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Matthew Montebello

# The Ambient Intelligent Classroom

## Beyond the Indispensable Educator

Springer

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*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
March 2018

Matthew Montebello

# 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.

# Contents

# 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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