

Studies in Computational Intelligence

Volume 840

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Matthew Montebello

The Ambient Intelligent Classroom

Beyond the Indispensable Educator



Springer

Prof. Matthew Montebello
Department of Artificial Intelligence
Faculty of Information and Communications
Technology
University of Malta
Msida, Malta

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>

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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
Urbana, IL, USA
April 2019

Prof. Mary Kalantzis
Prof. Bill Cope

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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

- 1 Introduction** 1
 - 1.1 Introduction 1
 - 1.2 Teacher-Centred Pedagogy 2
 - 1.3 Student-Centred and Reflexive Methodologies 6
 - 1.4 Learning Modalities and Affordances 7
 - 1.5 Conclusion 8
 - References 9
- 2 Ambient Intelligence** 11
 - 2.1 Introduction 11
 - 2.2 Historical Background 12
 - 2.2.1 Ubiquitous and Pervasive 15
 - 2.2.2 Internet of Things 16
 - 2.2.3 Smart and Calm Computing 18
 - 2.3 Enabling Technologies 19
 - 2.3.1 Techniques 21
 - 2.3.2 Sensors 24
 - 2.3.3 Setups 25
 - 2.4 AmI in Action 27
 - 2.4.1 Assisted Living 28
 - 2.4.2 Transportation 29
 - 2.4.3 Civic Environments 30
 - 2.5 Case for the Classroom 30
 - 2.5.1 Social Dimension 31
 - 2.5.2 Technological Dimension 31
 - 2.5.3 Educational Dimension 32
 - 2.6 Conclusion 32
 - References 33

3 Social Aspect	35
3.1 Introduction	35
3.2 Human Aspect of a Classroom	36
3.2.1 Multidimensionality	37
3.2.2 Simultaneity	37
3.2.3 Immediacy	38
3.2.4 Unpredictability	39
3.2.5 Publicness	39
3.2.6 History	40
3.3 Connectivism Learning Theory	40
3.4 Related Work	42
3.5 Implications to the AmI Classroom	45
3.6 Conclusion	46
References	46
4 Technological Aspect	49
4.1 Introduction	49
4.2 Technology in Education	50
4.3 Adaptive Learning Theory	53
4.4 Related Work	55
4.4.1 The ‘Intelligent Classroom’	56
4.4.2 iClass	57
4.4.3 ClassMATE	59
4.5 Implications to the AmI Classroom	61
4.5.1 Unobtrusive Hardware	61
4.5.2 Seamless Communication Infrastructure	62
4.5.3 Distributed Device Network	62
4.5.4 Intuitive User Interface	62
4.5.5 Dependable and Secure	63
4.5.6 Learner Profile and the Educator	63
4.5.7 Compatibility and Scope	64
4.5.8 Fruitfulness and Role	65
4.5.9 Student Outcome and Clarity	65
4.6 Conclusion	67
References	68
5 Educational Aspect	71
5.1 Introduction	71
5.2 Learning Models	72
5.2.1 New Learning Affordances	72
5.2.2 Modalities and Spaces within a School Environment	76
5.2.3 Merging Models	79

5.3	Personal Learning Environment	80
5.3.1	Personal Learning Network	80
5.3.2	Personal Learning Portfolio	82
5.3.3	Ambient Intelligent PLE	82
5.4	Related Work	83
5.4.1	Psychological Type Model	84
5.4.2	Learner Type Model	84
5.4.3	Experiential Type Model	85
5.4.4	Personality Type Model	85
5.4.5	Experiences Type Model	86
5.5	Implications to the AmI Classroom	87
5.6	Conclusion	88
	References	89
6	The Ambient Intelligent Classroom	93
6.1	Introduction	93
6.2	Background Rationale	94
6.2.1	Scenario Description	94
6.2.2	Virtual Space	95
6.2.3	Physical Space	99
6.2.4	Converging Technologies	102
6.3	Architectural Design	105
6.3.1	AmI-PLE	105
6.3.2	Smart Classroom	111
6.3.3	Combined Educational Environment	113
6.4	Implementation Details	114
6.4.1	Software Development	114
6.4.2	Classroom Setup	115
6.4.3	Interoperability Affairs	118
6.5	Empirical Testing	118
6.5.1	The Human Aspect	119
6.5.2	The Software Aspect	119
6.5.3	The Physical Aspect	119
6.6	Conclusion	120
	References	120
7	Future Directions	123
7.1	Introduction	123
7.2	Learning 4.0	124
7.2.1	Complete Automation	124
7.2.2	Global Knowledge	124
7.2.3	Assessment Repurposed	125

7.3	Evolving Educator	127
7.3.1	Digital Educator	127
7.3.2	Social Advocate	127
7.3.3	LifeLong Learner.	128
7.4	Digital Learners	128
7.4.1	Technology Adopter	129
7.4.2	Social Player	129
7.4.3	New Skills Assessed	130
7.5	Education Environments	130
7.5.1	AI Enabled	130
7.5.2	Authenticating Sources.	131
7.5.3	Holistic Skills	131
7.6	Conclusion	132
	References	132
	Glossary	135
	Index	139

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

List of Figures

Fig. 1.1	Medieval classroom [1]	2
Fig. 1.2	First classrooms [3]	3
Fig. 1.3	Classic classroom setup [4].	4
Fig. 1.4	Modern classroom configuration [4].	5
Fig. 1.5	Use of smart devices at university [5]	5
Fig. 1.6	Eight affordance of new learning [6]	8
Fig. 2.1	Topic map for embedded and mobile computing [23]	18
Fig. 2.2	AmI key technologies adapted from [32]	20
Fig. 2.3	AmI cyclic system [33]	22
Fig. 2.4	Components setup of a smart environment [36].	26
Fig. 2.5	AmI architectural setup [37].	26
Fig. 2.6	Reasoning engine of a typical AmI environment [36].	27
Fig. 2.7	Real-time interface of a typical AmI environment [37].	28
Fig. 2.8	Three-dimensional aspects of AmI classrooms	31
Fig. 4.1	Phenomenon converging in support of intelligent adaptive learning [14].	53
Fig. 4.2	Classroom environment leveraging an intelligent adaptive learning system [14].	54
Fig. 4.3	The ‘Intelligent Classroom’ interface [31].	56
Fig. 4.4	The iClass sensors, weather station and multimedia video projector [32]	57
Fig. 4.5	The iClass network infrastructure [32]	58
Fig. 4.6	The classMATE in action [36]	59
Fig. 4.7	The ClassMATE architecture [34]	60
Fig. 4.8	Technology Integration Planning (TIP) model [54].	66
Fig. 5.1	Prototype classroom with potentially 7 spaces and 18 modalities [19]	80
Fig. 5.2	Anatomy of a PLE [21]	81
Fig. 5.3	Experiential learning cycle by Kolb and Kolb [64].	85
Fig. 5.4	Honey and mumford addition to experiential learning [65].	86
Fig. 6.1	AmI-PLE front interface design	106

Fig. 6.2	Knowledge-making interface in AmI-PLE	110
Fig. 6.3	AmI classroom design	112
Fig. 6.4	AmI-PLE developed interface.	115
Fig. 6.5	AmI-PLE rich authoring interface.	116
Fig. 6.6	The smart classroom setup	117

List of Tables

Table 1.1	Learning modalities [7]	7
Table 2.1	Eras of technology evolution [23]	16
Table 2.2	Variety of AmI sensors	25
Table 5.1	Comparing Didactic and Reflexive Pedagogy	73