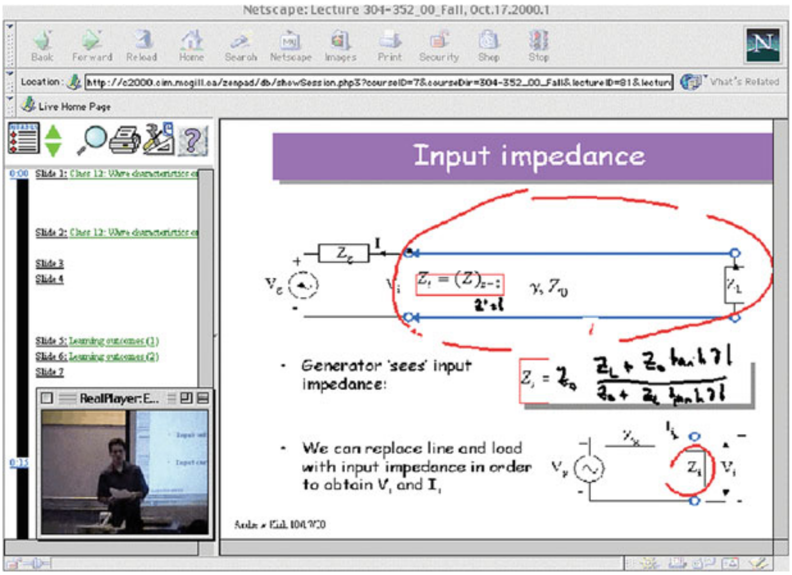


Fig. 4.3 The 'Intelligent Classroom' interface [31]

from the session viewed. The university network, similar to a VLE, was used as a medium to ensure that the resources were accessible by all involved;

iii. To allow students to interact with the same underlying system in order to perform tasks that are usually available over a VLE. A typical example would be the submission of assignments that need to be handed-in for assessment.

Having gone through these three objectives delivered by the 'Intelligent Classroom' and documented by Winer and Cooperstock [31] it transpires that the whole setup is not really intelligent in the sense that without it the users would otherwise require human intelligence. The authors recognise this fact and state the intelligence they refer to is not attributed to the classroom but to the ability of the instructor to employ the classroom intelligently by allowing the underlying system to deal with the technology while s/he focuses solely on the academic and teaching components.

4.4.2 iClass

The iClass project [32] is a better attempt at an AmI class developed at the German University in Cairo, Egypt. The project makes extensive use of available technologies

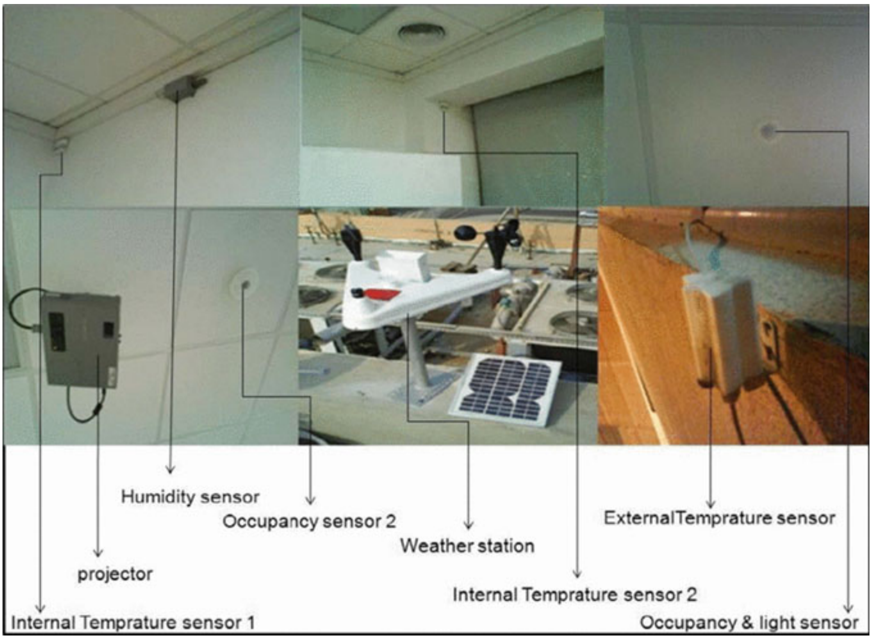


Fig. 4.4 The iClass sensors, weather station and multimedia video projector [32]

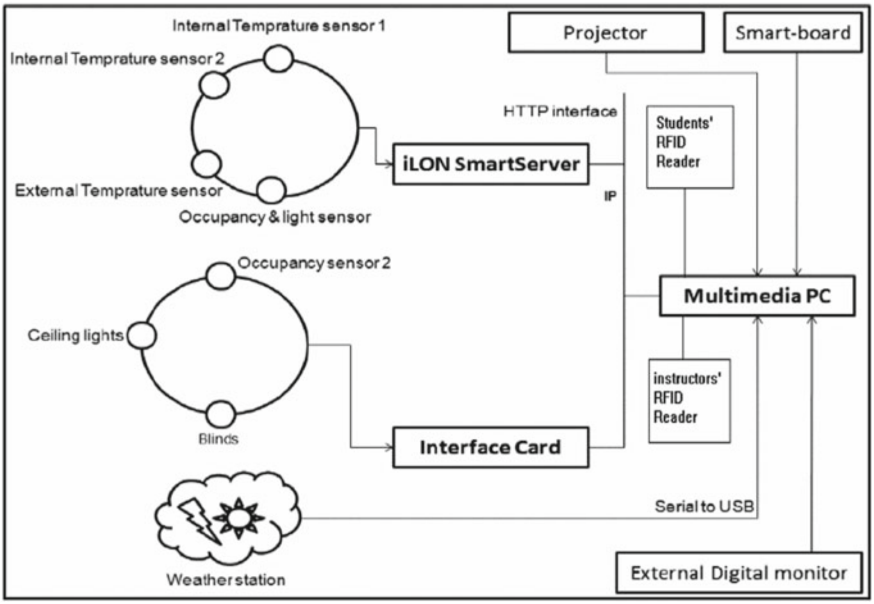


Fig. 4.5 The iClass network infrastructure [32]

but also combines additional features that include wireless communication, language support, and user profiles. The physical classroom itself, as shown in Fig. 4.4 has numerous embedded sensors and actuators, as well as a weather station and media projectors. These technologies are employed to control the different devices in the classroom amongst which are lighting, air conditioning, presentation devices, and monitors. Additionally, the iClass is characterised by three main components that are:

i. RFID technology (Radio Frequency IDs) is employed to keep a tracking record of persons within the classroom. Students and teachers carry RFID tags that allow respective readers to identify them and execute essential processes that otherwise take time and effort to perform [33]. This technology, as part of the iClass network (Fig. 4.5), can perform automatic class attendance as well as bring up the respective academic material associated with the teacher in class together with the course content for the class the present students are registered for. Figure 4.5 also shows how the different sensors within the classroom are networked with the display devices and the RFID setup;

ii. A basic speech interaction component that is made up of two sections. The first component is a simple speech recognition piece of software that enables the persons within the class to interact with iClass using a pre-defined grammar to perform standard tasks like controlling the light, adjusting the curtains, and regulating the air-conditioning unit. The second component involves the use of a fuzzy logic controller to capture the behaviour of users within established classroom states and eventually generate inferences to control future classroom environments based on past states. The intelligent system keeps refining itself as user behaviours evolve and environmental conditions change over time;

iii. User behaviour components are the third component upon which the iClass is based upon. Another fuzzy logic intelligent agent is employed to learn and adapt to basic learner behaviour through a simple generated profile. It does so by reproducing the behaviour of the learners as it automatically controls the environment. Additionally, it employs two types of adaptive behaviours to further refine its actions. If on the short term a user overrides a system action, this is perceived as an update to the stored rules. Alternatively, a long-term adaptation process triggers in when the learner' s behaviour evolves beyond a threshold limit from its norm, and the entire process of generating a user profile is required to be repeated.

The iClass project is slightly more elaborate than the previous project as it employs touches of intelligent behaviour especially in the third component related to user behaviour. However, the project was a one-off empirical study and tested for a short period leaving room for improvement and extensive testing.

4.4.3 ClassMATE

The third and final related work, classMATE [34], is an integrated architecture for pervasive computing environments that a number of researchers from the Foundation for Research and Technology in Greece and the University of Crete proposed and thoroughly tested. The idea started with the development of an augmented school desk [35], shown in Fig. 4.6, which brings together a number of technologies integrated within a classroom desk. The networked technologies included a processing unit, a screen for visuals, mini projectors, cameras, and infrared projectors together

Fig. 4.6 The classMATE in action [36]

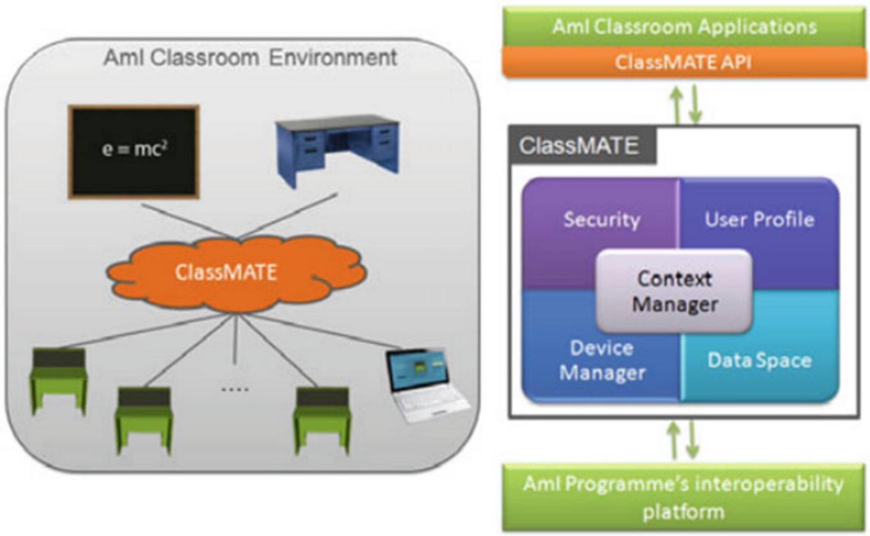


Fig. 4.7 The ClassMATE architecture [34]

with supporting software to enable a touch-screen and a smart-pen transmitter. This purposely designed school desk offers no intelligence in isolation, hence the same group of researchers combined it as part of the ClassMATE framework [36]. The architectural setup [37], shown in Fig. 4.7 is student-centric and planned within a context-aware classroom. All the operations are controlled by four core components that are coordinated by a fifth scheming component at a higher level.

The security service component is the first of the lower four core components and administers, while also supervising, all necessary authorizations that users, devices and processes require. The second core component is the user profile component whose only task is to ensure that every user is uniquely catered for including any requests, processes and individual profile generated. The device manager is in charge of ensuring that the different devices, especially those integrated within the school desk, are being monitored and serviced accordingly to ensure the system is operating efficiently and without difficulties. The final of the four core components is the data space component which has the arduous task of keeping track of all the content being consumed, generated and stored within a centralised content repository. Such a delicate task is crucial for the overall success of classMATE as a number of data sources need to be monitored and maintained, namely, applications generated meta-data, user-generated data, all data related to classes, as well as the academic content itself. The data space component, together with the other three components, are over-looked by the context manager that coordinates their operations as soon as an activity or interaction is initiated by the learner. ClassMATE is controlled by the context manager which is continuously monitoring the input devices waiting to detect any operational requests, triggering-off a series of reasoning schemes that have been planned as part of workflows associated with the respective user-requested operation.

The combination of technologies within a context-aware environment implemented within classMATE provides a good scenario of how an AmI classroom can be realised. The focus is mainly on the technologies employed especially the augmented school desk, while the user profiling element and minor personalisation attempts are given a minor role within the system. Another issue that classMATE, similar to the previous two related systems, is that they are not grounded within established learning theories and thereby making it obvious that their focus is not on the academic aspect or the learner but on the technological aspect, which was the focus of this chapter.

4.5 Implications to the AmI Classroom

The research related to ambient intelligence within a classroom is clearly biased towards the technological aspect from a physical devices point of view. However, this is also the case with main stream literature that usually converges towards emerging technologies when focusing on AmI environments. Even the European Commission follows this trend as its advisory group on Ambient Intelligence emphasises the importance of the interfacing middleware components between the human factor and technology when presenting its recommendations on smart AmI environments. In a report [38], published by the European Information Society Technologies (IST), the crucial role of the middleware is highlighted and stressed upon. The reason for this is both technical and ethical. The successful interoperability between numerous devices needs to be highly coordinated and standardised as supported by other researchers [39]. On the other hand, the middleware has the delicate task to ethically and sensitively interact with human subjects. To such ends the AmI advisory group points out five specific requirements in regard to a reliable and robust middleware that have significant relevance and insightful implications to the physical aspect of the AmI classroom. The following subsections will delve into numerous implications of technology to the AmI classroom that include the above mentioned requirements but also issues related to technology integration [40] that can influence both the social and educational aspects.

4.5.1 Unobtrusive Hardware

The first technological requirement refers to the unobtrusive attribute of the hardware. Within the AmI classroom the sensors and devices communicate over a wireless network and therefore in no way will it interfere with the educational process. Even though the technological aspect is as important as the two other aspects it need not be seen or interfere in any way. The trend of miniaturised sensors and integrated equipment further support this requirement and ideally get absorbed and disappear within the environment as predicted by Weiser [41] quoted at the end of Sect. 2.1. The network of unobtrusive hardware within the AmI classroom forms part of the IoT scenario where low-powered devices are collaboratively and complementary generating much needed data for the learning analytics processes to consume and accurately perform their intended tasks.

4.5.2 Seamless Communication Infrastructure

The wireless IoT network mentioned in the previous requirement has a necessity to be seamless to ensure that all the devices and associated applications can communicate and interoperate in an effective and functional way. The smooth and continuous communication is required within the AmI classroom as to ensure that data related to every individual student is passed on and processed in real-time to contribute to the immediate academic personalisation process. Other network attributes that are expected for a successful concept implementation will be expanded in the following technological requirements.

4.5.3 Distributed Device Network

One of such desirable network attributes is that it is distributed for the usual obvious reasons that it is much easier and effective to scale it up. Additionally, given there are numerous devices that need to be supported concurrently, it is much more secure when any of devices are down thereby not putting the AmI classroom network down or interfere with the functionality of the rest of the devices. A distributed network enables also the possibility that the different devices can enhance the performance levels through faster data transfer, combined processing power and augmented storage capacities.

4.5.4 Intuitive User Interface

The fourth requirement relates to a very important feature in the AmI classroom as the interface to the system, not necessarily visual, is intuitive, user-friendly and natural. Both learners and educators need to successfully communicate with the underlying system without any hitches as to cause any minor misunderstandings that will disrupt the learning process in any way. Devices, software agents and sensors will be required to interoperate automatically in an intelligent way without direct intervention from the users within a context-sensitive environment that enables multimodalities and machine-learning capabilities like pattern, speech and gesture recognition.

4.5.5 Dependable and Secure

This final technical requirement comes as no surprise as the network that has been referred to over and over again is required to be robust and highly dependable as the entire AmI system runs over it within the classroom. Educators, learners and school administrators will be putting their full trust, reputation, educational aspirations, and academic achievements in the performance of an artificially intelligent system that depends on the network. The trust in the AmI classroom itself depends on the network and therefore users tend to trust a system that proves itself to be successful, reliable, safe, and robust over a period of time.

4.5.6 Learner Profile and the Educator

Learner profiling is also considered a technological aspect as far as the AmI classroom is concerned as it does not fall in either the social nor the educational aspects. Similar to the other technologies the requirements apply just as well, with the learner unaware that a respective model is being generated and continuously refined to assist the same learner. The success effects of employing user profiles and learning analytics help the learner to further trust the system and enjoy what the AmI classroom has to offer. Important to point out that the human educator is not just indispensable within this AmI classroom scenario but an essential factor to complement the technological outputs produced by the underlying system. The educator is required to assume different roles as the situation requires and as needed by the AmI classroom itself. In some instances the educator is simply required to supervise while learners follow a recommended learning flow proposed by the system, while in some other instance the educator is required to coordinate or facilitate a process that learners need assistance with. Educators might also need to justify or rectify a particular outcome as they are fully cognizant of what is going on and are prepared to intervene should the system fail to perform its task. This might involve some technical fine-tuning, trouble-shooting and sorting out the occasional inconsistencies and software glitches. The educator plays an important role within the AmI classroom not just from a technical point of view, but also from a human touch as studies [42] have shown over and over that a classrooms environment is positively conditioned by the benchmarks and ethics of the educator. Social, emotional and relationship skills are essential as any other topic taught in class and transmitted by the human educator to all the learners on a daily basis through natural and instinctive interactions that defines us as emotional and social beings within a nurturing atmosphere [43].

4.5.7 Compatibility and Scope

The diffusion of a technological innovation has been investigated by researchers [44] who refer to the notion of compatibility between the design of the model employed to integrate the new technology and the existent practices in schools. This is an important consideration to keep in mind when designing an AmI classroom as the learners and the educator within the targeted environment need to be kept in mind without disrupting or drastically modify the valid processes that have already been established. Abiding by such a notion also increases the chances that the AmI classroom is received well, acknowledged and adopted by the same people who will be using it and taking advantage of the results. This was the case with a similar technological project [45] in education that analysed the level of usage of technology through a series of escalating intensities from enhancement to transformation. The researchers identify four stages starting from Substitution, to Augmentation, Modification and finally Redefinition. The model is quite straight forward as it promotes rigorous planning when developing models similar to the AmI classroom to ensure that they are highly compatible with the learners and educator as that would increase their successful chances of deployment and acceptance. This SAMR model puts into context how technology in education can progress from a straight forward and easy substitution which commonly occurs, to a much more difficult and intricate redefinition of how technology is employed whereby it empowers users to create new tasks that were previously inconceivable. This sheds important light on how the AmI classroom can be integrated in stages while being slowly phased in ensuring it is fully compatible with the existing processes and tasks. The AmI classroom needs to be technologically compatible so it will succeed as a model as both learners and educators feel good about it and approve it.

In line with compatibility issues is the concept of scope of performing such a technological integration. Researchers [46, 47] have queried and investigated the nature of several technologies as they got integrated within the educational process. Their main concern was whether the scope of a technology being pushed was to address a fundamental problem related to education from a global scope, or from a local scope addressing specific procedural protocols and modus operandi from higher authorities. The former scoping applies to the AmI classroom as it seeks to bring about fundamental educational changes through effective technology integration at a theoretical and philosophical level. Such scoping is suitable as it could identify and resolve potentially issues in educational theory as archetypal teaching assumptions and conventional teaching structures are reconsidered and explored. The AmI classroom is a typical example of a technological integration that exhibit global scope as it provides an ideal environment to rethink the traditional classroom within our educational institutions.

4.5.8 Fruitfulness and Role

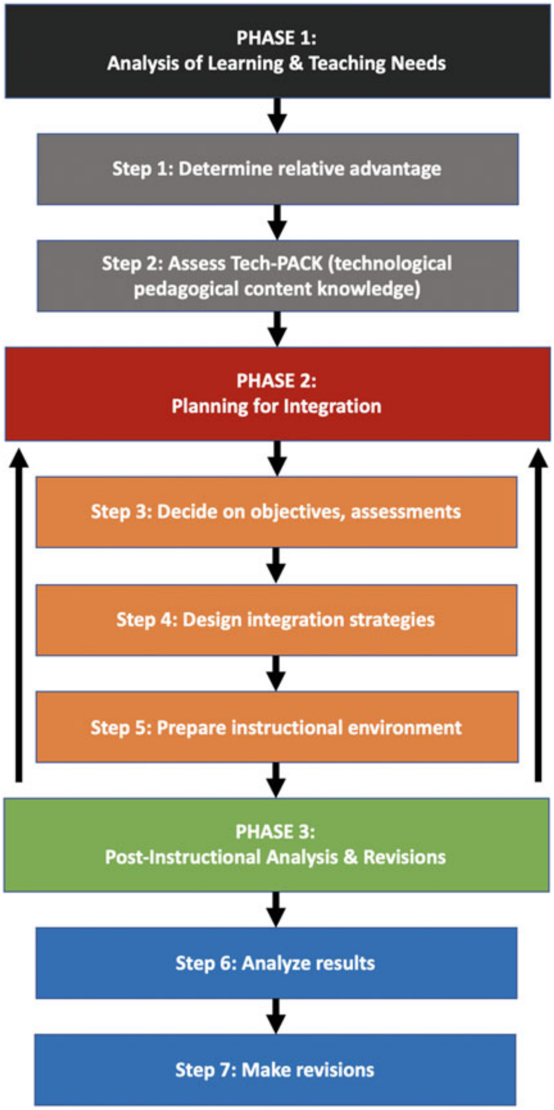
Is the AmI classroom fruitful of new research findings and valid educational contributions grounded in sound learning theories? Numerous researchers including Kuhn [46] argue that the fruitfulness of a conceptual model or a theoretical system should unleash novel and beneficial phenomena or previously disregarded relationships/setups amongst already established phenomena. Adopting a technology integration model like the AmI classroom because it is considered fruitful when a positive outcome is predicted and numerous advantageous consequences ensue. This was the case for the Technological Pedagogical Content Knowledge (TPCK) [48, 49] which highlights the necessity of three domains of knowledge, namely, technology, pedagogy, and content, in order to successful and fruitfully integrate technology within education. The model was employed by numerous researchers [50–52] across different disciplines simply because it was perceived as fruitful and beneficial to their work that involved technology integration. This simply goes to show that once a proposed technology integration model is tried and tested either across a number of disciplines or within a single discipline, then it is much easier to be adopted.

This brings into perspective the intended role of the technology to be integrated. Is the AmI classroom employing technology as a means to an end or as an end itself? It is imperative that technology integration is delimited by having a firm apprehension of how the integration process is bound to significantly and positively affect the learning environment. This is the case of another technology integration model called Universal Design for Learning (UDL) that the Center for Applied Special Technology in Massachusetts, USA, advocates and promotes in an effort to comprehensively address the interest and needs of learners by primarily focusing on their strengths and unique characteristics. The model [53] promotes the use of technology to upkeep quality education and full access. UDL is centered around three principles of how technology ought to be employed. The premise is that through technology it is possible to curtail any kind of educational impediment thereby optimizing learning outcomes. The role of technology in this case is to provide affordances to deliver a variety of representation, action & expression, and engagement. Same applies to the AmI classroom, with an intended role to employ and integrate technology as a means to provide quality education and enhance student outcome through personalisation and real-time learning analytics.

4.5.9 Student Outcome and Clarity

The student outcomes that the AmI classroom aims to enrich falls within the scope of the technology integration objectives. However, such objectives are not always set to high priority when a technology integration model is proposed. The Technology Integration Planning model (TIP) is purposely intended to ensure that technology integration is student-centric focusing on enriching learner outcome. The model [54]

Fig. 4.8 Technology Integration Planning (TIP) model [54]



whose sole purpose is to generate distinctive academic impressions stipulates that student outcomes need to be taken into consideration well ahead of the technology integration process. It asserts this through seven phases based on the established instructional design theory that are divided into three phases of activities (Fig. 4.8).

The first phase starts off the analysis of learning and teaching needs through two activities, which leads to the second phase that is intended to plan for integration. Following the three activities in the second phase, the third phase focuses on post-instructional analysis and revisions which incorporate an additional two activities.

The first phase is only executed at the beginning while the second and third phases recursively cycle in an effort to improve learning, sort issues, and optimise efficiencies. The strategy adopted by the AmI classroom is to focus on the learner and the social aspect before the technological aspect and adopt any of the technologies. The TIP model further proposes an appraisal to assess whether the student outcomes have been properly addressed, with a subsequent fine-tuning process to remedy any predicaments.

The adoption of a technology integration model offers clear and precise indications on how to go about the prescribed procedures. However, this is not always the case as vague and unclear models tend to obstruct the integration process rather than facilitate it. The AmI classroom, as presented in Chap. 6, purposely adopts a clear and justified process of technology adoption while focusing on the learner within the class community together with the educator. In a similar manner the Replacement, Amplification, and Transformation (RAT) model of technology integration [55] focuses on the impact that the technology might have on the educational process, settings and outcomes. The simplicity and limited scope of this model is what makes it clear and easy to follow with three potential impact categories, namely, replacement, amplification, or transformation. These three mutually exclusive categories enable researchers to efficiently tackle issues in a quick and confident way across contexts. Such simplicity provides the desired clarity to reduce the confusing speculation and problematic complex analysis. The AmI classroom aims to adopt generalised standards as to provide straight forward and clear model structures to ensure that the technological aspect is easily implemented and evaluated across the classroom context.

4.6 Conclusion

In this chapter the use of technology has been thoroughly investigated within an educational setting with particular focus to the application of ambient intelligence within a classroom setting. A number of projects related to smart classrooms 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 were introduced as they also form an essential part of this particular technological aspect. Finally, a number of important implications were taken into consideration as they shed important light on the overall success of the AmI classroom. Having gone through a meticulous technological analysis as the second part of the three-dimensional model, the third and final element of the AmI classroom related to the educational aspect can now be addressed and examined in the next chapter.

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Chapter 5
Educational Aspect

The roots of education are bitter,
but the fruit is sweet.

Aristotle

5.1 Introduction

The third and final dimension of the proposed Ambient Intelligent (AmI)classroom relates to the education aspect and follows the social and technological aspects from the previous two chapters. The philosophical reasoning behind the AmI classroom rests equally on these three pillars that are not necessarily mutually exclusive, but to a certain extent already blend into each other within current classrooms. The AmI classroom pushes these borders further together with the help of AI techniques to further personalise and enhance the entire educational process. In this chapter the education rationale behind the AmI classroom will be further expanded as a reflexive pedagogical rationale is assumed through a novel educational model of new learning affordances. Additionally, innovative spatial considerations within the learning environment are analysed as they shed light on the educational experience within the classroom. This is followed by an exploration of how personal learning environments lend themselves and are employed within this educational setup to address the customisation needs of each learner account. The few research projects that addressed educational issues when proposing smart classrooms are explored, however, the literature leaves much to be desired. Finally, before closing the chapter, a thorough analysis of the educational implications to the AmI classroom are presented and discussed.

M. Montebello, *The Ambient Intelligent Classroom*, Studies in Computational Intelligence 840, https://doi.org/10.1007/978-3-030-21882-9_5

5.2 Learning Models

In Chap. 1 it was made clear that the educational aspect of this work is inspired by two lines of thought summed up in theoretical models by Nair and Fielding [1] and Cope and Kalantzis [2]. The models come together to provide a setting for both the educational environment and the educational affordances of the electronic medium. How will the AmI classroom actuate and put into action both models? What are the benefits of each model that can compatibly provide an educational added-value environment? The following subsections will provide a detailed insight into both models and how they eventually can fruitfully merge into a functional system.

5.2.1 New Learning Affordances

The first model put forward by Cope and Kalantzis [3], follows a reflexive pedagogy to the contrary of a didactic one as digital educational technologies enable the promotion of real changes in the education system. Their notion of e-learning ecologies brings into perspective how technology brought about a set of new learning affordances that have an impactful effect on learners [4]. They describe it as a kind of metaphor to apprehend and justify the learning environment as an ecosystem whereby learners are within a continuous and complex interaction with other learner as well as with the textual, discursive and spatial dynamics. The work by Cope and Kalantzis [5] identifies seven new learning affordances that the Internet and associated technologies enabled. The model is based on previous theoretical recommendations that Bloom [6] advocated on mastery learning and how learners can be encouraged to convey their best learning qualities through suitable educational processes. The authors developed an original online learning environment whose specific design properties are grounded within a reflexive pedagogical rationale.

The seven affordances, shown in Table 5.1, are the enablers of the reflexive pedagogy within a model that compared to the didactic pedagogy require the functionalities provided by digital technologies. Every affordance, that will be further elaborated in some detail, has been implemented within a working system called Scholar [2]. This online learning environment that embodies the proposed model puts into practice the seven affordances as will be expanded further in Sect. 5.2.3.

a. The *ubiquitous learning* affordance refers to the luxury and convenience of pursuing academic studies anywhere and anytime away from the classroom and unrestricted by timetables or schedules. This is possible not only thanks to the fact that one can be networked all the time and thereby has access to the educational material, but also to the accommodating education aspect that has evolved and adjusted to enable learners to be able to freely and unrestrained use educational content and engage in learning processes. Does this make the educator redundant? Not really as the educator is not only involved in the compilation and preparation of the academic material that learners can access, but particular aspects of the content still requires the assistance of

Table 5.1 Comparing Didactic and Reflexive Pedagogy

	Didactic pedagogy	Reflexive pedagogy
Spatio temporal dimension	Confined by the four walls of the classroom and the cells of the timetable	*Ubiquitous learning*: anywhere, anytime, anyhow
Epistemic dimension	The learner as knowledge consumer, passive knowledge acquisition, memorization	*Active knowledge making*: the learner-as-knowledge producer and discerning knowledge discoverer/ navigator
Discursive dimension	Academics literacies: traditional textbooks, student assignments and test	*Multimodal meaning*: new media texts, multimodal knowledge representations
Evaluative dimension	Emphasis on summative assessments and retrospective judgement that serve managerial purpose but are not immediately actionable	*Recursive feedback*: formative assessment, prospective and constructive feedback, learning analytics
Social dimension	The isolated learner, with a focus on individual cognition and memory	*Collaborative intelligence*: peer-to-peer, learning, sourcing social memory, using available knowledge tools appropriately
Cognitive dimension	Focus on facts to be remembered, theories to be correctly applied	*Metacognition*: thinking about thinking, critical self-reflection on knowledge processes and disciplinary practices
Comparative dimension	Homogenizing one-size-fits-all curriculum, standardized teaching and assessment	*Differentiated learning*: flexible, self- expressive, and adaptive learning, addressing each student according to his or her interests, self-identity, and needs

or the capability of a human educator. Some topical content or educational aspect cannot be taught through reading, watching a video clip, or listening to a webinar, but requires direct first-hand supervision and guidance. This is the reason why the indispensable educator is still required and essential within any classroom and educational process. The fact that educational materials are available 24/7 and accessible from any networked device increases the chances that learners have less barriers to education and more possibilities to pursue their studies. It also brings into perspective the expediency of having such opportunities where before they were bound by space and time [7]. This affordance is significantly momentous for those learners who were disadvantaged both with space, like remote and geographically challenged locations, and with time, as in full-time workers who are unable to attend classes during the day.

b. *Active Knowledge Making* refers to the ever-increasing possibilities mainly through technology that allows and enables learners to contribute and actively produce artefacts. The trend took off when Web2.0 technologies enabled users to transform their role from consumers to producers as social media gained popularity and prominence [8]. The availability of numerous freely available online tools that harness and promote sound digital pedagogies are fun and educational for networked learners who get to enjoy the pleasurable experience of producing content rather than just accessing it and consuming it. Other added benefits of such an endeavour will be reflected in other affordances further on as the networked attribute and the additional features provided by Web2.0 tools provide the exposure of the learners' artefacts as well as providing the forum to react and provide feedback, creating the possibility of additional active knowledge making. Some examples of artefacts include project-based learning while employing multiple knowledge sources available online, and research-based knowledge making through freely-available educational resources. Such innovative, creative and problem-solving opportunities do not just enable learners to build and create new meaning from existing knowledge, but also to tap into the massive knowledge-base of online users and experts, referred to as crowdsourcing [9, 10].

c. *Multimodal Meaning* results from the rich repertoire of possible ways a user or a learner has available through the Web2.0 tools. The evolution of these online tools has provided innovative ways that not only add interest and transform the learning process but provide multiple media to choose from as to ensure the learner adopts the most meaningful way to deliver and reinforce the educational artefact. These prospects also reinforce the concept of mastery, mentioned earlier, as learners acquire experience and seek alternate ways to fruitfully employ digital media in a variety of ways linking text, images, online resources, alternate content, datasets, audio-visual material and other media. Such digital skills are an educational experience in their own right as learners acquire critical and analytical competences, but also promote deep educational thought processes that assist them in mastering and proficiently overcoming the intended content while providing meaning through alternate modes [11].

d. *Recursive feedback* is an important affordance that relates to the potential of networked learners to react and provide thoughts about the work of their peers. Such interactivity is also possible through the evolution of technology as online users are able to author and contribute to the content rather than just accessing it in a read-only manner. This opened up a massive opportunity window for assessment not just from the educator or automated point of view but also from multiple and interesting points-of-view including peers, colleagues, friends and online knowledge experts. This affordance also highlights the effectiveness of formative assessment in contrast to summative as learners are practically in control of their own outcome as they receive feedback and in-time response to influence their own assessment. Furthermore, the use of learning analytics has also been possible through such an affordance as learner generated data especially from the recursive feedback is productively employed to direct and guide the learner further [12]. One example of how this has been implemented is described further on in Sect. 5.2.2

e. *Collaborative Feedback* is made possible through the social nature of the technologies employed within networked learning environments. Learners can take full advantage of such an affordance and coupled with humans' nature to socially interact, a knowledge loop of information sharing is created whereby learners assist each other within an academically healthy eco-system. Forums, peer-to-peer feedback, team tasks, or online group chats provide excellent settings to build collaborative skills and negotiation aptitudes that provide the social glue for learners to support each other as well as a safe space to share experiences, new thoughts, innovative ideas, and creative food for thought [13]. Furthermore, the importance of receiving timely feedback as well as comments about comments generates a recursive loop with numerous contributors and perspectives helping learners while enriching their educational processes.

f. *Metacognition* refers to the e-learning affordance that enables digital learners to think about their thinking rather than didactically memorizing fact in a rote manner. This incites learners to critically think about the knowledge processes rather than reciting theories that need to be systematically applied. Learners automatically think in a metacognitive way when they have a task to perform as they tend to better assimilate patterns in what they do and understand how differences can lead to new and different theories. Reflecting about lessons learnt, analysing other learners' tasks and ideas, as well as being cognitive of the way forward help develop better learners who can apply their acquired knowledge to life while developing a lifelong learning capacity.

g. *Differentiated Learning* is a special affordance that allows the personalisation of the learning process in such a way that attempts to mimic what a human educator is most capable of. Individual learners have unique learning styles with a pace that fits their needs and content that is tailored to their interest and academic necessities. Artificially intelligent software integrated within online learning environments provide services that enrich the educational process as motivational levels and focused interest heightens [14, 15]. Data generated by learners together with personal academic profiles (more about this in Sect. 5.3) provide the required input to induce the digital underlying system to tailor the educational experience thereby enriching the process while optimizing the use of resources and energies [16].

5.2.2 Modalities and Spaces within a School Environment

The possible learning modalities are significantly conditioned by the physical classroom design and its internal set-up [1]. It is due to this precise reason that the AmI classroom subscribes to this notion of redesigning and repurposing the conventional classroom to allow the possibility of additional learning modalities. The eighteen modalities proposed by award-winning school planner Prakash Nair and top architect Fielding [1], that were listed earlier in Chap. 1 (Table 1.1), are testament that the classroom should have a multi-purpose design within which numerous forms of learning through a variety of set-up spaces can take place. The technology within the classroom, coupled with the physical setup, enables additional learning possibilities that potentially provide elevated levels of success over repetitive single-mode teaching methodologies. As a matter of fact, Nair and Fielding argue that such modalities are required to be supported within a comprehensive learning space to accommodate four facets of learner experience. They single out space, psychology, physiology, and behaviour as important factors that highly influence the setting up of a learning spaces during design stage.

In parallel with this model is a proposal by McIntosh [17] who adopted a concept of six spaces of social media with a classroom [18] and embellished it to propose seven spaces that are required within a learning space. The proposal of essential spaces takes advantage of the evolution of digital technologies to easily assimilate the eighteen learning modalities specified by Nair and Fielding [1]. The seven spaces and the corresponding modalities associated with the respective space are:

i. *Secret* spaces within a learning environment refer to isolated places similar to library cubicles where a learner or small group of learners can revert to for a short period of time to focus and work quietly on a particular task. Some learners prefer the privacy of such a space as it provides the right atmosphere and cosy setting to better converge all the required attention. Far and safe from the usual classroom agitation is also ideal for quiet and reserved learners who can be themselves and create a private space, not concealed or covert in some way but simply screened and curtained. The classroom is a massive social setting as discussed earlier in Sect. 1.2 and thereby could be intimidating and challenging for some learners while counter-productive at the same time, and for this reason a secret space would address these issues and ensure that adequate space within the same learning environment is available and acceptable to the educator. Three modalities out of the eighteen discussed earlier seem to perfectly fit this particular learning space as 'Independent study' (#1), 'One-to-one learning with the teacher' (#4), and 'Peer tutoring' (#2) can easily happen within the privacy of a secret place. The concept lends itself well because in all of the three modalities the individual learner is at the centre of the activity. The space provides the required privacy as well as the focused attention necessary for a learner, even if introvert, to acquire the most out of each of the three educational experiences.

ii. *Group* spaces have indirectly always existed as class breaks for group work and traditionally learners grab chairs from the same classroom they are in and circle them to create a communal space for their group to work and discuss. However, the space was not purposely planned, designed and created to support group dynamics and is only being conveniently adjusted to accommodate the need. So, this need has to be purposely addressed by creating a permanent group space for leaners to comfortably interact with all others while not being interrupted by the clatter from other groups. Such a space should conveniently have available resources for the group to optimally function like white/flip boards, communal electronic space, comfortable furniture, as well as a curtained space similar to the secret space but that can house more than one learner. The electronic medium is also part of the group space as communal chats and forums, as well as group video conferencing and conferencing facilities can extend the physical group space beyond geographical restrictions. Two modalities in particular, namely, 'Team collaborative work in small and mid-size groups' (#3) and 'Seminar-style instruction' (#12) can best be practiced within a group space. Both modalities would be optimally carried out and followed given that the learners are in full knowledge that the space has been intentionally designed and planned for them to function optimally and to ensure that they benefit from the best educational experience.

iii. *Publishing* spaces are necessary for manual work to be performed and for artefacts to be produced. Similar to a workshop where a purposely-established location is dedicated for the dirty work, publishing spaces provide the setting for learners to get into the mood and appropriate aura for them to be more creative and productive. These spaces can be hands-on crafts type of spaces but also electronic publishing and sharing ideas kind of spaces to ultimately plan, design, share, brainstorm, and eventually develop and refine an educational artefact. A secret or group space can potentially function as a publishing space if the learner/s decide to do so. Similar to the other spaces this space extends to the electronic medium and can potentially accommodate networked learners publishing together over a virtual space with communal publishing interfaces and shared whiteboards. 'Storytelling' (#17) and 'Learning by building' (#18) are two modalities proposed by Nair and Fielding [1] that compatibly fit with this particular space. Both methodologies can lend themselves to more than one space, but in this case they are good demonstrators that the publishing space can also be oral or visual, and not just hands-on or electronic.

iv. *Performing* spaces bring out an important aspect in every learner because they provide the space and the time for every individual to boost their confidence and self-esteem that will result extremely handy later on in life. Use of display technologies will feature in this space as learners are able to present their work, ideas and artefacts while publicly sharing their work and efforts. Such a task not only helps learners to perform in public but also provides the ideal setting to collect feedback and reactions of other learners and educators. This applies also to the arts and drama domains where learners are given the opportunity to act out, engage even more, and role-play within the specially-allocated performing space which conceals any explicitly intended learning goals. Some learners perform better than others due to their extrovert character, however, this does not exclude other introverted learners to venture and experience such an alternative creative form. Three modalities can easily apply to this particular space as 'Performance and music-based learning' (#11) and 'Art-based learning' (#16) offer any learner the opportunity to perform and excel. Additionally, the 'Student presentations' (#10) can also be held within the performing space as learners are encouraged to develop presentation skills in an effort to polish their performance abilities.

v. *Participation* spaces are open spaces that provide the freedom and scope for learners to accomplish tasks in a hands-on manner. Practice and psychomotor skills help learners internalise information in much a natural way without the need of forcing any educational techniques or study strategy. These spaces not only support group events or creative tasks, but also events where learners can accomplish and achieve goals through the production of a tangible artefact providing an addictive satisfaction of achievement that is usually associated with game theory. As a matter of fact, games or gamified activities are one of the most common ways of how to get learners to participate. Play and adventure provides natural ways to increase participation and therefore providing spaces to promote, support and encourage such activities increases their likelihood of successfully happening. Two modalities lend themselves very well to this space due to its practical nature. 'Community service learning' (#13) and 'Project-based learning' (#6) involve learners within a participatory mode whereby a dedicated space can boost the level and quality of the participation of each individual learner.

vi. *Watching* spaces are less engaging and partaking than the previous two learning spaces as learners can easily play a secondary role or play no role at all. Majority of learners get used to comfortably not getting involved at all and simply allow others, or the educator, to provide some kind of activity in class. The point here is that in some circumstances learners need to simply play a secondary role and stop to listen, appreciate and allow others to tell them things, show them, or even to surprise them and fascinate them. The person in the primary role does not necessarily be the educator, but another learner, or a visitor, or even an educational video clip or piece of music. The space for watching needs to be comfortable, casual and acoustically sound. Additionally, use of technology can further enhance such a space with recording facilities as well as devices to easily integrate numerous media and input streams. The modality 'Lecture with the teacher or outside expert at centre stage' (#5) is the standard methodology that fits well with this space which unfortunately tends to dominate classroom setup all around the world as the one and only modality accepted and practiced. This does not mean that the watching space or the fifth modality is inadequate or inappropriate, but that without the variety and distinctiveness of the other spaces the other modalities have minimal likelihood and opportunity to ever occur.

vii. *Data* spaces have already been referred to earlier in some of the other spaces as online networked environments can be considered learning spaces in their own right. Additionally, numerous sources of data can be made accessible and employed as input streams to enhance the educational process. The use of weather stations as mentioned in Sect. 4.4.2 and RFID technology are excellent examples of how real data can be employed to achieve numerous educational objectives like monitoring/controlling class temperature or optimizing the use of the other spaces depending on usage by learners over the previous weeks. Furthermore, the popularity of employing tangible user interfaces within educational environments is increasing the possibilities of having data generated by machine-readable devices that are able to detect movement, patterns, and sounds to eventually activate corresponding processes that allow learners to realise and understand how data around them is now detectable and discernible allowing them to control it and use it wisely. From a practical point of view two modalities that could easily adopt the data space are the 'Research via the Internet with wireless networking' (#9) and the 'Distance learning' (#8) modality. In both cases the data space is considered to be the ideal online environment for learners to adopt such a methodology to perform a component of their overall education. Additional modalities via other learning spaces are necessary and beneficial for the overall holistic academic formation of each learner.

5.2.3 Merging Models

From an educational aspect the AmI classroom adopts the merging of the models presented earlier as their combination characterises an ideal pedagogical ideology that perfectly supports such a setup. The modalities [1] incorporated within the learning spaces [17], as envisioned in Fig. 5.1, provide a sound education setting together with a technological friendly environment to house a group of learners and educators as a social unit. Within such a purposely designed learning space the affordances [5] are better positioned to be effectively employed and academically beneficial. The overlap of these models provides a practical solution as well as a functional learning environment whereby diverse lines of thought converge to offer a combination of technology application, design principles, and educational theories in a compatible and operational way. This will be reflected in the next chapter where the AmI classroom concept will be fully presented and discussed. To complete the setup from an educational aspect the virtual learning environment that will accompany the AmI classroom will now be presented and considered within the context of the above merged models.

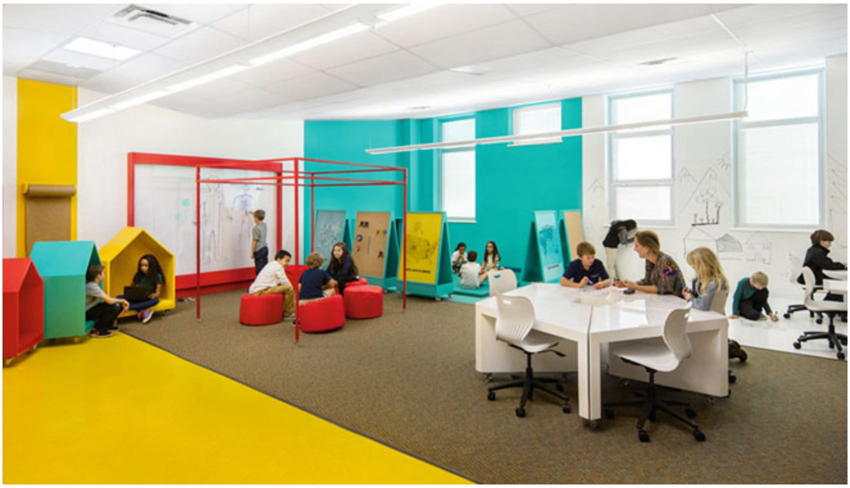

Fig. 5.1 Prototype classroom with potentially 7 spaces and 18 modalities [19]

5.3 Personal Learning Environment

The academic content together with the learner' s personal academic record also form part of the educational aspect within the AmI classroom. Artificially intelligent techniques, as stated in Sect. 4.5.6, are applied to generate a learner profile that is eventually employed to customise the content as well as the feedback and the learning environment. All this is incorporated within a Personal Learning Environment (PLE) of each individual learner which has been a main theme in a previous book [20] that investigated how e-learning can be effectively enhanced through the interjection of AI.

PLEs are employed to house all the elements required to personalise an electronic learning process that can be subdivided into two main components as identified by Morrison [21] in Fig. 5.2. Both the personal network and the portfolio are essential components within the AmI classroom as their role within the holistic scenario is crucial. The technological aspect of the two elements has been discussed in Chap. 4, while their contribution will become obvious in the next chapter, however, a brief run through each of them will help clarify their functional characteristics.

5.3.1 Personal Learning Network

The Personal Learning Network or PLN is intended to provide the knowledge backup that a learner seeks as supplementary content while following an academic programme. Normally, learners revert to academic books, lecture notes, online information, and colleagues to support them in their studies. This can be considered an

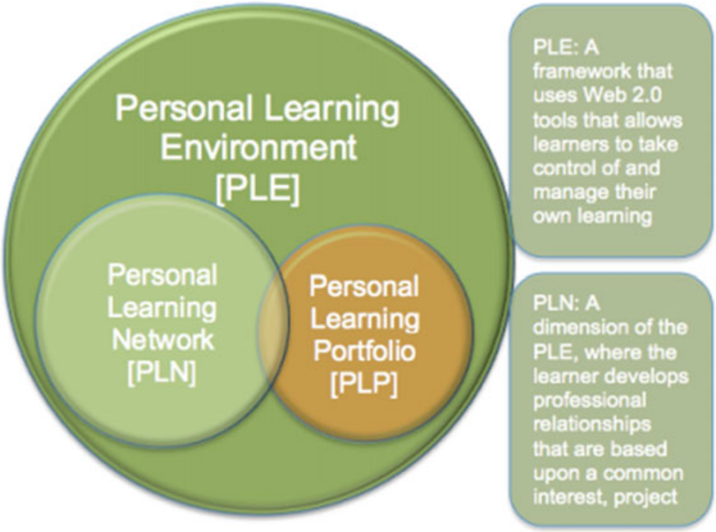

Fig. 5.2 Anatomy of a PLE [21]

academic support network physically made up of people and resources that every individual learner builds and develops around oneself. In a similar manner, an electronic version of this support system is made up of a network of contacts, programme online resources, forums, knowledge-bases, and expert/guru sites. As time goes by the learner continues to evolve such a personal learning network refining it in the process and enriching with other virtual resources that befit the academic need of the same learner. Educational researchers [22] have acknowledged the valid academic contribution of such a support network mainly made up of hyperlinks to online resources as well as contacts from social networks and crowdsourcing sites [23]. The academic needs of the learner will change over time but also along the educational programme currently being followed, thereby, it is only natural for the PLN to respectively evolve to accommodate the evolving needs and academic requirements. Web2.0 tools [24, 25] also enable learners to enrich their PLN further as they endorse through technological integration the possibility for learners to engage into collaborative and cooperative activities where not only they are knowledge consumers but active participants. Tools that allow learners to curate online knowledge, share, generate and provide feedback will further form part of the personal learning network that eventually overlaps and form part of other students' PLN creating a healthy knowledge sharing eco-system that all participant can benefit from in their own individual ways. As discussed in Sect. 3.3 the Connectivism learning theory [26, 27] is at the base of the AmI classroom and the PLN further reinforces this claim as it emboldens connected learners as they nurture their personal repository of available academic resources to ensure they can supplement their educational needs not just with knowledge itself but also with the knowledge of where and how they can have access to it.

5.3.2 Personal Learning Portfolio

The Personal Learning Portfolio or PLP is an encapsulation of a learner' s academic history that includes achievements, challenges, tasks performed, assessment details, academic preferences, and any other information related to the educational record of that specific learner. In reality academic portfolios have been physical compiled and filed within educational institutions [28] to support the educators' decisions on what the learner' s academic needs are [29]. In the AmI classroom the PLP is electronic and is simply another name for the learner profile as it represents the entire set of characteristics required to encapsulate the learner academically [30]. This includes the entire series of academic experiences attributed to the learner that to date contributed to the record of academic achievements and knowledge. Additionally, the PLP incorporates the educational pedagogies and procedures that were adopted during such experiences thereby keeping record of what works and does not work for this particular learner. All this is held in combination and in reflection of the learner' s finest quality attributes in an effort to expose a full and comprehensive representation of the learner' s academic abilities, potentials and propensities. The versatility of an electronic PLP makes it ideal within an AmI classroom as the variety of students combined with the heterogeneity of educational situations is to be expected. Additionally, the fact that the AmI classroom is meant to be completely and continuously networked through the PLN, it falls to reason that the PLP is effectively functionable within a plethora of academic environments to accommodate different learner needs, interests and academic demands. This goes in line with the two models adopted by the AmI classroom whereby the PLP strongly motivates learners to adopt a self-directed role [31] as motivation levels experienced by online learners [32] have been documented to improve over time [33]. The enthusiasm boost that PLPs incite within online learners is well documented [34, 35] especially in tandem with the PLNs where like-minded learners are academically matched to further collaborate, share and create knowledge within a healthy networked academic eco-system [31, 36]. Further proof can be found in similar work where PLPs are employed to tailor learning experiences [37, 38], customise Internet browsing [39, 40] and provide personalised e-learning [33, 41].

5.3.3 Ambient Intelligent PLE

The PLN and PLP come compatibly together within the AmI classroom as a supporting environment that can easily be referred to as an ambient intelligent PLE or AmI-PLE. The concept is based on the combination of having the online network sustaining the overall functionality of the technologies within the classroom coupled with the academic profiles of the learners being generated, updated and fed into the same underlying system. Intelligent PLEs or iPLEs have been subject of discussion and research [20, 42, 43] as personalised e-learning marks the future of online education. The AmI-PLE adopted within the AmI classroom can be categorised according to the three categories proposed by Al-Zoube [44] as a web-based architectural system rather client-server as it houses the PLN and additional online Web2.0 services that accompany it. Numerous projects [45, 46] adopted this approach as its benefits are numerous and also well documented [47].

The AmI-PLE can also be categorised as a stand-alone developed-from-scratch application rather than the recommended [48] extension of the existent VLE as additional functionalities are added-on according to the learners' needs or those suggested by the educator or the academic institution. The decision to adopt such a strategic move lies in the fact that current VLEs are inherently philosophically biased towards a non-student-centric design which is in contrast to the AmI classroom ideology. The merged models that underline the educational aspect of this proposal are designed around the learner as the catalyst within the intelligent environment who initiates, controls, selects, generates and uses data provided over the surrounding network. The educator ensures that the learners are taking full advantage of such a liberal PLE as learners are required to be mature enough, disciplined and fully in control of the academic process. Such techniques have been successfully employed and endorsed by numerous research projects and educational researchers [49, 50]. The AmI-PLE subscribes to the notion of learner-in-control under the indirect supervision of the indispensable educator as numerous researchers [51, 52] argue in its favour. Not only is this approach much more trustworthy from an educational point of view [48, 53], but ensures that the AmI classroom provides a balanced and nurturing environment that has been previously tried and tested [54, 55]. The choice of such an AmI-PLE was also intended to cater for additional technologies in such a way that it accommodates and takes full academic advantage of the rapidly-growing and ever-evolving open educational resources [56, 57].

5.4 Related Work

Very few academic projects have been reported that focussed solely or mainly on the educational aspect of a smart classroom, however, the few that did still failed to ground their work into sound learning theories. This means that either this particular aspect was an afterthought to the projects that typically were directed towards the use and application of new technologies, or else the educational aspect was taken for granted and was assumed to be a simple matter of merely performing a straightforward transfer from the established traditional classroom. Such an assumption not only retains inherent issues but erroneously presumes that learning theories and pedagogical techniques that were adequate and worked in one situation can ingenuously be adopted and applied to any other educational situation. Researchers [58, 59] have shown that switching educational modalities goes beyond the physical and technological. The educational connotations that such a transition partakes has to be meticulously investigated and exclusively planned for the new purposely designed educational environment. This includes the assimilation of respective learning theories upon which the educational researchers subscribe their reasoning and methodology to. To such extent Bajaj and Sharma [60] argue that learning styles are instrumental when the learning environment is changing and needs to be adapted. Similar to the above reasoning they subscribe to the notion of employing learning theories to ensure that the technology-enhanced environment adequately adapts to the learners' learning styles. The following learning theories are closely related to the work presented here and which have been associated with the adaptation of learning environments.

5.4.1 Psychological Type Model

Mayer and Myers [61] are notoriously known for their widely administered personality indicator assessment test that is based upon their psychological type theory. The model delves into the psychological type differences in humans that eventually predisposes them to learning. The authors argue that there exist four categories of such typologies, namely, extravert and introvert, sensing and intuition, thinking and feeling, and judging and perceiving. The type model simply states that these categories and combinations of them influence how learners perceive the world around them including the learning environment. This will affect the way the same learners respond to the environment as they interact with it and eventually influence the benefits they exert out of it, the way they interact with others, and how they adapt their learning to accommodate the evolving surroundings.

5.4.2 Learner Type Model

There are four types of learners according to Felder and Silverman [62] with each type having two learner styles associated with them. The first dimension distinguishes between active and reflective learners as the former actively participate in order to learn with a hands-on predisposition. On the other hand, reflective learners are more of the thinkers who ponder well and reflect on the issues and learning content presented to them. The second dimension distinguishes between sensing and intuitive learners where the use of sensory functionalities or intuitive capabilities are employed to absorb experiences and learning situations to then transform them into educational occurrences. In the first case sensing learners tend to be good at factual and concrete learning materials, while intuitive learners are more inclined towards theoretical and abstract materials. Visual and verbal learners constitute the third dimension as seeing-is-believing and learning works best for the latter type, while the former learn best from written or spoken textual representations. Finally, sequential and global learners are particular in their learning rate as some learners prefer small chunks and shorter steps while others prefer looking at the larger picture and learn in a generic way. This model has been extensively employed [63] and found to effectively enhance the learning process when applied to design a course with styles that match those of the learners.

5.4.3 *Experiential Type Model*

This model is based on a learning theory by Kolb and Kolb [64] who applied experiential learning to higher education by proposing a four-staged learning cycle to understand and represent different learner styles within an educational environment. As shown in Fig. 5.3 the four stages are *Concrete Experience* at the centre top, cycles to *Reflective Observation* on the right, onto *Abstract Conceptualisation* at the bottom, and closes the cycle with *Active Experimentation* on the left.

A diverging learning style between the concrete experience and the reflective observation represents those learners who would rather passively watch then participate, typical of the watching space that was mentioned earlier. Such learners are happy to accumulate information and available resources to complete their educational process. Assimilating learners fall in the next quadrant around the cycle in between reflective observation and abstract conceptualisation. This learning style highlights traits of conciseness and to the point with conceptual ideas as ideal instruments within the learning process. The third quadrant around the cycle brings the abstract conceptualisation and active experimentation together to identify converging learners who would rather solve problems and figure out practical solutions as a process to learn. Finally, the accommodating learner style lies between the active experimentation and concrete experience to represent those leaners who are much more practical in their approach relying mainly on their hands-on experience as an ideal way to acquire knowledge and learn.

5.4.4 *Personality Type Model*

Honey and Mumford [65] extended the previous model proposed by Kolb and Kolb to recommend a model as shown in Fig. 5.4 representing four learning personality

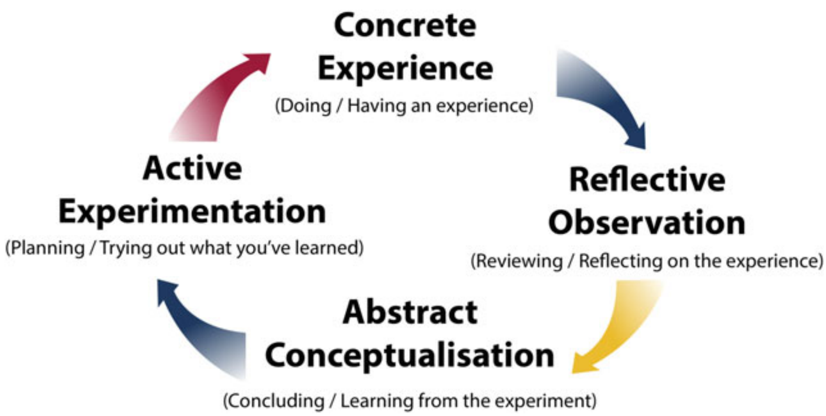

Fig. 5.3 Experiential learning cycle by Kolb and Kolb [64]

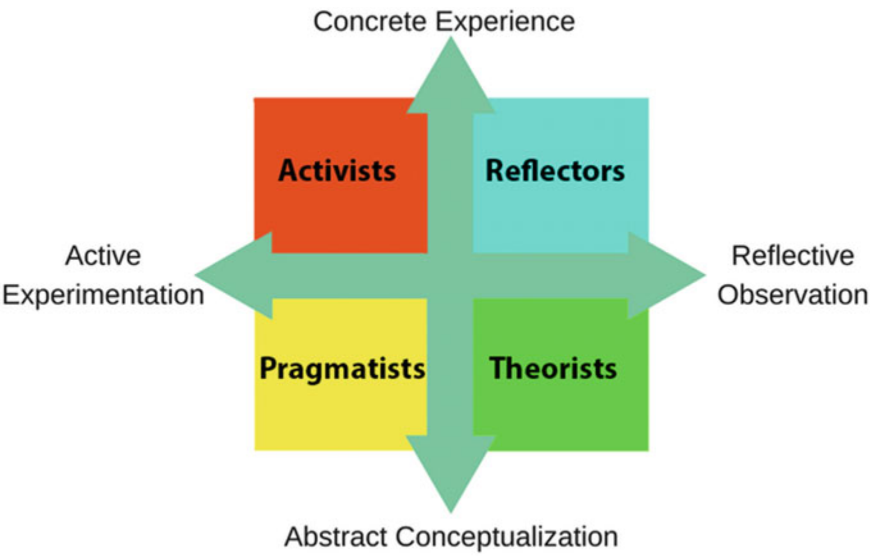

Fig. 5.4 Honey and mumford addition to experiential learning [65]

types. The first are the *Activist* learners who are industriously working hard to learn through some educational activity like problem-solving or actively doing something constructive leading to an educational experience. The *Reflector* learners prefer to watch and ponder on situations that can lead to a learning situation. Activities in this case could include observation, self-reflection and other thought-provoking activities that do not require active participation. The third type of learners are the *Theorist* who are much more comfortable with employing theoretical models and ideas that would typically manifest themselves in activities like statistical modelling, conceptual prototypes, and theoretical exemplars. Finally, the *Pragmatist* learners are practical types who apply their acquired learning experience to activities like case-studies and applied problem-solving situations.

5.4.5 Experiences Type Model

The final learning theory that relates to the educational aspect of the AmI classroom is a model proposed by Fleming and Mills [66] referred to as the VARK learning theory model. The Visual, Aural, Read/write, and Kinaesthetic styles represented by the VARK acronym highlights the four information groups that are used for learning. Experiences accumulated through the learning experience are preferred over others due to their particular attribute which learners single out over others. The *Visual* learner is most academically productive when employing graphical representations like charts, images, flow-diagrams and any other information-representation form that can be used instead of written or oral forms. The *Aural* learner on the other hand is happy to listen and speak as information in this form is more effectively learnt. Typical examples are traditional lectures, recordings, radio, speaking to others and any other auditory media. Those leaners that prefer the *Read/write* learning style are much more in favour of written information that can be read and even noted. Books, notes, reports, documentation and any written material is the ideal medium for such learners. Finally, the *Kinaesthetic* learner is perceptually biased towards practical and experiential learning situations that can be simulated, demonstrated, or even realistically displayed as in video clips, case studies and any other tactile medium.

5.5 Implications to the AmI Classroom

The educational aspect is considered to be the major influence in the design and implementation of the AmI classroom due to the obvious fact that the ambient under consideration is an educational environment. This may not have been the case with other similar projects about smart learning spaces or intelligent classrooms as they mainly focussed on the technological aspect probably because it was the primary motivator for their research project. In this case the motivator is the technology-enhancededucation theme and thereby the implications of the educational aspect are important and noteworthy.

The first implication is the adoption of learning theories as part of the fundamental plan and design of the AmI classroom. This is a significant and distinctive variation from other similar projects documented showing a conscious and clear decision to ground the proposed research project in a sound and established learning theory. The implications of this resolution are mainly a reassurance that the suggested set of instructional principles stipulated by the learning theory have been thoroughly investigated, studied and evaluated by academic peers along the years. These accepted principles can efficaciously guide the practice of teaching and the functional design of the proposed learning environment.

Another implication of the educational aspect is reflected in the academic benefits that are attained from the AmI classroom. Initial empirical studies [67] have shown over and over again that students' performances improved when taught in intelligent environments compared to traditional classrooms. The reason behind this positive educational implication could potentially be due to the elevated levels of cognition instilled through the enhanced environment as learners are continuously and methodically given feedback and reinforcement on every activity logged into the online environment. The learner-generated data is employed as part of the learning analytics exercise to refine the individual feedback and provide supplementary academic material, but also to formatively assess learners' progress automatically. This positive effect of a smart classroom also applies to high-performing learners who understandably perform even better. The motivational and engaging effect is engendered amongst all learners irrespective of their ability and/or skills level. This brings up the next implication of mixed-ability learners within the same classroom.

Student-centred approach has already been documented [68] to alleviate issues related to mixed-ability classes as smart classrooms not only highlight this capability but enhance class management and promote differential strategies through technology. These factors were acknowledged as the most effecting techniques to mitigate the antagonistic effects that mixed-ability learners encounter in traditional classrooms.

The educational implications of the merged models, whereby the e-learning affordances are emphasised and conveyed through the different learning spaces and modalities, are enough to justify the effort and energy in pursuing the deployment of AmI classrooms. The available variety of media, modalities, spaces, feedback, personalisation and motivations induce learners of all abilities to perform better as tailored supplementary tools are promoted. Additionally, the content that adjusts to the individual learner needs and interests ensures that every unique person progresses at their own pace while continuously supporting learners to engage in knowledge-making activities while highlighting the premise that every learner is a valid and essential member of the class. The physical environment and the online learning space provide ample opportunities for individuals as well as groups of learners to fruitfully engage when appropriate and suitable according to the academic needs of the same learners.

Finally, it is imperative to highlight the educational implications of having an educator throughout the process. Contrary to popular belief that a smart classroom would eliminate the need of a human educator, the AmI classroom requires the expertise, dedication and sensitivity of an educator who is required to professionally switch roles according to the educational and social needs of the individual learners as well as of the entire class.

5.6 Conclusion

The educational aspect of the Ami classroom has been analysed and investigated in great depth throughout this chapter as numerous issues have been raised and put into context. The learning models that have been adopted and merged have been introduced and explained in detail highlighting the most salient educational issues that apply to the AmI classroom. The seven e-learning affordances have been confidently integrated due to their beneficial contributions especially when merged with the eighteen learning modalities that the seven different learning spaces enable and accentuate. This led to the virtual environment that accompanies the physical AmI classroom whereby an intelligent personal learning environment was argued to be ideal. The AmI-PLE compatibly brings together the learners' personal network (PLN) that incorporates all the education resources, contacts and links, together with the personal portfolio (PLP) which encapsulates the learners' academic profile that is specifically personalised to the individual learner. These two aspects employ the technological tools from the previous chapter to provide the software infrastructure deployed within the learning environment purposely developed for the AmI classroom. Finally, a number of learning theories and types were brought into context to assimilate related work in the area with respective learning theories that were adopted, namely, connectivism for the PLN and the adaptive learning theory for the PLP. This brought the chapter to an end as a number of implications of the educational aspect to the AmI classroom justified the decisions taken and the choices made.

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Chapter 6
The Ambient Intelligent Classroom

The philosophy of the school room in one generation
will be the philosophy of government
in the next.

Abraham Lincoln

6.1 Introduction

The three aspects from the previous chapters, *Social*, *Technological*, and *Educational*, come together to provide the sound foundations to a proposed AmI classroom. In Chap. 2 the case for the AmI classroom was made following a justified need to change and accommodate to new technological realities while evolving learning models that have been proposed and documented are put into perspective. The AmI classroom is a complex combination of all these three aspects that each in turn carries its own recursive complexity that will invariably contribute to this amazing concept. Amazing because it shifts how classrooms have been looked upon, assumed to be, and expected to deliver. This chapter will go through the sequential order of how best to understand and appreciate the AmI classroom as the next sections provide a walk-through of the rationale, design, deployment and empirical studies. In each of these phases all three aspects play an important role and are therefore brought into context to ensure that the philosophical rationale that went into the background as well as the technical and practical details that accentuate the realisation of the proposed environment are presented and revealed to the reader in all their impacting contribution and operational bearing. As mentioned throughout the book the educator is considered an integral part of the classroom and of this project, and in no discrete way is technology being brandished or assumed to replace or do without the necessity of the human educator. In light of this fact, the focus of this chapter is all about the rest of the AmI classroom beyond the indispensable educator, ergo the sub-title of the book.

M. Montebello, *The Ambient Intelligent Classroom*, Studies in Computational Intelligence 840, https://doi.org/10.1007/978-3-030-21882-9_6

6.2 Background Rationale

The rationale behind the AmI classroom has been broadly highlighted a number of times as different concepts where being introduced in the previous chapters. However, before delving into the complexities of the design in the next section, it would be operationally helpful to demarcate the specific background issues that will be reflected in the design and eventual deployment. The following subsections cover the different background matters in a sequential and incremental way from epistemological principles adopted to group dynamics followed and from learning theories endorsed to the engagement of learner profiling techniques. To better display and expound on the different background issues it would be worth envisaging all the various matters in the light of a scenario of how the AmI classroom would function and operate. The scenario will then be explored from three points of views to comprehensively cover the virtual and physical spaces together with the various technologies involved.

6.2.1 Scenario Description

Envisage walking into a learning space similar to the one depicted earlier in Fig. 5.1 rather than a traditional classroom where a variety of spaces are optionally available for learners to settle down and informally engage in some kind of educational activity. Every learner has the availability of an electronic device to be able to log-in onto the classroom virtual system. The device of choice can be a tablet, laptop, or even a thin client in the form of touch-screen stations and secluded stations scattered around the learning space. An educator or a number of facilitators can potentially be available to assist and provide academic support to the learners. Additionally, learners and educator/s are signed-in over the virtual learning space and are interacting, posting, providing feedback, creating content, curating knowledge, and accessing numerous social-media apart from browsing online, interacting face-to-face or following others in some part of the learning space. An educator who administers the virtual space ensures that knowledge sources are continuously available as learners seek and venture from one topic to another. The same educator ensures that the physical learning environment with all the different available spaces are well stocked with educational materials, games, knowledge charts, practical worksheets, exploratory tasks, experimental equipment, latest gadgets, and a diversity of educational inspirations whose objectives are to entice learners to pick them up, try them, and eventually learn something new through them. All materials on the virtual space have corresponding physical counterparts, and vice-versa, to congruently support the learning activity which the learner picks up from either the online environment or the physical space. As individual learners interact with the online learning space as well as physically get involved in different learning spaces, they are continuous tracked and electronically trailed with the corresponding education activity being pursued.

The underlying system employing learner profiling techniques suggests additional resources to supplement whatever the learner is ensuing. Furthermore, alternate educational possibilities are proposed to specific learners in-line with their previous activities and in synch with the educational objectives set by the learner. Throughout this process the system is also keeping record of all assessment-worthy scores to formatively assemble the academic progress that the same learner can access and monitor.

This busy scenario of the AmI classroom might appear out of control with learners all over the place, but the learner-centric concept integrated within an informal social setting surrounded by supporting technologies is providing the educational experience through the seven e-learning affordances and within the seven learning spaces that have been intentionally set up. The academic activities prepared and proposed through the online environment are in synch with the displays and the spaces as the underlying system keeps track of the learner's interests, needs, activities, and positions around the classroom. At the back of it all the learner profile is being generated and refined to provide further recommendations as well as learning analytics to provide an appraisal of the overall educational experience.

6.2.2 Virtual Space

The virtual learning environment as envisaged in the previous scenario and as described in Sect. 5.3.3 is intended to accompany the individual learner throughout the academic experience while interacting with peers in the learning spaces as well as the educator. The virtual space is intended to represent the personal learning environment for each individual learner providing customised services, assistance and guidance through the intelligence scattered around the learning ambience. The specifications for such a virtual space can be listed as follows:

- An *individualised sign-in online system* is the basic requirement for learners to have access to a personalised learning environment that is supported by numerous functionalities. The online web-based system has an Internet browser as interface thereby eliminating issues of user interface upgrade and platform compatibility. Additionally, learners will be capable of accessing the virtual space anytime and anywhere from any device that can support a web-browser and which has Internet access. Finally, the virtual space is required to be secure and adopts latest authentication software as well as anti-virus capabilities to ensure that the all sensitive data pertaining to the learner is safely stored and efficiently retrieved in order to rapidly set up the interface as well as the contents according to the unique characteristics of the learner;
- *Intuitive learner interface* with an adjustable and tailorable functionality to allow learners to explicitly modify the interface to adapt to their particular tastes and comfort. The design of the interface will be better specified in Sect. 6.3.1 but should follow latest web design principles especially those adopted by popular

social sites that learners would be most accustomed to. Such interfaces place a focus at the centre on the most salient issues they require the user to focus on, with secondary matters and additional functionality on the lateral sides not to distract the learner. Finally, the setup of site settings and other controls should also be intuitively strategically planned and carefully crafted as users will want to quickly and accurately have access to the right information at a click of a button;

- *Social-media capabilities* that go beyond the look-and-feel of the interface should form part of the virtual learning environment to employ strategies that have successfully captivated and enthralled online users. The concept of learners being members of specific interest communities where they can share and contribute to areas that they all are enthusiastic about. Additionally, typical functionalities that users experience in social media are imperatively required as they provide desired educational capabilities like sharing knowledge, providing feedback, commenting on posts by others, posting updates, and other engagement-provoking activities. Furthermore, other members from other communities can also be matched and proposed to join another community thereby contributing to the knowledge base of that community;
- *Rich editing functionality* enables learners to apply themselves and be even more creative and productive. Numerous online learning environments lack the powerful editing tools that one encounters in prominent word-processing packages. Such tools provide room for learners to seamlessly switch to the virtual space and proceed with their editing skills acquired over the years. Additionally, integrating rich media and hyperlinks directly from social media that render a thumbnail of the resource directly on the learner's artefact provide added-value experiences and quality creations. Similarly, having extensions that enable the inclusion of technical terms like formulae through a dedicated micro editor, Unicode and LaTeX incorporation, as well as switching to HyperText Markup Language (HTML) equivalent, provide further editing intensity that an online digital learner needs and appreciates. Finally, finer capabilities that facilitate editing tasks like predictive text, ontological inclusion, and automatic name recognition of other members, are opportune and convenient;
- *Learning analytics* are a necessity within modern learning environments as they provide supplementary implicit information that would otherwise go unnoticed. Learner-generated data is collected by the underlying system as the learner interact with the virtual space. This data is processed and mined to extract further information about the same learner. Analytics provide information that assists students directly to comprehend the way they are progressing as well as insights into their learning patterns while providing recommendations on how to improve and optimise their efforts and learning experience. Learning analytics are also useful as input data for the intelligent underlying system to propose a personalised academic programme as well as recommend an optimal strategy for the learner to follow as the strengths, weaknesses, interests and preferences of the learner are also taken into consideration. A final outcome from such analytics is the advantage

of providing formative assessment along the course of the learning programme thereby supplying a continuous incentive for learners to perform better which in turn enhances the retention rate;

- *Crowdsourcing* provides the opportunity for enriching the online learning environment through the expertise of others who offer and furnish their knowledge regarding a particular topic or matter. This could be achieved by having information feeds from external sources or even social media that employ push technology to supplement further information. Through the power of the online crowd learners are able to take advantage and fruitfully utilise contributions posted by others. This could be in the form of a knowledge-base dedicated to a particular topic or could also be a repository of information in the form of an open educational resource. The virtual space can easily accommodate such additional information on the periphery of the interface as a secondary source of information that is available should the learner require it. Another way of employing crowdsourcing within the online learning environment is to encourage learners to not only form part of a communal group but to participate and contribute to a collective group task. Similar to a brainstorming exercise but in this case with a specific real-life challenging dilemma that learners have to analyse and evaluate together while individual propositions can be posted synchronously to provide creative and realistic solutions;
- *Recommendations* are typically provided by human counterparts who either have the expert knowledge about a particular domain or who comprehend with some confidence what best suits the needs of a particular learner. The underlying system running through the online learning environment can potential monitor the actions and outcomes of a specific learner, coupled with the previously highlighted learning analytics, to offer the learner customised academic recommendations. Such an action is considered to be intelligent as otherwise requires a human educator to provide the same assistance. The technology to achieve such an outcome will be listed further on in Sect. 6.2.4 as part of the technologies, but the resulting suggestions will form part of the virtual space. Similar to the crowdsourced information, this secondary information is peripheral to the learner's main focus at the centre of the online learning environment and is thereby either strategically positioned on the side of the same interface, or else flagged through a visual notification on a menu to indicate to the learner that some information requires attention;
- *Knowledge sharing facilities* are an important aspect within the online learning environment as it propagates a healthy eco-system whereby learners teach each other through knowledge they extracted, generated or curated from online sources. Traditional VLEs rarely allow learners to know about each other let alone share information or resources. The AmI classroom virtual space needs to promote and encourage learners to practice even more this knowledge sharing practice as it encourages a good team spirit and reduces academic competitiveness. Digital learners are already well accustomed to such practices as numerous social media enable multiple channels of sharing information. Therefore, with the knowledge sharing facilities as part of the virtual space learners will easily transfer their

skills and habitual routines of sharing information with their group of friends or the members of their classroom community. Group tasks become even easier to accomplish as the dedicated VLE facilitates common working areas and shared repositories apart from multiple communication streams;

- *Communication streams integration* ensures that leaners have multiple ways of keeping in touch with other learners who are members within their community but also with other potential recipients who could potentially contribute in one way or other to the educational process of each individual learner. The social media capabilities mentioned earlier have enabled the connected web user to transform oneself from just a consumer of knowledge to a contributor and author. Communication streams also encompass interactive activity amongst learners who can revert to chat facilities, group chats, video conferencing, mixed capabilities of video/audio/chat one-to-one or group, as well as possibilities of presentation functionalities that include common boards, shared screens, distributed presentations, and collective knowledge authoring environments;
- *Peer-reviewing possibilities* form part of the e-learning affordances that one of the models being adopted supports and argues in favour simply because such practices engender beneficial educational connotations. The articulate process of verbalizing constructive feedback to convey it to one of your peers is already an educational experience that traditional schooling rarely advocated and practiced. Learners are able to provide reviews to their peers through specific channels within the same virtual learning space. Learners are encouraged to practice such educational processes not simply because they are given due credit, but because it provides them with a golden opportunity to mentally switch from composing a narrative for themselves or an educator to a larger and heterogeneous group of receptive listeners. This change in the target audience leads learners to embolden their narrative and develop critical analysis skills as they take into account and make allowance for a bigger and undetermined group of readers. Additionally, in order to provide quality peer-reviews learners are also sharpening their reading and comprehension skills as they meticulously and observantly pay attention to detail as well as take into consideration a number of issues while performing a review exercise. The use of rubrics provides additional assistance for inexperienced learners and thereby enriches even more the learning experience;
- *Widget integration* is another way to ensure that academically useful functionalities are easily and effectively incorporated within the personal learning environment. Digital learners are accustomed to plug-and-play applications that can easily be assimilated to the browser, the device, or the application that is already being productively employed but which could do with additional add-on functionality. The educator can assume the role of administrator to assemble a host of potentially academically-advantageous widgets that can be recommended by the underlying system or explicitly suggested or selected by learners themselves. Alternatively, learners can suggest specific widgets to be included into the list of available educational applications that can be amalgamated within the virtual space. These widgets

can also be employed within the AmI classroom to enhance and embellish the different displays that are scattered around the space. Typical functionality of such widgets could potentially provide streaming of education content, list activities happening in different spaces of the classroom, portray artefacts that have been created and posted by other learners, as well as live feeds from social media related to current educational activities. The use of such displays will be expanded further in Sect. 6.2.3;

- *Academic content* is something that might be taken for granted as typically all virtual learning environments are predominantly content repositories. The problem with such a notion is that personal learning environments are undervalued when employed to download academic content and maybe submit coursework only. The virtual space is an integral part of the AmI classroom and requires the functionality of providing the academic content similar to a conventional VLE or LMS, but, in combination with additional functionality that is adequately employed to assist learners in their education. Semantically tagging content provides the meta-data that can be employed to further employ the same content when personalising delivery. The aggregation, sharing, recommendation and manipulation of academic content not only provides additional functionality but also ensures that the same content is being efficiently utilised and reused.

6.2.3 Physical Space

The classroom is considered the physical space, and as envisaged in the scenario at the start of this section, the AmI classroom is meant to be a multi-purpose learning space that permits a variety of learning modalities through different available spaces purposely planned and allocated. The learning environment as described in Sect. 5.2.3 provides an ideal setting to identify the requirements for the physical space to accompany the previously described virtual space. The specifications include:

- *Different spaces* provide the setting for learners to engage in specific activities. The setup and the surrounding furnishings give the space a particular identity that supports learners to partake in a specific learning process for which the same space was planned and designed for. The seven learning spaces referred to earlier in Chap. 5 provide a good description of what the ideal ambience should look like in order to establish an ideal atmosphere to incite and encourage a specific learning modality. Within the space itself additional materials go into creating the required learning ambience. Apart from the items covered below that are directly related to the academic theme, the space requires seating of some form and corresponding working tops. In some cases, the seating could be conventional chairs like in the watching and group spaces, or in other spaces like secret and performing spaces the use of cushions is more convenient and functional. Working tops vary as well accordingly to need of the learning space or modality. Lecture format and publishing spaces would require the use of classic desks or table tops, while in other cases like independent study or participation spaces would need no working tops as at all as learners can handle devices as they sit on a sofa or simply settle in a collection of bean bags to discuss a specific topic. Other objects play a critical role within the physical spaces and each will now be covered;

- A myriad of *modalities* as listed in Table 1.1 can be practiced within spaces that have just been described. The different modalities are highly dependent on the topic at hand and the way it is most effective to learn such a topic. Individual preferences of learners and educators also have a decisive influence on which modality to adopt as well as which space to employ. However, if the physical space is not purposely and appropriately set up to accommodate the different modalities than the educational process is being challenged in some way, resulting in an inefficient practice of that particular modality. Worth pointing out that a modality is not equivalent to a teaching technique or a specific pedagogical approach, but a potential learning situation that can be supported by the configuration of the physical space. The concept revolves around the idea that specific learners are much more open and receptive to a particular learning process within a particular space and at certain times. Alternatively, other learners can potentially be susceptible to a different modality to learn the same thing in a completely diverse space. The physical space needs to accommodate the different modalities to ensure it caters for the varied learning inclinations of the different learners;
- *Sensors* play a fundamental role within the Ami classroom as introduce in Sect. 2.3.2 and later expanded in some depth in Sect. 4.5. Numerous sensors and cameras scattered around the classroom and strategically placed in the different learning spaces will enable the tracking of learners in specific parts of classroom. Such information would be useful for the underlying system to work out if two or more students are sharing a common space and to provide corresponding academic information over the virtual space to the different learners working in the group. Alternatively, if a learner is working alone in a secret space and would like others to join or an educator to assist, then the underlying system can identify who is closer or more appropriate to address an academic query. Some learners might want to inform all others in class that a specific activity is about to take place at a particular space in the class. The AmI classroom should be able to direct all those who want to participate or inform those who have shown interest to a specific topic that is being dealt with at a specific space in the class. All this would be possible through the use of identification tags in the form of colourful bracelets that each student wears together with tag readers, sensors, fixed cameras and others integrated within the devices used by learners in class. Specific spaces in the room could be set to identify a learner automatically as soon as the learner is in close vicinity and triggers off the devices to accommodate the specific learner;
- *Learning resources* are required to be available around the AmI classroom within the different learning spaces to assist learners in the learning process. Physical learning aids are an integral part of any learning process as they supplement corresponding academic content presented by an educator or over the virtual learning

space. This is conspicuously even more evident when a specific academic task has been planned and positioned within a specific learning space with the requirement of distinctive learning resources to accompany the task. All the resources can easily be tracked by the underlying system as individual tagging labels can easily be electronically identified through readers around the class rendering them easily to locate;

- *Learning/Teaching Equipment* are also required as part of a functional classroom. The traditional projectors, electronic whiteboards, printers, scanners, laminators and educator computer/devices are just a few pieces of equipment and apparatus that can easily be transferred from a traditional classroom to the AmI classroom. Specific equipment can be strategically positioned in different learning spaces to assist particular learning processes and modalities. Similar to the learning resources all the equipment is tagged to easily identify and locate through the various tag readers that are strategically positioned in class;
- *Educational gadgets* provide a considerable and valid contribution to the learning process as they offer learners an exploratory aspect of innovation and excitement. Gadgets are employed to implicitly provide a learning medium through the aspect of innovation while attracting learners' attention to pick them up and try them out. The use of tangible devices are a typical example where physical objects act as interfaces between learners and the digital environment. Pattern recognition devices and QR-codes make it possible for a computerised system to understand how simple objects and patterns can trigger-off processes like switching on lights and adjust sound. Other educational gadgets that are widely being employed include Virtual Reality (VR) kits, drones, remotely-operated devices, interactive table-tops, robotic kits, and smart glasses;
- *Communication devices* that include computers, laptops, tablets, and smart phones are electronically devices through which learners can connect and interact with the virtual learning space. These devices are potentially owned by the learners themselves or else made available within the same classroom. The main idea of having access to such devices is primarily of having access to the online environment and the interactions provided by the underlying system, but also to ensure that learners are not powering-down when they enter the AmI classroom at school. Sign-in facilities ensure that learners are able to log into the classroom network from any device and authenticated using their identification bracelet to ensure security measures are in place. The identification bracelet could also be employed by individual learners to access personalised information and tailored academic content through fixed displays positioned in different spaces around the classroom. These displays can also employ widgets to transmit interesting information, ongoing activities, and access to the virtual learning space;
- *Classroom props* are physical inanimate objects that are movable or portable and that have no direct educational connotation distinct from the learners, the learning spaces, the virtual environment, and any of the electronic devices. These props do not include the furniture or the specific learning space items but items that

are required to fill-in and complete a learning space in an effort to enhance the educational process. Some examples include simple props, like hats, costumes, handheld objects, cartoon artefacts and wigs, that learners can carry or wear to get into a particular role as part of an educational event. Additionally, other props like scene set-ups, lighting effects, household articles, and other extra space add-ons, can be used to embellish the space further and create a required atmosphere that further supports the ambience in which the educational process can flourish. Other examples of props can include partitions, curtains, plants, sound effects, and atmospherics. RFID tagging in this case can also be employed to identify and locate any physical items in the classroom;

- *Educational materials* include all other items that do not fall in any of the above categories but can still assist in or facilitate the educational process. Typical examples include board games, physical/practical games, knowledge charts, practical worksheets, exploratory tasks, experimental/investigative equipment, educational/programmable toys, latest gadgets/gizmos, variety of stationary to produce physical artefacts, and additional materials that are required to glue together a complete educational experience. The diversity of these materials is proof that the objective here is to inspire leaners and entice them to pick up the item, try it out, and learn from it. They can be used in conjunction with other items within the physical space or in isolation within a specific learning space. All the items can be localised through the intelligent digital tagging and can also be proposed to a learner by the system when associated with other items or processes that are in current use.

6.2.4 Converging Technologies

The virtual and physical spaces have been thoroughly expounded and what clearly emerges is that both are dependent on each other and both require the use of technology. The aspect of technology was also covered in Chap. 4 as the AmI classroom engages the use of different technologies at different levels. A number of technologies in the form of software as well as hardware come together and converge towards a common goal to collectively ensure that the two spaces are compatibly amalgamated. As a matter of fact, these technologies listed and justified below can be considered as a third space that in unison constitute the AmI classroom. The three spaces reflect the three aspects, social/physical space, educational/virtual learning space, and the technological component/space. Having gone through the requirements of the first two spaces it would be beneficial if the technological specifications are also listed in one place to explicitly affirm what is being expected. The list includes:

- The *profile generator* is a software technology employed to create a model of a learner in a way that it replicates as close and real as possible the academic persona. Details of the profile generator were introduced earlier in Sect. 4.5.6 after that it was associated with the adaptive learning theory in Sect. 4.3. However, now that the virtual and physical spaces have been specified in some detail the profile generation component can better be brought into context and identify exactly what is expected of it within the AmI classroom environment. As soon as learners enter the AmI classroom they will be tracked by location sensors and if they engage in activities within any of the learning spaces data will be generated. Furthermore, once learners log into the virtual learning system additional data will be collected recording every single activity performed together with artefacts produced, comments posted, reviews done and received, as well as bookmarks placed, sites visited, likes registered and downloads performed. All this data is recorded to form part of the learning analytics for each individual learner and used as input to the profile generation component to generate the learner profile. The specific profile is furthermore employed to recommend academic content to a learner and to suggest what activities to follow or what tasks best suit the particular learner. As additional activities take place they keep being logged and new data generated, collected, processed and eventually contribute to refine the learner profile further in a continuous cyclic manner;

- A *Recommender system* is required to generate suggestions and match the learner profile created by the previously described profile generator to academic content and available resources. The AmI classroom provides additional content and activities that can potentially be matched and recommended to the learner. A task that has been planned in a particular space is tackling a number of topics that could potentially be of interest to a number of students. Particular students prefer working in groups while others might be more comfortable working alone in a secret space. The system will recommend the activity to these students over the individual interface of the virtual learning space together with notifications on the visual displays in class. Some of these students might decide to accept the recommendation and attend while others pursue whatever they were working on. Those who do attend will be tracked at the place where the activity is happening and reinforce that aspect of their learner profile especially if they further contribute through comments, feedback and other related artefacts. Another scenario envisages a learner who has been going through numerous websites during the evening at home while logged into the AmI-PLE which has been keeping track of all the activity and adjusting the academic profile accordingly. As soon as the same student arrives at school and is detected within the classroom the underlying system infers what can be recommended to this particular student as soon as access to the AmI-PLE is established. Recommendations in this case can be an activity in a specific space where it can be performed as a continuation of some activity. Alternatively, a recommendation could be in the form of customised academic content to supplement what had been covered the previous night and thereby reinforce what learning had happened. An assessment exercise in the form of a knowledge artefact or a physical piece of craft could also be recommended by the system to concretise on the respective educational knowledge acquired from the previous evening;

- *Learning analytics* is another technology that results from the combination of data generated by the learner and intelligent processing techniques that extract or mine additional information from that data. The acquired information can potentially be reflected and passed on to the learner within the virtual space as discussed earlier in Sect. 6.2.2 but can also be employed within the context of converging technologies as a specific physical space can be identified to positively enhance a learner's performance. Imagine a scenario where a learner has been participating in educational sessions within the AmI classroom. The underlying system has generated a respective academic profile while accumulating data, creating analytics, and further refining the profile as the number of interactions increase. The academic content is also being customised as well as the mode of delivery is directly manifested in the learning spaces that have been employed during the same period. Ideal settings coupled with optimised course content and employing specific resources that have all been proposed by the recommender system attempt to replicate the most effective learning process. The learning analytics can assist in achieving better academic outcomes as all the technologies within the AmI classroom converge to work towards one common goal for each individual learner;
- Numerous *sensors* have been mentioned in previous sections as they perform a variety of functions that enable useful and essential operations. However, sensors can also be considered as essential catalysts that bring technologies together especially between the virtual and the physical. Learner identification coupled with localisation of that same learner plays an important role in all the three topics mentioned above as the personalised learning analytics are fundamentally grounded on the learner profile that eventually leads to the useful output by the recommender component. Additional sensors embedded within the educational resources as well as image recognition sensory equipment can potentially play an educational role in the various activities taking place in the different learning spaces. Worth mentioning that additional resources, emerging technologies, as well as supplementary sensors like wearable devices, mixed reality kits, and drones can easily be integrated within the AmI classroom to bring the other technologies together while generating further learner data that leads to a sharper profile and eventually precise and useful academic recommendations;
- *Teaching aids* include all other educational resources that do not fall in the above categories but still are critical in providing a medium for technologies to converge. Specific teaching aids like microcontroller programmable kits are widely employed in educational setting to develop digital devices that are able to interactively sense and intermingle with other physical objects or spaces as well as digital signals. Other aids like tangible interfaces bring the digital technologies and physical interaction into one medium as they provide an excellent educational environment. Additionally, once the tangible device is located within a particular learning space where a specific student or group of students have chose to work in, all the technologies can work in a coordinated effort to enhance the educational experience. This could include learner preferences or interests that the profile would have highlighted, coupled with respective academic content or physical

resources to accompany the particular educational exercise. The resources that are proposed are not in use in any part of the AmI classroom and can be automatically located by the system.

6.3 Architectural Design

The design of the AmI classroom follows the requirements specified in the previous section where the background rationale of the proposed intelligent or smart environment has been thoroughly analysed. The analysis partitioned the virtual space and physical space as two completely different entities due to their nature, and then concluded with their combination as the technologies converged. The first subsection covers the design of the AmI-PLE virtual environment as the user interface needs to reflect the specifications indicated in Sect. 6.2.2. This is followed by the floorplan of the actual smart physical classroom to accommodate the learning spaces and modalities listed earlier and expanded in Sect. 6.2.3. Finally, the combined educational environment where technologies and spaces converge are discussed from a design point of view to set the scene for the implementation details in the next section.

6.3.1 AmI-PLE

The virtual space is predominantly characterised by the user interface that every individual learner interacts with following a successful logging-in to access the online learning environment through a web browser. Apart from the initial sign-in screen where the learner is asked to enter a username and a corresponding password to gain access, new users can register and sign-up by providing some basic information about themselves. Once the learner signs-in and accesses the main interface a number of partitioned segments are expected to be seen, as depicted in Fig. 6.1, that perform or display specific functionalities or information as specified earlier. These include the following:

- A *Title bar* that will contain a number of basic items which the learner reverts too only in specific need to change some kind of setting. Apart from a recognisable logo at the left-hand side of this top bar a number of icons provide numerous functionalities, namely:
  - *Adding new updates, tasks, activities or events* that the learner either finds out about, searches for, or have been proposed as beneficial recommendations to the academic programme. Such events will automatically have a calendar entry and a reminder sent out in due course;

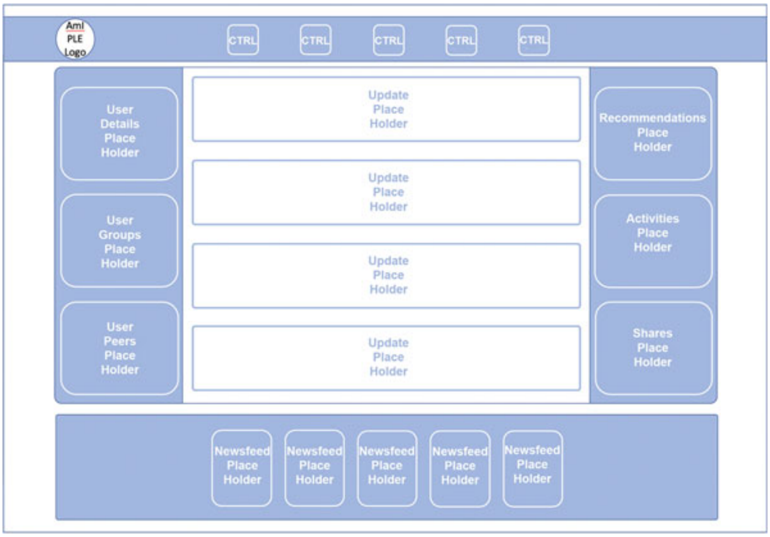

Fig. 6.1 AmI-PLE front interface design

– *Available academic content* associated to the respective education programme being followed will be available similar to functionality within any standard VLE. However, in this case additional content provided from external sources and social networks can potentially supplement the available academic content;

– *Other groups or communities* are available to join should a learner share common interests or has been recommended to do so by the educator or inferred by the underlying system through the profile generation and recommender components. Once the learner joins other academic groups their updates are also displayed on the learner's centre panel;

– *Messages* from other members and other interests groups can be passed on between groups or individual learners and thereby a notification would appear to notify the learner. Furthermore, the AmI-PLE itself, through the recommender system, can identify content, topics, or items of interest that a specific learner can benefit from and is notified accordingly;

– The *Personal icon* is typical of an online registration system where members are given the possibilities to access settings, profile details or logout of the AmI-PLE. Similar to other online systems this icon could actually be a thumbnail image of the learner to provide a much more personalised feel to the learning environment.

- The *Left panel* incorporates at least four segments which all provide information about the learner. The details provided by the system have a dual purpose. Other learners can browse through the public details of any other learner, while the hyperlinked details can be followed by the user to access personal groups and interests. The four different sections include:
  - *Learner profile image* together with a one-liner of how the learner describes oneself. Similar to social media platforms the possibility of adding the learner within an interest group or of sending a message is made available to instil a sense of social networking behaviour amongst learners;
  - *Learner group memberships* are listed and hyperlinked to the individual groups or classes. These also provide an insight into which courses or topical areas the learner is interested in and would like to receive updates from;
  - *Learner peers* are listed and hyperlinks to their profiles are available for others to check out. Additionally, once a specific learner group is followed the respective members of that interest group populate this section within the left panel;
  - Finally, the *learner interests* are listed to indicate to other learners and educators what are the main areas of interest. Additional areas of interest can potentially be proposed by the recommender system as the learner pursues interaction with the AmI-PLE and shows a particular interest or liking to a specific topic.

- A *Central panel* that has a single task to display all current activities happening related to every community the learner forms part of. Similar to a timeline of typical social media interfaces, this panel is aimed to inform the learner with any updates or what is happening in any of the classes or interest groups in a chronological order. Items displayed in this most prominent part of the interface could include:
  - *Updates* from different learners in any of the interest groups the learner is a member of. These updates are a mixture from all the groups and displayed in the order they occur. However, should a learner decided to focus on one specific interest group then the updates will only be sourced from that particular group still in chronological order;
  - *Comments* posted by different learners that are co-members in any of the interest groups of the learner are displayed in the central panel with a short snippet of that same comment. Should the learner indicate by clicking the comment to investigate further then the full contents are brought up within the central panel as leading attention. Similar to the updates if the learner selects a particular interest group to focus on then only the comments related to that group are displayed;
  - *Content contributions* are an important aspect of the AmI-PLE as they provide new and additional academic points of view to the attention of the learner. Any kind of knowledge-making activities that have been posted in any of the interest community groups are listed as part of the updates and hyperlinked to the

resource itself for an in-detail disclosure. A learner has the option to comment on any of the updates, comments or content updates providing feedback and/or much needed review. Once the learner comments then this is brought up in the list of updates to notify the original author and all other learners within the group;

– *Shares* also provide a source of academic content that has not been authored by the learner as links for various information sources are communicated to other learners in the group. Sharing of content is typical of social networks where users distribute a resource which they find interesting or note-worthy so that their peers, friends, or followers are exposed to it and can access it. In this case a learner might come across some interesting content with which an emotional connection has been established and thereby is compelled to impart the same emotion onto others. The content shared could be a webpage worth book-marking, a video or image that displays some important concept, information or deemed helpful, as well as post from other social media available that might trigger further thought. Shares are an excellent source of data to inform the profile generator what a specific learner deems valuable and so important that it needs to be shared. The recommender component feeds upon this information generated by the profiler and suggests similar content. Worth pointing out that curating information sourced from other portals and sharing it provides much focussed data that helps watering-down exactly the specific interests of the learner.

- The *Right panel* is intended to include at least three other segments that contain learner specific content. These are sourced through the different actions of the learner and contribute to the generation of the personal profile. The learner might need to refer back to previous posts, comments and feedback provided, shares done, as well as any knowledge-making artefacts submitted for others to provide feedback and reuse. The three subsections within the right panel include:

  – *My Recommendations* encapsulate the intelligent component of the AmI-PLE as the underlying software system is monitoring all the learner's actions and data generated through various interactions to provide academic suggestions and personalised content. This is only possible through the pattern-matching process of the profile generated for a learner to available content sourced from different information portals and social media as well as content posted by other learners and educators. The recommendations are directly related to the topical areas and communities in which the learner is subscribed as a member in. However, there are different kinds of recommendations that will appear in this list and once the learner accesses the resource recommended and accepts or rejects the recommendation it will be used to provide feedback to the profile generation and recommendation process. Recommendations can be in the form of websites, instructional videos, photographic materials, educational tools, academic projects, shares from other learners, artefacts posted in other groups, and all other kind of media available online. Additionally, and this will be expanded further later on in Sect. 6.3.3, the recommendations can be related to activities within the physical learning spaces involving learning aids and a pre-set academic task that have well-defined educational outcomes;

  - *My/Community Activities* is a chronological list of all activities performed by the learner while using the AmI-PLE. This does not include views or bread-crumbed clicks but tangible actions like posting, commenting, liking, providing feedback, submitting a knowledge artefact like presentations, blogs or ideas, sharing a resource like a video or a social media post, and updating personal settings. Every activity listed is hyperlinked to the actual activity to which the learner can return to update, reply to any comments or manage the resource in some other way. The list also provides the learner the opportunity to toggle the display of activities from a personal view to the activities within the interest group or community. This is similar to the central updates list but specifically focussed on what the activities related to this particular learner or specific community;
  - *My/Community Shares* are actual resources the learner has shared within the interest group and thereby are directly related to a specific community or group. The list not only provides a repository of files submitted by the learner for others to access within the group, but also an excellent medium to refer back when in need of a particular resource. Similar to the previous list, the learner can toggle to all the resource shares or files that have been performed within the community. Such a capability provides a much-needed file-sharing functionality that usually requires learners to revert to another medium like Google Drive [1] or Dropbox [2] where files intended to be shared by all can be transferred to, accessed, downloaded, and shared.

- The *Bottom panel* is aimed to house any social media sources the learner subscribes to thereby displaying content related to the individual interests and needs of the same learner. Numerous available social networks provide newsfeed interfaces to integrate within a webpage to provide a continuous stream of live feeds directly from the source into a destination third party webpage. The content provided within the newsfeed is all current newly published content that can be customised and filtered to deliver specific topics or focussed material. The source provider pushes regular updates once a learner subscribes to a specific content source provider. The AmI-PLE provides a space within the bottom panel to aggregate these feeds of web content that potentially provide food for thought as well as material for a learner to work with. The available list of source providers can be edited by the educator to ensure a current and updated stream of content providers are always available for the learners to select from and have at their disposition. Among the most valid and widely employed content source providers that offer a newsfeed are:

  - *Facebook* [3] is the current top social network available connecting over two billion subscribers worldwide. Its newsfeed provides freshly published content related to specific subscribed topical areas or featured news;

– *Twitter* [4] is another content provider as subscribed users narrate or tweet about anything and everything. Its newsfeed provides featured news items as well as links to further content resources that potentially provide beneficial academic content for learners to access and reuse;

– *Youtube* [5] is the most popular video-sharing portal currently on the web where visitors can upload original content and share with all web users. From an educational point of view Youtube is widely employed by educators as they make extensive use of video material to supplement their lesson plans banking on the fact that learners and people in general are more receptive to an audio-visual representation than to a simple narrative. AmI-PLE learners are able to not only access and view such material but also to integrate it in their own knowledge-making artefacts when creating a personal update;

– *Google News* [6] is one of the most comprehensive current up-to-date news source provider that aggregates its stream from numerous web sites. A learner can benefit and make use of educational content provided from a continuous flow of news that can easily be customised to specific needs and interests;

– *Time Magazine* [7] is one of the well-established and long-standing news providers in print and online as it provides continuous news content from all over the world. Time is a highly reliable source for learners as it cites all its sources and pushes academic-worthy news feeds that can be reused in knowledge-making.

• The *Knowledge-making interface* is the place where a learner is able to create and post a personal update that could potentially be a task or part of an assignment.

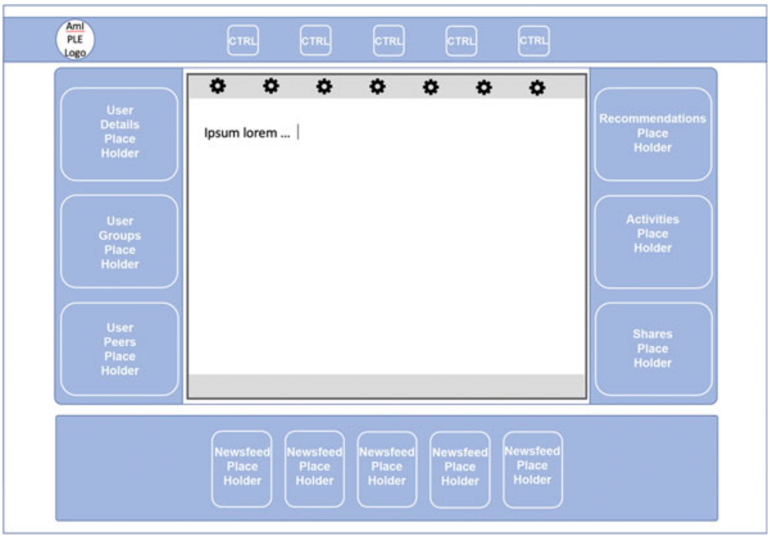

Fig. 6.2 Knowledge-making interface in AmI-PLE

Once the AmI-PLE user clicks on the top left icon on the Title bar the central panel switches from a list of current activities and updates happening to a rich editing interface as specified in Sect. 6.2.2. The interface shown in Fig. 6.2 depicts a classical editing workspace whereby a learner is free to author and create an artefact. The following functionalities are all included in this design, namely:

– Traditional word-processing capabilities;
– Integration of rich media like images, video, audio and file attachments;
– Hyperlinks directly from social media that render a thumbnail;
– Technical terminology like scientific formulae;
– Unicode support;
– LaTeX support;
– Toggle to HTML equivalent and edit.

6.3.2 Smart Classroom

The design of the smart environment is mainly devised on the proposals and ideas of Nair and Fielding [8] as stipulated in Sect. 5.2.2. The spaces identified earlier need to feature in one way or another and the target learner audience is at higher education with medium-sized groups of learners. The design shown in Fig. 6.3 illustrates a massive open space that is well-maintained and highly-lit environment using a mixture of natural light and artificial light fixtures.

The four corners of the learning environment are repurposed to serve different functions ranging from a typical classroom at the top left corner for learners to perform as in a presentation as well as for learners to watch when an educator or a guest speaker delivers a lecture in a classical way. The top right corner is envisaged for individual/independent learner study or maximum one-to-one engagements represented as a secret learning space where learners can seclude themselves from all others. The bottom right corner is secluded using temporary partitions to isolate a group learning space where learners can collaborate together as well as discuss and brainstorm. This space can also be employed as a data space as learners work on a common project and develop ideas as well as artefacts as a group. The fourth and final corner in the bottom left is a series of workstations typical of publishing space where learners can still work together but have fixed stations with plenty of table-top space. It can also be considered a data space where individual learners can work on a personal project and have access to resources as well as space to spread out and comfortably complete some academic task. At the centre of the room and conveniently portable to any other part of the classroom is a central console conference table to bring groups of learners at one point or even an individual learner requiring space to perform a task while happy to interact with others in such a communal space. This central console

Fig. 6.3 AmI classroom design

can be envisaged as accommodating three kinds of learning spaces, namely, a group learning space where a group of learners can collaborate, speak, and work together on an idea or a project, or simply just socialise and discuss an academic topic. It can also be envisaged as a publishing space as learners meet up and work on a common project as each contributes and chips in. Learners participating together will need such a face-to-face space to better communicate and efficiently converge on the task at hand.

Whichever learning space is considered in any of the five locations within this classroom design, learners can use any of the resources mentioned in Sect. 6.2.3 apart from their personal device. It is also assumed that a WIFI connection is available for all the learners to connect and to access the AmI-PLE that works in tandem with the available resources and sensors in the smart classroom. Additionally, the dividing partitions of these five areas are not fixed and can easily be moved or adjusted to reconfigure any of the spaces. The lecture area at the top left corner can switch to a theatre-like arena to house a bigger audience as it becomes part of the central area with the additional boundary removal of the bottom right space. Such a flexibility provides the scope for creativity and originality as learners are encouraged to courageously venture and experiment with new ideas. Around the classroom are several other resources like display screens, projectors, portable cabinets, and flexible chart holders that can also attach to the walls.

Items that have no direct contribution to the AmI classroom are not envisaged as part of the learning spaces but are still required for the successful implementation of this proposal. Amongst other things it is worth mentioning that in some designs

[8] the inclusion of a number of items are common like bathrooms, sinks, sports-related items like basketball hoops, kitchen units, vending machines and others. Such additional items provide an additional level of comfort and appeal to the environment which would potentially support and facilitate the educational process even further. However, it is out of the scope of the AmI classroom and this book to look into these issues further.

6.3.3 *Combined Educational Environment*

The coming together of the AmI-PLE and the smart classroom has already been referred to in the previous sections as the designs of the two separate spaces have been discussed and elaborated. The location-based identification helps in positioning the learners within specific learning spaces and interacting with tagged devices scattered around the classroom. Additionally, interactions with the virtual space and with other learners in relation to specific topics provide the necessary input for the profiler and recommender to suggest new activities, use of specific devices, and proposed content pushed at the specific learning space the learner is at, apart from the top part of the right panel within the AmI-PLE interface. In another combined educational setting, the educator sets an academic task for the intelligent system to identify and suggest those learners whose overlapping interest matches the theme of the task. The time and an adequate learning space within the AmI classroom can also be recommended for the group of learners to meet up and work as a community.

The use of video conferencing facilities in addition to the access to the AmI-PLE during a scheduled class meeting might suggest that the smart classroom is actually redundant and that learners can do without it. However, it is envisaged that a scheduled class is not held either face-to-face or synchronously over a video conferencing medium. The two are not mutually exclusive and can occur at the same time during the same meeting. The concept takes the AmI classroom to its highest potential as the virtual and physical spaces are combined in a digital/physical synchronous interaction which have the AmI-PLE in common. Learners who are physically present at the educational institution can turn up and attend the meeting in person, while those other learners who cannot make it to physically attend can connect via the synchronous video conferencing facility. In both cases all the learners will sign-in to the AmI-PLE and will all be virtually interacting together including the educator. Those who are in the classroom have obviously been picked up by the location sensors and thereby their presence is known to the educator. They might opt to revert to a secret learning space within the AmI classroom while attending the meeting or simple move their stuff to the central space to meet those attending in person for the meeting and then go back to whatever they were doing after the meeting is over.

Another important notion to point out is the use of cameras as catalyst to further reinforce the concept of the AmI classroom. The strategically positioned cameras can focus on those learners who are within the AmI classroom while personal webcams integrated within the devices of all the attendees, physical and virtual, can bring all the learners and educator together as the instrumentation compatibly combined with the virtual AmI-PLE brings into being a social unit. All three aspects, social, technological and educational, that have characterised the AmI classroom through this book are now happening in a real scenario as part of the empirical testing described in Sect. 6.5.

6.4 Implementation Details

The development process can easily be divided into two parts following the specification and design stages presented in the previous sections. On the one hand is the software development process of the virtual AmI-PLE interface and functionality, while on the other is the physical setup of the learning space with all its contents. The interfacing handshaking between the two is also an important issue but does not involve any kind of implementation aspects as long as the two spaces perform as expected and designed.

6.4.1 Software Development

The development of the AmI-PLE turned out to be an undemanding and straightforward process as a bespoke learning environment developed at the University of Illinois at Urbana-Champaign satisfied most of the requirements and design details. The learning environment, called Scholar [9], was designed and developed by Cope and Kalantzis [10], as stated earlier in Sect. 5.2.1, specifically to embody the seven e-learning affordances adopted in the AmI classroom. However, it was necessary to adapt this environment to accommodate the specific requirements and design details of the intelligent component within the AmI-PLE (Fig. 6.4).

The learning analytics enabled within the Scholar environment could be fruitfully employed to generate a learner profile together with two additional components. The first component, a parser, was required to extract learner interests and academic needs from all the posts, feedback and artefacts submitted by the same learner. A second component, an information agent, is required to collate all the content from the various sources. The content is required to be accurately tagged and efficiently saved to ensure that the recommender component can easily match educational material to the various learners' profile and quickly retrieve it to suggest to the different learners. Within this setup learners are required to create an account the first time they interact with the AmI-PLE and populate personal information that starts off the profiling process. The recommender agent will propose news feeds to append within the bottom panel while numerous suggestions will pop-up at the top section of the right panel. Amongst the recommendations are proposed community memberships as well as invitations to accept memberships into groups that the respective educators would have conveyed to their course participants. Figure 6.5 depicts the rich editing

Fig. 6.4 AmI-PLE developed interface

interface that was also part of the Scholar environment that enabled the authoring of strong multimedia knowledge. The learners are encouraged to incorporate such resources as well as external sources to provide the best medium to put forward their narrative. Different media are useful not simply to embellish an artefact but to efficiently employ the adequate medium that best conveys the knowledge rationale of the learner. Working in groups is also possible as any activities, shares, or posts occurring within a group that a learner is a member of will pop up on the central updates panel and within the right panel if the central panel is occupied by the authoring interface. This provides an opportunity for learners to give direct feedback to their peers as well as share the content to other groups. Such a functionality, similar to those in social networks, spawns-off new ideas and fresh collaborations while supporting further knowledge making.

6.4.2 Classroom Setup

The physical classroom was setup in preparation for the empirical study as part of a study-unit on the use of AI in education. The learning spaces were set up from scratch within a large room that previously was not designated as a classroom. The five different partitions of the classroom were setup as designed in Sect. 6.3.2 and shown as a collaged image in Fig. 6.6. Sensors and cameras were all set up and connected through the WIFI system to provide input to the underlying system that was being controlled from a server in a nearby office that served as a control room.

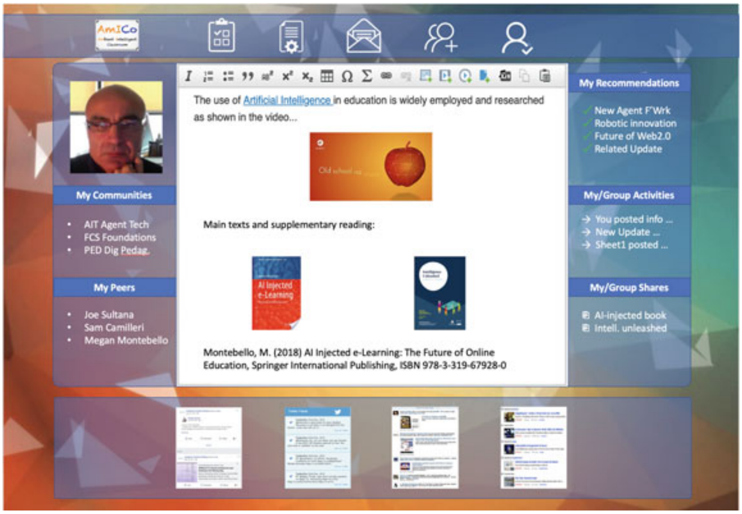

Fig. 6.5 AmI-PLE rich authoring interface

An electronic card system was employed to provide 24/7 access to the Ami classroom for all the participants of the empirical study.

The learning space at the top left corner was set to resemble a lecture room setup to enable a speaker to orally address a group of learners in a traditional one-to-many method. The possibility of using additional teaching aids like a whiteboard and/or a digital screen would allow the speaker to supplement the delivery through their use. Additionally, the listeners can also make use of personal devices within the same learning space. A nearby sensor using Bluetooth technology notifies the learners through the AmI-PLE with links to available resources related to the current academic session.

At the top right corner are the secluded secret spaces that enable individual learners resort to a quiet and reserved working area. Similar to the previous space, all the furniture and partitions can be conveniently moved around to accommodate additional learners as well as alternate configurations. Bluetooth sensors within these secret spaces allow the AmI-PLE to recommend individual tasks related to the specific interests of the learners or propose a selection of media off the knowledge sources that would be opportune to access when a learner is quietly in a secret space away from the rest of the other learners. Use of headphones, display screens, personal devices, and soft lighting are available and recommended in such spaces.

The informal group space shown in the bottom right hand corner of Fig. 6.6 provides a group of learners the opportunity to have casual face-to-face interaction while potentially using personal devices on their laps and digital screens and whiteboard on the side. The central conference-style table space can be seen at the centre of the collage as learners used it frequently it offers a similar functionality but with the possibility of having larger table-top space. This is ideal for group activities working

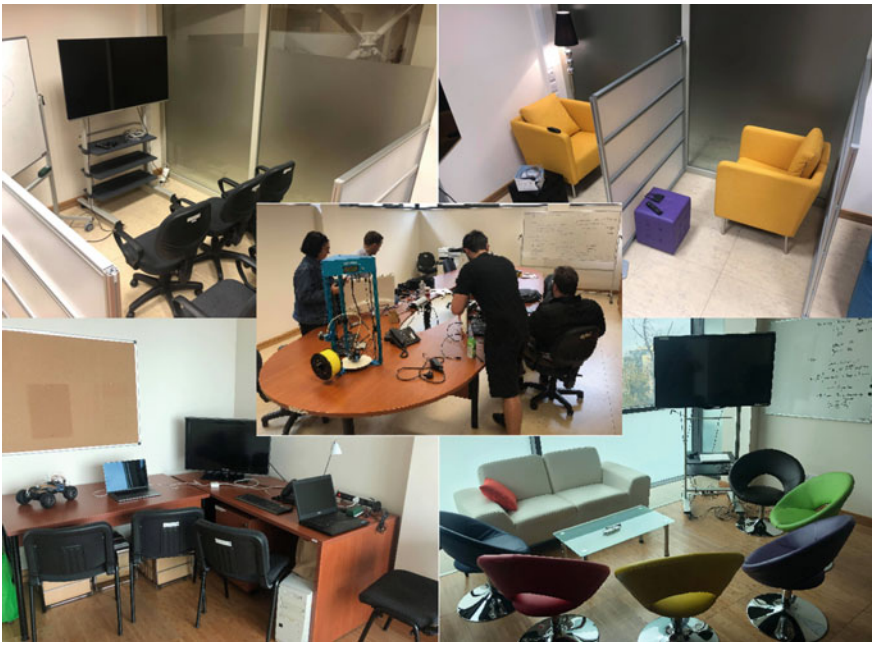

Fig. 6.6 The smart classroom setup

on a task and making use of the available space efficiently. In both cases these spaces promote participation and collaboration with an option to move around and employ additional resources. Bluetooth sensors, overhead cameras and personal webcams provide additional information to the AmI-PLE that triggers off the recommender agent to suggest academic alternatives.

Finally, the working stations in the bottom left corner provide ample space for learners to work individually or in groups on a project or an academic task that requires time and effort over a computer. Even though such tasks can be performed in other spaces, some learners might need the extra desk space to spread out their resources and collaborate with others who are working on other components of the same task. This space is also available as publishing areas where additional resources like printers, scanners, cameras, copiers, laminators, Arduino boards, tangible devices and other education resources are stored and accessible to use and employ. Location sensors assist learners to identify the whereabouts of resources while Bluetooth and RFID tags and readers close the gap between the virtual AmI-PLE and the physical resources.

6.4.3 Interoperability Affairs

As far as instrumentation is concerned and the successful communication between the devices, the physical space and the underlying system, numerous setup hick-ups needed to be ironed out, but which provided room for double checking their functionality and their positioning. The tests performed ensured that the devices were sending and receiving information from each other and that the range of operation was restricted to smaller areas to function within the learning spaces allocated. Furthermore, apart from the successful communication, data-type compatibility had to be tested and confirmed before the actual empirical study occurs to ensure that the data exchanged was error-free and consistent.

6.5 Empirical Testing

The testing performed was not the typical software testing traditionally performed when deploying a software application, but merely the use of a slightly more complicated teaching aid with university students who started attending a course last year. As performed at the beginning of classes of the academic year students are called to a particular venue to a first lecture during which a general introduction is given and the approximate unofficial ground rules are set. In this case fifteen students registered for a course about the use of AI in Education and totally agreed to take up the challenge. The investigation into the proposal and proof-of-concept of an AmI classroom was set as a course task and thereby adopted as a mission for them to accomplish. All the students were enthusiastic to participate and form an integral part of the team behind the conceptual idea being proposed and experimented. In this regard the empirical study could not have had a better start with the enrolment of such participants as these learners were ideally positioned within the domain of investigation as their predisposition to technology, devices and social media is above average. Throughout the fourteen weeks of classes the learners experimented with the different technologies and above all made use of the various learning spaces. The AmI-PLE was employed through all the sessions even though the learners attended classes either face-to-face within the AmI classroom or through a video conferencing connection. The outcome from the empirical testing can be documented in three parts as learners and educator provided feedback through the experience as well as after, the performance of the AmI-PLE has been logged, and the physical space configuration has been significantly and fruitfully employed throughout the testing of the AmI classroom.

6.5.1 The Human Aspect

The learners that participated in the first version of the AmI classroom were millennials within a higher education institution that welcomed the progressive interface of the AmI-PLE, but moreover related to the social-networking look & feel and practices to which they are so accustomed to and are fondly comfortable with. The possibility of having a variety of spaces to perform different tasks was appreciated and embraced as reflected in both the quantity of contributions, posts and feedback, but also in the rich and diverse quality of the knowledge artefacts they developed and submitted within their community. As an educator the task at hand is far more intricate and significantly substantial due to a number of factors. First and foremost, the fact of populating the knowledge sources for the first time and ensuring the reliability and soundness of the integrated social networks takes a lot of effort and time. Secondly, considering the innovative nature of the empirical study, an element of prudence and caution on the overall effectiveness of the AmI classroom took its toll as additional and supplementary materials, resources, academic content, instructional tasks, and knowledge providers were, over and above the scheduled counterparts, explored and held in store as a back-up plan.

6.5.2 The Software Aspect

The software aspect performed very well considering that the basic and major component of the virtual learning environment has already been in extensive use, tried and tested, and reliably robust and trustworthy. What was under closer scrutiny was the intelligent recommender component that had already been in use from a previous project. The iPLE component was adapted from the personalised e-learning project that has been extensively documented and tested [11, 12]. The combination of this important component as part of the Scholar environment as it sourced the necessary input data from the learners' interactions was also received very well by the same learners as they embraced the recommendations inferred by the AI agent. Additionally, the basic profile generator that was also adapted from the previous project performed as expected and delivered a functional learner profile that the recommender agent could apply and successfully achieve the expected outcomes.

6.5.3 The Physical Aspect

The spaces brought about a welcome change to the learning environment as the learners took full advantage of the available devices and resources purposely set for their use. Such commodities and dedicated spaces are rarely found within the educational institution except for the library that provides some of the spaces but in a much formal setting. Learners opted to make use of the different spaces even during their free time and suggested that the AmI classroom remains permanently set up as it helped them in their other studies. They claimed that the informal learning spaces had a positive effect on their education as the direct combination with the online learning environment provided an additional level of effectiveness. When asked about whether the use of sensors and cameras had any effect at all during the fourteen weeks, they asserted that after a few days they got used to and ignored them completely. They were aware of their presence only when the recommender agent posted notifications on the AmI-PLE as a result of their movements around the class and their actions within the virtual environment.

6.6 Conclusion

The Ambient intelligent classroom came to a realisation in this chapter as the three fundamental pillars supporting it had been expanded and presented in the previous three chapters. The three aspects, social, technological and educational, can clearly be seen permeating through the AmI classroom setup as three facets were reviewed through the process of analysis, design and implementation. The specifications of the virtual space, the physical space together with the requirements for the technologies to converge were stipulated and declared to set the scene for the design. Designs of the virtual AmI-PLE and the physical smart classroom were presented and discussed together with a hypothetical design of an educational environment that combined both together. Finally, details about the software implementation and logistical classroom setup were expounded together with interoperability issues between the two. The chapter closed with an evaluative assessment of three aspects, human, software and physical which once more reflect the three original grounding aspects of the AmI classroom. The empirical study was performed to test the viability and practicality of the AmI classroom as a proof-of-concept without looking into too much detail into the educational connotations of employing such a setup. The book proposes the adoption of the AmI classroom as a next step in the evolution of classroom education as it investigates the contributing concepts. Further study and research will be required to better understand and elaborate on the viability and long-term effectiveness of such an innovative and pioneering setup.

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Chapter 7
Future Directions

The direction in which
education starts a man
will determine his future in life.

Plato

7.1 Introduction

The closing chapter of this book brings the narrative of the *Ambient Intelligent Classroom* to an end, but marks the beginning of further work on the development and authentication of a formal and permanent setup. The inception, research and proposal of the AmI classroom unravelled numerous notions that brought together interesting and unseemingly incompatible concepts that fell into place and brought this new idea of the next generation classroom to a realisation. The fact that it is based on a trio of concepts that independently provide a plethora of things to the table, but together complement each other within the complexity of the classroom. The evolution of technologies and the pervasiveness of World-Wide Web push the idea even further as formal education is being transformed in clear view of all those who stop and reflect of what such changes will mean to learning. Such connotations will have serious repercussions on the main players of such a scenario as the role of educators and the educators themselves have to change and adapt to accommodate a new era. This new era of learning will also generate a new breed of digital learners who unaware of their own transformations provide incredible insights to educational technologist and researchers alike. Last but not least, and this book is a sort of precursor to this, the learning environment will have to continue to evolve and regenerate itself to ensure that it effectively provides the ideal conditions and fitting surroundings for the learning process to carry on, flourish and thrive.

M. Montebello, *The Ambient Intelligent Classroom*, Studies in Computational Intelligence 840, https://doi.org/10.1007/978-3-030-21882-9_7

7.2 Learning 4.0

7.2.1 Complete Automation

The popularity, relevance and practical application of Artificial Intelligence will persist and intensify as its effectiveness within the academic domain is not only deemed and proven to add-value to educational software, but that software development houses continue to invest and believe in its potential. Learners are much more receptive and consenting to novel technologies injected with intelligent software than educators, subject coordinators and school administrators. Learners are already being brought up around technologies which they take for granted, as well as software that performs tasks that usually requires some kind of human intelligence to perform. Some typical examples include natural language processing, image recognition, and advanced recommendation systems when shopping, watching movies or booking a holiday. However, when it comes to their education they tend to trust and accept whatever their professional educators and trainers propose and employ. If AI is to further contribute to the enhancement and support of educational software then it is obvious that technology-enhanced education researchers together with software developers are required to persist in their relentless efforts of investigating ways on how AI can further be applied and integrated within educational processes that would otherwise not be possible or that are already being fruitfully employed within other domains like tourism, sales, military, and motor industry. The question remains whether people will ever trust AI enough to allow software to complete automatic processes that usually requires a professional's thought process and decision. The future direction seems to be that learners and younger generations will increasingly enable intelligent software to assist them and automatically trust and rely on their advantageous benefits. Educators and administrators will typically challenge the complete automation until they realise that they have to and cannot do without intelligent software. Do we want to have history repeat itself and have our academic institutions the last entities to embrace and adopt the potential of technology-enhanced education? Or do we want to make sure we are ahead of all other domains and guarantee that tomorrow's professionals and workers are fully acquainted with what technology and AI has to offer?

7.2.2 Global Knowledge

Another future direction is related to the availability of knowledge and the ease of access to it. The current scene makes it already very clear that learners and educators revert to the web when they need to acquire information or search for a specific resource. The web is an excellent place to draw-off online expertise as numerous knowledge sources are available that provide a plethora of rich media to accommodate the information needs of all. However, this bring about a number of issues that need to be addressed as learners become more and more dependant or addicted to the freely available and easily accessible WWW knowledge. Do we need to be concerned about required skills to tap into such a massive and rich resource? Are the searches done efficiently or are the learners missing out on recalling all potential sources? Are the sources being acknowledged through proper citation and duly given credit? Are we witnessing a new breed of plagiarism professionals who are employing additional tools to overcome being caught? The point here is that we need to ensure that a positive and beneficial feature that learners and educators can take full advantage of for their respective academic needs and that was made possible through technology, is not tainted through misuse, abuse and discredit. Searching skills are required to be refined while other related skills are necessary to ensure that learners are truly going away with a positive educational experience. Apart from the proper referencing techniques to credit knowledgeable sources and original authors, learners need to acquire critical skills to discern and distinguish between sources that are unreliably not official or fake and sources that are academically acceptable and trustworthy. In a similar manner, learners need to be aware that the knowledge resources they create and place online for all others to provide feedback and reuse need to be properly claimed and given due credit when others adopt them. The concept of having a global knowledge repository that the WWW is providing can truly be considered a success when users make proper and ethical use of it while ensuring that they dynamically contribute to such a knowledge-base rather than just simply being passive consumers.

7.2.3 Assessment Repurposed

The third forward-looking notion towards the next learning generation is the repurposing of assessment from the traditional summative examination to a fairer and much more realistic formative appraisal. Exams conveniently served educators and educational institutions to assess learners' academic performance at the end of an academic programme. However, exams are only considered effective and appropriate if they successfully differentiate between different learners as assessments are expected to be distributed in a normal bell-shaped chart whereby approximately fifty percent of the learners are average achievers and twenty-five percent are low as well as high on either side of the bell shape. In reality a consensus on best practices has never been reached within the academic domain as learners required to be assessed in some way to evaluate their academic achievements, intellectual levels, critical skills and creative dexterities. Summative assessment does not manage to appraise all the work performed during the academic programme and evaluate the different factors that have been learnt. Thereby a formative and discreet way to assess learners in a fair and most equitable way should have possess a number of the following attributes:

- *Embedded* in a way where every piece of effort, minor as it may be, insignificant, and of whatever nature it is, should count towards the overall learner's academic achievement. Every artefact, comment, post, contribution, whether originally authored, curated, referenced, or collaged, short and secondary as it may be, contributes to the bigger picture [1]. Every data-point that is semantically legible and that has been generated by the learner influences and has an impact on the formative academic assessment and final grade. This has been the case within Scolar [2] and eventually in the AmI classroom;

- *Distributed* across the different actors that are contributing to the educational process. If the AmI classroom is taken as an example then the educator, the learner together with the other learners in the group, as well as the AmI-PLE can all factor in as part of the formative assessment. Such techniques are already being employed in MOOCs [3] where peer-reviewing [4, 5] is considered a valid and convenient way to assess learning outcomes. Similarly, computer-assisted assessment [6] has been previously employed and documented;
- *Object-Oriented* focussing on the tangible artefact authored by the learner as part of the knowledge making process. Such outputs are reflections of the learner's acquired abilities and skills as proposed by numerous educational researchers [7–9]. Learners choose to employ a specific medium which best represents the message they need to transmit [10];
- *Epistemically dependent* whereby learners are assessed on their deep metacognitive learning rather than on memorised information. Researchers [11] have argued that assessment should focus on the cognitive aspect whereby the process and product of knowledge making provides the evidence required for assessment. Such an epistemic concept [12, 13] was also practiced in Scholar and the AmI classroom;
- *Performativity dependent* rather than normativity as learners are induced in mastering the topical area through thinking and acting processes. This philosophical argument is based on Bloom's theoretical recommendations [14] on how to aim towards mastery learning together with other researchers [15, 16] who have looked into alternate ways of assessment educational achievement [17];
- *Participatory dependent* as learners are encouraged to collaborate and form social bonds with other learners to apply their collective intelligence [18]. Through such a process learners tend to become much more self-efficient in a way that they become responsible and in full control of their own education;
- *Differentiating* rather than contrasting or seeking the differences between learners. The use of non-standardised assessment supports the notion of comparing and equating learners' academic performance and skill acquisition in a way that does not necessarily have to be the same to demonstrate that they are equal. The productive diversity in assessment and learning endorsed by Kalantzis and Cope [19, 20] brings all this into context as they propose a differentiation principle where it is acceptable to have learners proceeding at their own pace without the pressure of all being at the same academic point in time. Even though some learners go through particular academic content at a faster rate than others, it does not necessary indicate that they are better or brighter, and not does it mean that in both cases the learners cannot achieve mastery in the topical domain.

7.3 Evolving Educator

The educator, as any other specialist, is required to professionally evolve and adjust while keeping up-to-date with any developments within the domain of expertise and/or operation. The challenges faced by educators continue to escalate as technologies, external influences, and liberal mind-sets are imposing even more demands than ever experienced within the classroom. The shifting role of educators is also a delicate and convoluted undertaking that involves training, experience and cognizance in order to successfully switch roles and act accordingly. In the next three subsections future directions of the evolving educator are discussed and put into perspective.

7.3.1 Digital Educator

The digital revolution has disrupted the lives and professions of educators in ways that a fundamental re-thinking in teacher training and in-service courses needs to be done. The impact of digital technology together with the novel tools, distinctive processes and diverse mindsets that such a paradigm shift brought about challenged the way educators lived and controlled their classrooms. Learners have pre-schools skills that numerous teachers do not understand and are not able to harness, understand, or take advantage of. The educator is required to be distinctively and methodically trained and prepared for a different kind of game completely. Teacher trainers' roles also need to adjust and accommodate the chasm that the digital era has brought about. Educational researchers [21, 22] have been claiming that ground-breaking pedagogies are required to transform the professional development of educators as a direct consequence of the digital wave, as teacher trainers themselves need to reassess and adjust their professional identity within such a context. The digital educator is not a person but a state of mind whereby the ICT set of tools and techniques assume a completely and unconditionally independent role from the subject of specialisation. Furthermore, the digital within the educator is not only an additional asset within the pedagogical skill-set, but a valuable support system that promotes the educator's professional identity [23].

7.3.2 Social Advocate

Social media have also impacted learners and educational processes that the educator needs to take stock of, adjust and accommodate. The use of social networks as knowledge sources through crowdsourcing has been documented and widely employed [24, 25]. Educators, as consumers of social media themselves, need to not only employ it as a source for supplementing their academic content but also as an essential medium of communication with their learners. Educators are required to employ the learners' preferred mode of communication as they are continuously using it and accustomed to it. The social aspect of the classroom has been discussed at length within the book and plays a pivotal role within the classroom, therefore, advocating the social as much as the technological and the educational is essential as much as it is effective. The evolving educator is required to subscribe, enrol, try out, register, create an account, and participate in current and emerging social networks not to be present where learners are currently hanging-around but to be proactively enthusiastic when learners decide to join. The educator should be the promoter of such communication media proposing novel and interesting alternatives while providing a sense of excitement, enthusiasm and anticipation.

7.3.3 LifeLong Learner

The proactive necessity mentioned in the previous subsection applies to the education and training aspect to ensure the educator is abreast of the learners and the domain of expertise [41]. In-service training, CPD courses, workshops and seminars are usually imposed by education officers or HR managers, and yet they are not enough to ensure that the evolving educator is up to scratch. A personal need and necessity to get to know what is trending in your specific area, what new tools are emerging, and which techniques are being more effective, is a typical behaviour of an educator who is continuously in touch with the latest news, current research, and budding technologies. An effective educator in this digital era needs to be a passionate champion of the chosen area while employing latest technologies, most recent research findings, and current lines of thought. The life-long learner has copious possibilities in achieving such a goal due to the high availability of online resources. Some examples to assist educators in their quest to remain well-informed about their topical area include open education resources, freely accessible MOOCs, crowdsourced knowledge, forums, webinars, information videos, mobile apps, and other push technologies.

7.4 Digital Learners

Learner are much more digitally oriented than any other actor within the classroom as they have been brought up and are only conscious of a world where the digital has conditioned the way they communicate, shop, acquire information, and perform all other mundane chores at home and at work. Within the academic arena the same situation gave rise to necessary changes that unsurprisingly had a radical effect on the educational, sociological and technological dimensions as educators, administrators, researchers, and philosophers struggled to come to terms with such a radical change [26, 27]. Learners are challenged with the contrasting forces that the digital introduced within their homes, society at large and within the classroom and schools [28]. Other players like parents and educators provide an additional take on the challenges learners are faced with as a continuously changing and demanding medium poses serious psychological strain on the learning process due to the multitude of opportunities that the new and transformative pedagogies have enabled [29]. The next subsections go through a few of the issues that will characterise the future directions of the digital learner.

7.4.1 Technology Adopter

Young learners are notoriously known to pick up technologies in their stride and quickly get accustomed to novel techniques and processes. However, some learners especially those in higher education tend to be set in their ways and long-established habits or learning practices. Researchers [30] have shown that learners that tend to experiment with and adopt new technologies tend to creatively and fruitfully employ the technology to boost cooperation and collaboration thereby reinforcing their learning behaviour and academic performance. Even though digital learners can be portrayed as early adopters, educators and peers are usually considered the main catalyst to such an adoption and thereby need to be encouraged to proactively venture and experiment with new emerging technologies. Social media and Web2.0 technologies play an important role in identifying and recommending the use of new technological tools and concepts. However, learners are still required to take the next step and try out what features and functionalities these technologies offer. Ideally learners become addicted and motivated to the excitement of discovering, adopting and promoting novel educational technologies to their peers, parents and educators.

7.4.2 Social Player

The addiction of learners to social media has been abundantly documented by researchers [31, 32], yet the need to engage learners within a social setting is essential from an educational point of view, as well as from a developmental perspective [33]. A social player can be exhibited in numerous learning activities that do not necessarily involve social networks. Typical examples that involve learners in a collaborative social behaviour include virtual worlds [34], games [35], as well as MOOCs [36] and other virtual learning environments as shown with the AmI classroom. Finding the right balance within a healthy learning pattern to engage in social activities, online and face-to-face, is crucial, while at the same time ensuring that the individual personal characteristics of each learner are preserved together with the engagement of other educational activities that contribute to the proper foundation of an educational experience.

7.4.3 New Skills Assessed

The future directions of assessment discussed earlier in Sect. 7.2.3, shed important connotations on the digital learner and which new skills would be appraised to contribute to the formative assessment. The ideas within the repurposed assessment implicitly encourages learners to interact with the learning environment while following the activities being presented. In this way the different and unique skills of individual learners are accounted for without focussing on the assessment process itself. The evolving learner is required to appreciate that the education process is a character-forming, developmental, and valuable process that assists learners in acquiring, cultivating and amplifying necessary life-skills. Their activities within an educationally-sound programme help them harness such skills and contribute to the overall assessment process to ensure that the topical subject has been mastered. These skills are further refined and augmented through the use of appropriate media, argumentation, critical and thinking techniques, as well as creativity.

7.5 Education Environments

The environment is bound to have major changes in the future as the traditional classroom is grossly outdated and inadequate for today's learners especially with the massive evolutionary changes in the technology involved and the teaching aids required. This book proposes a radical change to the physical classroom to create a number of learning spaces that address specific academic needs. Numerous authors like Carol Goodell [37] has been suggesting since the early 70s that the classroom is in need of a change, while others [38] argue that changing the classroom environment can increase learner engagement. The next three subsections delve into three specific issues out of many related to the social, technological and educational aspects of the classroom to discuss what future directions can bring about.

7.5.1 AI Enabled

The application of AI to education is not a new proposal but has been documented over and over again including sections within this book. The contribution of AI within the AmI classroom is above average and yet in the future the influence of AI will permeate the classroom even more as educators tend to trust AI-enabled applications even further. Enabling AI within the classroom to raise the level of automation as suggested in Sect. 7.2.1 requires a series of obvious benefits for the learners and the educator. The smooth running of an AI-enabled classroom would be instrumental to the benefit of the learners, which is the most important, but also to the credibility of the AI technology being employed. It will take one minor educational setback to jeopardise the credibility of the AI within the classroom that had been building up trust through the years. For this reason, it is important that the developers together with the educational consultants ensure they deploy an AI-enabled system that is highly reliable and unfailingly trustworthy.

7.5.2 Authenticating Sources

Another issue of concern when technology-enabled classrooms will become more popular and in demand is the validity and authentication of knowledge sources together with the validity and veracity of online information. Digital learners tend to assume that anything that is found online is genuinely correct and accurate even though educators and parents duly point out that an element of judgement is required. Such a shrewd skill to figure out in a cunning way whether a source or a piece of information is valid goes a long way if learners only entrust content that is cited. If an automated system is collecting information from a variety of knowledge sources to populate a knowledge-base within an AI-enabled classroom then proper authentication digital certificates are required. An electronic trustworthy system is required to ensure that knowledge sources are academically safe and can be employed within an educational setting where it can be safely assumed that it is perfectly safe for learners to access, use and cite such information.

7.5.3 Holistic Skills

Additional skills beyond those learners acquire through formal learning will be required to ensure learners procure a holistic education. Critical and creative thinking are good examples of typical skills that learners would benefit from and which unfortunately are not something one can learn in a straight forward way. Future education environments should encourage the practice of such skills through specifically focused tasks that engage learners in complex reasoning undertakings [39, 40]. The education environment enables learners to express themselves through cycles of interaction that involve a mixture of knowledge making, exchange of ideas, feedback to and from other learners, as well as essential interactions with the educator. Furthermore, the repurposed assessment proposed earlier supports the appraisal of these higher-level epistemic performances thereby encouraging learners to further engage and sharpen such holistic skills.

7.6 Conclusion

A number of future directions have been identified and discussed in this chapter in light of the AmI classroom that has been presented in this book. This work proposes a number of initiatives based on personal ideas, established models and reputable learning theories which will hopefully shed light on the future of classrooms. The first chapter brought into context the evolution of classrooms from basic meeting venues where people aggregated to inform themselves and learn to formalised and systematic classroom with rows of desks and chairs as we know them today. The topical area that features throughout the book, Ambient Intelligence, was then expanded in Chap. 2 to ensure that the reader has a full picture of its potential and applicability. The chapter closes with a case for ambient intelligence within the classroom which is argued to be grounded on three fundamental dimensional aspects. The first aspect refers to the social nature of a classroom which is discussed and examined in the next chapter whereby the classroom is envisaged as a hive of social activities with the learners and educator being the main actors within what is described as a living entity. The next chapter tackles the second aspect related to technology where hardware and software technologies come together to help realise the AmI classroom from a technical standpoint. The third aspect was covered in the following chapter and tackled all the educational issues involved with an important grounding in two learning models from educational literature that contributed to the realization of an AmI Personal Learning Environment. Finally, the book reaches a climax with an in-depth coverage of the AmI classroom itself, from its inception, to analysis, design, and eventual implementation and testing. This provided the suitable scope of this book of conceptualizing and providing a proof-of-concept implementation of the AmI classroom. It also delivered a number of important pointers for future research to take the AmI classroom to the next level as educators and educational administrators potentially consider embarking on a large-scale project of deploying numerous AmI classrooms that would lead by ground-breaking example of how classrooms will evolve in the not-so-distant future.

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Glossary

Adaptive Learning Theory: A learning theory that conceptualises the use of technology to customise and tailor educational resources to accommodate the specific and unique needs of each learner.
Ambient Assisted Living—AAL: A popular sub-area of Ambient Intelligence which specifically caters in assisting persons who require help and supervision within their own living habitat.
Ambient Intelligence—AmI: Artificial intelligence applied to an enclosed environment like a room, an office, a house, a boat, car, plane, or even a city. The ambient that surrounds the user or learner intelligently recognises the uqiqueness of the person and reacts accordingly in a personalised manner.
Artificial Intelligence—AI: The use of computer science techniques to develop computer programs in an attempt to simulate human behaviour. These programs perform tasks that usually require a human to do and thereby convey a sense of added value when compared to simple computer tasks.
Connectivism Learning Theory: A theory first put forward by Siemens [1] presupposes that in the digital information age knowledge is the product of influences from a number of sources, both human and non-human. When an individual is able to reconcile all the connections from the various information sources in a meaning-making exercise, learning happens.
Crowdsourcing: The use of online users to collectively contribute and aggregate information towards a common goal. Initially coined by Jeff Howe and Mark Robinson to describe the way commercial entities outsourced tasks to the crowd over the World-Wide Web [2].
e-Learning: Is learning on Internet Time, the convergence of learning and networks. e-Learning is a vision of what corporate training can become. E-Learning is to traditional training as eBusiness is to business as usual [3]. Different versions and generation of e-learning exist as technologies evolved over the years.
Intelligent Adaptive Learning—IAL: Intelligent adaptive learning is defined as digital learning that immerses students in modular learning environments where every decision a student makes is captured, considered in the context of sound learn-

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ing theory, and then used to guide the student's learning experiences, to adjust the student's path and pace within and between lessons, and to provide formative and summative data to the student's teacher. This type of learning tailors instruction to each student's unique needs, current understandings, and interests, while ensuring that all responses subscribe to sound pedagogy [4].

Internet of Things—IoT: An electronic network of all objects in the real world connected and uniquely identified with the ability to communicate and coordinate amongst themselves. The smart devices could also be embedded in everyday objects that enables them to transmit and receive data.

Learning Technologies: Different media, technology-based applications and tools that can be used to facilitate and support learning. Learning technologies also include the 21st century digital practices that would require a specific set of skills and attitudes.

Pedagogy: The art and science of teaching. Usually taken for granted however effective teaching requires specific skills and experience. Educators can employ a plethora of teaching strategies to optimise the use of the learning medium selected.

Personal Learning Environment—PLE: A combination of personal academic tools, services and communities that a learner makes use of. Electronic personal learning spaces are traditionally made up of two components, namely, a personal learning network and a personal learning portfolio.

Personal Learning Network—PLN: A virtual and informal network of friends and resources that a learner can interact with and from which information and knowledge is extracted for personal use. A personal learning network usually forms part of a personal learning environment.

Personal Learning Portfolio—PLP: A compendium of academic works that act as educational evidence of a particular learner. It is commonly part of a personal learning environment and is used to assess the learner, keep an academic record, and act as feedback to the learner.

Self-Determinism Learning Theory: A learning theory that promotes the motivation of the self within a learning environment. Deci and Ryan [5] initial theory about intrinsic and extrinsic motivation and basic psychological needs applied to the educational domain.

Social Constructivism Learning Theory: A theory posited by Vygotsky [6] that describes how meaning making can be aided by the social context in which the learner is found. Therefore, community and collaborative activities become an important influence on the learning.

Social Networks: This term refers to the connections between individuals in a community. Christakis and Fowler [7] define this as "an organised set of people that consists of two kinds of elements: human beings and the connections between them... Real, everyday social networks evolve organically from the natural tendency of each person to seek out and make many or few friends, to have large or small families, to work in personable or anonymous workplaces" (p. 13).

Technology Acceptance Model—TAM: Based on the Davis [8] theory of reasoned action it models how learners come to accept, usefulness and ease of use, a system like an e-learning environment.

Virtual Learning Environment—VLE: This term broadly encompasses virtual spaces that are used for learning. Such environments can include Learning Management Systems (LMS), Multiuser Virtual Environments (MUVEs), Virtual Worlds (VWs), and Serious Games.
Web 2.0: O'Reilly [9] coined this term to demarcate a phase within the evolution of the WWW whereby websites allow user-generated content thus encouraging web user to author, contribute, share, and distribute their own and others material. Social media were a direct result of this particular phase that also has dynamic characteristics in contrast to previous static read-only counterparts.
World-Wide Web—WWW: The massive knowledge base of information spread over the global network of servers known as the Internet. Different generations of WWW represent the evolution of how this technology has radically changed over a short period of time from a read-only, to a read-write and share.

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