Linda Daniela *Editor*

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Editor
Linda Daniela
Faculty of Education, Psychology, and Art
University of Latvia
Riga, Latvia

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Foreword

Society is currently facing various challenges arising from the technology and the different digital solutions which open up new opportunities; to make them meaningful, however, certain competences are also needed. Education can ensure the acquisition of these competences, but in order to be successful in that, educational sciences need to transform, as it is clear that technological advancement is current and not simply a future event.

The technology-enhanced learning (TEL) process is one of today's topicalities, where technology and digital solutions can be used for a variety of purposes to radically change the learning environment. However, educators are not always ready for these challenges. On the one hand are the possibilities created by technology; on the other, however, are the regularities of human development, which include the conditions of physical development and the conditions of metacognitive development that are essential for a human to be able to analyse information, to make responsible decisions and to innovate. This points to the need to update the role of pedagogy so that changes can take place in the education process. The opportunities created by technology should be used to support individuals in the process of knowledge building through technology as a support for acquiring new competences and as a tool for developing new knowledge while bearing in mind the risks that technology can create and preparing future generations to mitigate these risks.

The idea of smart pedagogy introduced in this book is innovative and absolutely necessary for further development, since pedagogy is a driving wheel for learning to take place. The role of smart pedagogy in the context of the technology-enhanced learning process is clearly demonstrated, and the basic principles that are essential in the transformation of education are defined. The text defines the topical competencies needed by educators, indicates future research directions and defines the concept of smart pedagogy.

Professor Linda Daniela together with colleagues has taken on the mission to develop the concept of smart pedagogy. In this book, alongside the ideas developed on smart pedagogy and smart learning, research results on technology-enhanced learning at different levels of education are summarised, from preschool to tertiary education. However, there is an urgent need for further development of these ideas, as technological progress is becoming faster day by day, and humans need to be prepared not only as competent users of technologies but as developers of innovations, too. The summarised research results shed light on the positive outcomes of the technology-enhanced learning process and suggest the future directions in which research needs to be developed.

For meaningful use of the technology-enhanced learning environment, the development of smart pedagogical approaches is an absolute necessity, as they can answer some of the questions raised by educators: How to support learning through technologies? How to increase students' interest in learning if it is acknowledged that metacognition is influenced by technologies? How to use technological possibilities to support students with special needs in their learning process? How to support learning in the transformed educational space? How to ensure cybersecurity? These are challenges which must be met, and future generations should also be prepared to meet these challenges.

Riga, Latvia Ina Druviete

Preface

Why Smart Pedagogy?

With technological progress, technologies and digital solutions increasingly entering the educational environment, the attitude to technology can be characterised as fear and fascination, where there are a number of people who believe that technologies create chaos in education, where students are not fully engaged in the learning process and do not take responsibility for their knowledge building because they are fully engaged with technologies which provide the possibility of reaching information immediately. There are statements, for example, that the use of technologies makes people lazy. Technologies are blamed for a great many of the problems we are facing or will face in the near future: for example, technologies will take over all the jobs; technologies reduce the ability and desire to learn; the use of technologies reduces attention span; and so on. On the other hand, there is the effect of fascination, where technologies are assumed to be the tools which will solve all possible problems; they will make the learning process interesting; students will become motivated; they will ensure rapid knowledge growth and will support the sustainable development and the wellbeing of the society.

Like many fairy tales where the happy ending is always coming, the same is true for technological progress. It must be admitted, though, that particular effort is needed to ensure that everyone knows how to interact with technologies to learn and to develop innovative solutions which will support wellbeing and sustainable development. For education, this effort means learning how to use the technologies meaningfully. Technologies by themselves cannot develop innovations and cannot take decisions if they are not developed by humans (at least for the time being). This highlights that there should be a transformed learning process which beyond the time and space frame to support future generations in developing the competences needed for living and working in a technology-rich environment.

It may be thought that these immeasurable possibilities of access to knowledge and to learning content, where the human has the possibility to learn at his own pace and learn what is needed at any moment, diminish the role of pedagogy; in reality, though, the reverse is true. The role of pedagogy becomes more important because there is an urgent need to find ways to teach and to support learning in the transformed learning environment. To support these changes, it must be acknowledged that pedagogy should change to become smart pedagogy, which has three clear dimensions:

1. Human developmental regularities, which include the conditions for the development of cognitive processes, the conditions for sensory development and the conditions for socio-emotional development
2. The taxonomy of the educational process, which includes the goals to be achieved and the regularities of the learning process necessary to achieve these goals
3. Technological progress, which entails the need for changes in teachers' pedagogical competence, one of the most important components of this competence being predictive analytical competence

Smart pedagogy can support educators in finding the answers on how to support learning in the transformed educational process, how to incorporate technologies into learning to support the development of metacognition, how to support knowledge building, how to support the development of digital competences and so on. All of this indicates the necessity to ground the new direction of pedagogy, which in this book is defined as smart pedagogy, to ensure smart use of different digital technologies.

In the first chapter of the book, the concept of smart pedagogy is defined, and the need for a new pedagogical direction using a technology-enhanced learning process is outlined. The subsequent 22 chapters detail the actual competencies needed by educators and give future directions for concept development and research. Further publications will follow in the future.

Organisation of the Book

The book is organised into two parts where the first part is devoted to the development of the concept of smart pedagogy with 10 chapters and the second part is devoted to researches on technology-enhanced learning (TEL) process with 13 chapters. A brief description of each of the chapters follows.

Concept Development of Smart Pedagogy

Chapter 1 defines the idea of smart pedagogy for technology-enhanced learning, and the author explains why the term "smart" has been chosen to define the pedagogical aspects of TEL. In addition, a conceptual model of the educational process in which smart pedagogy is the driving force of technology-enhanced learning is developed. There is outlined the necessity for *predictive analytical competence*, which is emerging for TEL.

Chapter 2 characterises smart pedagogy (smart teaching and smart learning) in the context of the fast-changing digital world. As part of the theoretical framework of the text, authors refer to elements of the concept of network society by Manuel Castells, liquid modernity by Zygmunt Bauman and mobilities paradigm by John Urry.

Chapter 3 introduces with reality of a major paradigm shift, in the form of the fourth industrial revolution, or Industry 4.0, that requires a rapid response through Information 4.0. New technologies and infrastructures enable learning to be personalised to each individual learner. Technological objects metamorphose from tools or environments into personified agents that help teachers evaluate the potential and progress of each learner and might eventually decide for them.

Chapter 4 seeks to update views on didactic practices in the rapidly changing field of education and addresses the timely problem of paradigm transition when shifts in deliberate education have been imposed upon by at least three factors: increased access to digital technologies in the learners' everyday life and teaching-learning, reform of educational content towards the acquisition of competencies valid for the twenty-first-century social developments and, in response to these, appropriate changes in teachers' professional competence to maintain a learner's learning-centred didactics with learners.

Chapter 5 makes readers aware of cognitive development of children in different age groups in order to offer teaching methods and tasks that can be well-perceived by students and that foster the development of their cognitive abilities. This chapter provides a brief overview of cognitive development of children at different school ages, including development of executive functions and cognitive abilities, and gives examples of how information technology tools can be effectively used for different age groups.

Chapter 6 focuses on the role of incentives in the new educational environments, which are flooded by cutting-edge technology, and the value of the gamification in learning process. Students with different learning styles, interests, motivations and cultural background coexist in classrooms, and the multisensory approach supported by technology seems to serve the principles of differentiated instruction, providing teachers with the opportunity to adapt the process to the needs of each child.

Chapter 7 examines the nature of smart pedagogies and their intersection with mobile pedagogies. Authors unpack notions of innovation and disruption. Then they discuss smart mobile learning activities for school students identified from a systematic literature review, together with the pedagogical principles underpinning them. They argue to encourage smart pedagogies; teacher educators should support teachers to implement "feasible disruptions". Consequently, implications for teacher education are explored.

Chapter 8 attempts to analyse how art didactics and creative technologies define a framework of active critical tasks, triggering students' thought and artistic creation. Particular emphasis is placed on the process which is not theory but mostly activity. They reflect, compensate, avoid prescriptions and become hardened against the aims of predetermined agendas. Aesthetic education shapes technique. Students, with the help of software programmes, create and are cut off from chain reactions that are in line with dominant cultural standards.

Chapter 9 discusses a plethora of practical suggestions which could be considered to make pedagogy smarter, more active and attractive to students while simultaneously being efficient and obtaining results. Authors argue that pedagogy should not be centred only on unique and exclusive resources but ensure an articulated relationship with other resources.

Chapter 10 provides an overview of the place and role of learning platforms in the pedagogical process, defines the differences between learning platforms and learning management systems and offers a toolkit for evaluating learning platforms.

Research on Technology-Enhanced Learning Process

Chapter 11 explores the application of a new method to assess the emergence and evolution of collective cognitive responsibility (CCR) based on peer valuation of impactful builders in an undergraduate course. This study suggests that peer valuation of students' contributions could be one way to approximate students' engagement in CCR and potentially empower less committed participants to become impactful builders and collaborators.

Chapter 12 presents a qualitative and quantitative analysis aiming to understand the dimensions that make it possible to set up a smart teacher training within the small school context. The quantitative analysis and qualitative study were carried out to investigate the elements in the educational path that promote innovation, sustainability and replicability.

Chapter 13 aims at exploring principles of teaching and learning in the context of smart technologies. The chapter addresses the basic question: In what ways are children empowered by the use of smart digital technologies?

Chapter 14 gives an insight into the study's aim to explore the impact on kindergarten children's mathematical competence after the implementation of a software application for comparison, classification, one-to-one correspondence and counting with tablet computers. The results of the study support a positive correlation between children's early numeracy competence and the integration of tablet computers in teaching and learning numbers.

Chapter 15 proposes the combination of gamification with game technologies in order to produce smart learning environments. Within that scenario one may employ the developmental flexibility of game engines in order to achieve high-level content delivery offered by video-game environments. This chapter presents how common problems may be resolved via the development of media-rich smart learning environments with the use of proprietary multimedia development environments that do not require advanced programming experience.

Chapter 16 explores the Bridge21 activity model designed to support the development of an innovative twenty-first-century learning environment in second-level schools. Over the past 10 years, the model has been developed, trialled and tested with over 14,000 students and over 2000 teachers, both in informal and formal educational scenarios. This chapter introduces the Bridge21 activity model and provides approaches and techniques to those who wish to design Bridge21 learning experience. It empowers schools to build on what already works well for teachers and students while creating the space for innovative ideas and alternative approaches to teaching and learning. It presents a shift in focus from the teaching of individual subjects to the teaching of key competencies and twenty-first-century learning skills.

Chapter 17 presents a few attempts of prospective mathematics teachers to use digital tools to teach different mathematics topics to secondary school students. Suggestions are made to increase the smartness of the learning environments used by the prospective teachers so that they can develop technologically enhanced mathematics pedagogical content knowledge (TEMPCK).

Chapter 18 presents a literature review of virtual reality applications in education (with emphasis on both technological and pedagogical aspects, integration and evaluation criteria), as well as shows the results of a small qualitative study conducted with teachers and an educational media specialist.

Chapter 19 focuses on flipped learning and online discussions initiated in the online learning system Moodle. In discussed action research project, flipped learning preceded online discussions that were organised at the end of the course. The aim was to improve students' preparedness for a discussion topic and engage them in active learning. Authors claim that this approach seems to be the key precondition for improving the quality of smart learning we tried to establish in our higher education context.

Chapter 20 highlights the pedagogical approach taken by the author in his teaching, both at secondary school and university undergraduate level. It begins with an overview of how a variety of digital approaches to teaching such as technology, pedagogy and content knowledge (TPACK) were developed. Then it explores these approaches such as flipped learning and blog journaling in detail by examining their strengths and weaknesses and which apps the author suggests they be used with. This chapter concludes with the lessons learned from this action research approach taken by the author.

Chapter 21 discusses different techniques of texture iterations to correct and improve the texture of the 3D models of the Great Wall. Overall, several pedagogical aspects, such as tools, value integrators and interactions of VR, in the smart learning environment are presented and discussed in this study.

Chapter 22 analyses the learning principles governing the learning theories of blended learning, personalised learning, adaptive learning, collaborative assisted learning and game-based learning towards capturing requirements of these theories that can be successfully met and aspects that can be significantly facilitated by technological solutions. There is also presented a generic learning process structure that can model the above learning theories along with a prototype implementation.

Chapter 23 explores the concept of gamification and reviews current research and publications about gamification for education. The systematic literature analysis of publications was chosen as research method. The study shows that there is little research that give comprehensive insight into the concept of gamification for education, because the concept of gamification is relatively new.

Riga, Latvia Linda Daniela

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Firstly I would like to thank all of the authors for their time and expertise to preparing their chapters for this book and who put their effort in developing the ideas of smart pedagogy.

Secondly, I would like to thank the referees, the role of which took most of the authors; I highly appreciate their double task taking the part in the reviewing process as well to ensure the quality and the coherence of the book. Without the support of all of the authors and referees, this book would not have become a reality.

Also, I would like to thank my family who gives me the power.

Lastly, I would like to express my gratitude to my University where I can work and develop my ideas.

Riga, Latvia Linda Daniela

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Part II Research on Technology-Enhanced Learning Process

Notes on Contributors

Stylianos Asteriadis is an associate professor in the Department of Data Science and Knowledge Engineering at Maastricht University. He has published over 50 peer-reviewed papers in the fields of computer vision, intelligent visual interactions and artificial intelligence. He is conducting research in AI in health, ambient assisted living and automated human emotion recognition, with particular focus on in-the-wild applications making use of computer vision and deep learning technologies. Stylianos Asteriadis is a co-organiser of the 2018 IEEE Conference on Computational Intelligence and Games (CIG) and the organiser of various international peer-reviewed workshops, while he serves as a PC member and reviewer in many international conferences and highly ranked journals. He is currently teaching the courses of Computer Vision and Human-Computer Interaction & Affective Computing in Maastricht University. Also, he is the PI, for Maastricht University, of the large-scale Horizon 2020 EU projects MaTHiSiS and ICT4Life.

Carl Bereiter is a professor emeritus at the Ontario Institute for Studies in Education, University of Toronto, and a co-founder with Marlene Scardamalia of the Institute for Knowledge Innovation and Technology (IKIT). He is a member of the US National Academy of Education and has been twice a fellow at the Center for Advanced Study in the Behavioral Sciences. Along with Marlene Scardamalia, he developed CSILE, the first networked system for collaborative learning. The current version, Knowledge Forum®, is being used in innovative applications worldwide at all educational levels from primary grades to university. He has published widely on a variety of topics in instruction, cognitive psychology and educational policy. Recent publications include *Innovation in the Absence of Principled Knowledge: The Case of the Wright Brothers* (in *Creativity and Innovation Management*, 2009) and, along with Scardamalia, *Theory Building and the Pursuit of Understanding in History, Social Studies, and Literature* (in *Enhancing the Quality of Learning: Dispositions, Instruction, and Learning Processes*, 2012) and *Self-organization in Conceptual Growth: Practical Implications* (in *International Handbook of Research on Conceptual Change* – 2nd ed., 2013).

Branko Bognar is an associate professor and was a primary school teacher for 6 years and a school pedagogue in a primary school. In the role of a school pedagogue, he tried to help teachers to introduce changes in order to break the boundaries of traditional teaching. He cooperated with Pestalozzi Programme, which is the Council of Europe programme for professional development of teachers and education actors. Within this programme he led education for groups of teachers – action researchers by using an online platform. This action research project gathered participants from nine European countries. He led the scientific project "The Development of Creativity in the Lifelong Education of Teachers". Within this project he was responsible for leading teachers – action researchers' learning communities mostly by using Moodle, an online learning management system. In his teaching at the Josip Juraj Strossmayer University of Osijek, he also uses Moodle system. A particularly important activity is a discussion on the web forum which lasts for several weeks and fosters constructivist learning. His main professional interest is connected with introducing changes into educational practice whose aim is to break the boundaries of traditional teaching. Accordingly, he endeavours to promote the idea of action research in Croatian educational context and abroad particularly by using web-based technologies and e-learning. In addition, he puts emphasis on development of teachers' and students' creativity and creative approach to science.

Katarzyna Borawska-Kalbarczyk is an associate professor; she works in the Department of General Didactics of the Faculty of Pedagogy and Psychology, University of Bialystok. Her research interest is a combination of information education, media education and general didactics. In her research works, she mostly concentrates on the issue of students' information literacy in the context of information overload and processes of information competence development. She also studies the ways, determinants and effects of the use of digital technologies by children, adolescents and adults. Besides, she deals with the analysis of school learning environment, the directions of its modernisation and the changes in education connected with the development of information civilisation. She has published more than 80 scientific articles concerning the problem of adolescents' information literacy, the analysis of the educational process and its multiple determinants as well as the student and school condition against the background of changes in the information society.

Kevin Burden is a professor of Educational Technology in the Faculty of Arts, Cultures and Education (FACE) at the University of Hull. In 2015 he was awarded a National Teaching Fellowship by the Higher Education Academy in recognition of his support for staff and students in using digital technologies to support innovation and change. He is currently the convener of the technology-enhanced learning (TEL) research group at the University of Hull where he leads a team focusing on the interface between learning and digital technology, and he is particularly interested in exploring how educators use technologies to support and augment their own learning and that of their students. His recent work focuses on teacher education futures and the role of technology in these. He is currently leading a number of

STEM-related projects funded by the EU and the British Council to investigate the impact of mobile technologies on learning, particularly for marginalised and difficult-to-reach communities.

Jake Rowan Byrne is an assistant professor in Contemporary Teaching and Learning and Computing and a programme coordinator for the Postgraduate Certificate in 21st Century Teaching and Learning. He received the B.Eng. honours degree in mechatronic engineering from Dublin City University, Ireland, in 2006, and the M.Sc. degree in technology and learning from the University of Dublin (Trinity College), Ireland, in 2008, and the Ph.D. degree in computer science from the University of Dublin (Trinity College), Ireland, in 2013. Since 2013 he has been a research fellow and STEM programme manager with the University of Dublin's (Trinity College) Bridge21 educational programme, Ireland. He is the author of a book chapter and several articles and is a coinventor on a wearable technology patent. His expertise is in computer science education, 21st Century Teaching and Learning, skills development, educational technology and teacher professional development.

Samuele Calzone is a researcher at the National Institute for Documentation, Innovation and Educational Research (INDIRE); principal investigator of a project on the result of the National Operational Programme (NOP) on Education for the implementation of the European Social Fund (ESF) and the European Regional Development Fund (ERDF) in the period 2014–2020 in Italy; and expert on Pedagogy and Philosophy of Education. His areas of expertise include adult learning, school governance, pedagogy, smart education, virtual education and students' key competencies. In particular, he is focused on the introduction of ICT at school and on the teacher digital skills and media education. At the moment, he is working on the tailored learning in adult education, as well as he is leading a project entitled "Monitoring and Research" on the results of the NOP 2014–2020. This programme contributes to an improved education system, better qualifications of students and better school buildings and equipment. He is a member of National Team PAIDEIA – Innovation Plan on Adult Learning – and he was a member of Steering Group for the Evaluation of the Investment in digital infrastructure and digital skills for school in the southern Italy (NOP 2007–2013). He also was a high school teacher of philosophy and history.

Bodong Chen is an assistant professor at the University of Minnesota in the Department of Curriculum and Instruction. His research is at the intersection of computer-supported collaborative learning, learning analytics, online learning and network analysis. His research projects involve devising pedagogical practices, computer software and data analytics for collaborative learning; investigating complex learning processes in authentic settings; and applying nascent computational methods to both empirical research and software engineering. Dr. Chen's work is broadly published in premier venues such as *Educational Psychologist*, *International*

Journal of Computer-Supported Collaborative Learning, *Computers & Education* and *The Internet and Higher Education*.

Linda Daniela is professor and senior researcher, chair of the council for Ph.D. Defence in Pedagogy and head of the Scientific Institute of Pedagogy at the University of Latvia. She also serves as expert in education at the Council of Sciences of the Republic of Latvia. Her expertise spans smart pedagogy, virtual education, smart education, digital learning materials, educational technologies for learning, educational robotics, educational processes and solutions for reducing social exclusion from the educational processes and behavioural problems. Professor Daniela is an author and co-author of more than 50 publications about processes in all dimensions of education. She has been involved in more than 30 research projects. At the moment she is leading the research projects "Human, Technologies and Educational Quality", "Audio Learning Materials for Preschool Education" and "The Gap Between Political Development Documents and Real Practice of Digitalization of Higher Education".

She has been involved in editing books and journals on technological aspects in the knowledge society.

Petros Daras is a principal researcher grade A at the Information Technologies Institute (ITI) of the Centre for Research and Technology Hellas (CERTH). His main research interests include multimedia processing, multimedia and multimodal search engines, 3D reconstruction from multiple sensors, dynamic mesh coding, medical image processing and bioinformatics. He has co-authored more than 50 papers in refereed journals, 31 book chapters and more than 150 papers in international conferences. He has served as a regular reviewer for a number of international journals and conferences. He was the chair of the IEEE Interest Group (IG) on Image, Video and Mesh Coding (2012–2014) and key member of the IG on 3D Rendering, Processing and Communications (2010–). He regularly acts as a reviewer/evaluator for the EC.

Ioannis Deliyannis is an assistant professor in the field of "Analogue and Digital Technologies of Interactive Multimedia" at the Department of Audiovisual Arts at Ionian University, Corfu, Greece. He holds a computer science degree (1997, University of Wales Swansea) and a Ph.D. in the field of interactive multimedia (2002, University of Wales Swansea). He worked within the Computational Fluid Dynamics research team as a research student under the supervision of professors P. Townsend and M. F. Webster. His research work is largely related with multimedia applications, visualisation and web-based technologies applied to complex scientific fields such as computational rheology and the development of educational systems for research and interactive learning.

His research interests include the application of interactive and multimedia communication technologies in the area of audiovisual arts. He is the author of a series of journal and conference publications in the above fields, followed by a series of books targeting the experimental and creative aspects of the technologies involved.

He is involved in the design of user-centred software products and services, focusing on the use of mobile sensory systems to create intelligent interactive systems, entertainment education systems, educational applications for people with disabilities, multimedia adapters, holograms, interactive navigation, narrative applications and augmented and virtual reality systems.

Personal website: https://yiannis344.wixsite.com/index, https://inarts.eu/en/lab/staff/deligiannis/

Santa Dreimane is a Montessori teacher at preschool in Riga, Latvia, and expert at the Scientific Institute of Pedagogy of the University of Latvia. She has a master's degree in social sciences and a master's degree in educational sciences.

Her expertise spans Montessori pedagogy, children's social adaptation and gamification. She is an author of publications about children's social adaptation in a mixed-age group at Montessori preschool educational institution.

At the moment she is taking part in the research project "Audio Learning Materials for Preschool Education".

Ina Druviete is vice-rector for Humanities and Educational Sciences at the University of Latvia, Dr. h. c. at Daugavpils University and member of the Latvian Academy of Sciences. She is the author of more than 300 publications in general linguistics, sociolinguistics, language policy and educational sciences and translations of scholarly books. She is member of the Latvian Parliament (2002–2014) and minister of Education and Science, Republic of Latvia (2004–2006, 2014). She is vice president of the European Federation of National Institutions of Language (2006–2009), member of the editorial board of the journal *Language Policy* (Springer) (2003–2010) and present member of the editorial board for *Studies in World Language Problems* (Benjamins), *International Journal of Indo-Baltic Culture and Studies*, *Taikomoji Kalbotyra*, *Linguistica Lettica*, etc. She is vice-chair of the Presidential State Language Commission. She is a member of UNESCO SDG-4 Steering Commission (2016–2018).

Marta Muñoz de Escalona-Fernández is a teacher for the Andalusian government and has a master's degree in educational psychology. Her research interests include knowledge-building pedagogy and educational technology in elementary education.

Ray Gallon is president and co-founder of the Transformation Society. He currently teaches at the Universitat de Barcelona and the Université de Strasbourg and serves as co-chair of the Primary and Pre-primary Research and Development Community (RDC) of the Association for Teacher Education in Europe (ATEE) and co-chair of the Transformation Society and Information 4.0 Research and Development Group (RDG) of the World Federation of Associations for Teacher Education (WFATE). He has also taught in graduate and undergraduate programmes at New York University, The New School, Université de Toulouse Le Mirail, Université Paul Valéry and Université de Paris Diderot.

Ray has over 20 years' experience in the technical content industries, including major companies such as IBM, Alcatel and General Electric Healthcare. Previously, Ray was an award-winning radio producer and journalist, working with broadcasters such as CBC, NPR, France Culture, Radio Netherlands International, Deutsche Welle and WDR. In the late 1980s, Ray was programme manager of WNYC-FM, New York Public Radio.

Ray is president of the Information 4.0 Consortium. He is a former international board member of the Society for Technical Communication (STC) and past president of STC France. He is a frequent speaker on communications topics at conferences and seminars around the world.

Calixto Gutiérrez-Braojos is an associate professor in the Department of Research Methods in Education, University of Granada, Spain. He is member of the social and environmental education research group at Andalusian research group, H-890. He has carried out several research stay at the University of Toronto; Institute for Knowledge Innovation and Technology; University of California, San Diego; Laboratory of Comparative Human Cognition; and the Autonomous University of Barcelona, SINTE research group. His research interests include research methods, knowledge-building pedagogy and high mental functions and environmental education.

Liena Hačatrjana has received her doctor's degree in psychology based on her research on complex problem-solving skills, cognitive abilities and executive functions of adolescents.

She has experience working as a lecturer at the University of Latvia (on subjects of intelligence and problem solving), a human resources consultant and a researcher for several projects. Currently Liena Hačatrjana is working as a senior expert on transversal skills and cognitive abilities in a government project regarding a new curriculum development for the schools of Latvia. She works also as a private consultant and researcher; her latest projects are related to researching the development of transversal and social-emotional skills of students and an international comparison study of educational policies on effective school leadership.

Anđelija Ivkov-Džigurski is a full professor in the Department of Geography, Tourism and Hotel Management, Faculty of Sciences, University of Novi Sad and the head of the Chair of Social Geography.

She is in charge of teaching methodology of teaching geography, innovations in teaching geography, geographic basis of general and special ethnology, active learning in geography, animation and logistics in tourism and hotel management (organised and facilitated 40 thematic humanitarian events), population policy and family planning and selected chapters of methodology of teaching geography.

Professor Ivkov-Džigurski is a member of the committee in charge of the subject geography in primary and secondary schools, within the Institute for Promotion of Education (Republic of Serbia).

She has been engaged in 34 national and international projects, and she is an author and co-author of 218 scientific papers, 15 books (1 textbook, 3 handbook and 11 monographs) and 1 tourist guide book. Also, she has been appointed reviewer in many domestic and international journals.

She is an active member and the chair of the subject section geography within the Serbian Society of Subject Didacticians.

Polyxeni Kaimara is a Ph.D. candidate in design and development of interactive educational-entertainment systems (edutainment) at the Department of Audiovisual Arts at Ionian University, Corfu, Greece. She holds a philosophy, education and psychology bachelor's degree, a master's degree in developmental and educational psychology (both from Aristotle University of Thessaloniki), a master's degree in public health in the field of behavioural studies (*National School of Public Health*) and a degree in counselling and guidance (postgraduate diploma of ASPETE, National School of Pedagogical and Technological Education). She is a certified trainer and assessor of EOPPEP (the Greek *National Organization for the Certification of Qualifications & Vocational Guidance*) and trainer of the Institute of Training (INEP) of the National Centre for Public Administration and Local Government.

She currently works as a psychologist at a centre for education, social support and training for people with disabilities. Her research interests focus on the design and evaluation of educational systems for special education and training, the emerging technology in learning and the implementation of digital games aimed at designing programmes for inclusive education. Her vision is to show that the proper use of new technology, such as VR, AR and holograms, can help to create "a school for all" without discrimination and exclusion. Her works are published in a number of conference proceedings and journals.

Panagiotis Karkazis is an assistant professor in the Department of Computer Engineering at the School of Engineering of the University of West Attica. He received his degree in electrical engineering from the Technological Institute of Piraeus in 1999 and M.Sc. in electronic communication from Kingston University, UK, in 2005. During the period 2009–2014, he completed his Ph.D. in the Department of Electrical and Computer Engineering of the Technical University of Crete. From 2008 to 2016, he teaches the courses of Computer Networks, Internet Protocols and Telematics Applications in the Department of Automation of the Piraeus University of Applied Sciences. He has extensive experience as a software engineer for embedded systems in the telecommunications industry (R&D). Moreover, he has participated, as a principal researcher, in many national and European research projects on the fields of the embedded systems, IoT, cloud computing and SDN. He has more than 35 publications in scientific journals and conferences and contribution to the IETF Standard: "A Trust Framework for Low Power and Lossy Networks".

Ramunė Kasperavičienė is professor at Kaunas University of Technology (KTU, Lithuania); vice-dean for studies at the Faculty of Social Sciences, Arts and Humanities of KTU; and expert at Kaunas Biomedical Research Ethics Committee. Her expertise is within translation studies, new media language, foreign language learning and teaching and digital literacy. She is also a practicing translator, interpreter and language editor. She is currently involved in two international research projects on digital technologies and young children as well as on crowdsourcing and language learning.

Matthew Kearney is an associate professor in the Faculty of Arts and Social Sciences (FASS) at the University of Technology Sydney (UTS). He is currently deputy director of the STEM Education Futures Research Centre at UTS. His research interests are in the field of technology-enhanced learning and focus on how digital technologies can be used in pedagogically transformational ways in school education and teacher education. Outputs include major project reports and over 60 refereed publications: see https://www.uts.edu.au/staff/matthew.kearney.

Sharon Kearney is a postdoctoral researcher in the Centre for Research in IT in Education at Trinity College Dublin, the University of Dublin. She also currently co-manages two Erasmus+ projects, Teaching for a Sustainable Tomorrow and Access21, aimed to transform education and access to education in Europe. She received her Ph.D. in computer science in 2018 in the area of developing models of 21C teaching and learning for second-level English education. She formerly taught second-level English in a variety of contexts and has experience conducting professional development for teachers of various disciplines.

Her expertise is in English education, new literacies, 21st Century Teaching and Learning and teacher professional development.

Alicja Korzeniecka-Bondar is an assistant professor and works in the Department of General Education and Research Methods in Education of the Faculty of Pedagogy and Psychology of the University of Bialystok, associate dean for Part-Time Students Affairs of the Faculty of Pedagogy and Psychology and editor-in-chief of journal *Parezja: Czasopismo Forum Młodych Pedagogów przy Komitecie Nauk Pedagogicznych PAN* [*Parrhesia: Journal of the Forum of Young Scholars at the Committee of Education Sciences of the Polish Academy of Sciences*].

Her interests concern the following issues: everyday life worlds of education subjects, creative combination of pedagogical theory and practice, temporal dimensions of the functioning of school and education subjects, building a scientific community of learners and academic writing skills and their improvement.

She is the author and co-author of 70 scientific articles concerning the problem of teacher's day-to-day work and temporal dimension of everyday school practices. She has published one book and coedited four. At the moment, she is finalising the book *Everyday Time at School: Phenomenographic Study of Teachers' Experiences* (Krakow 2018).

Laurinda Leite is a full professor at the Institute of Education, University of Minho, and director of the Research Centre on Education.

Her main research areas are science education, science teacher education and technologically enhanced education, including online teacher education.

She is an author and co-author of more than 150 articles, book chapters and other refereed papers. Besides, she has coedited international proceedings and books.

She has also been member and coordinated competing research projects focusing on key science education issues. Nowadays, she is involved in the coordination of a Portuguese-speaking country curriculum reform project.

Helen C. Leligou is currently assistant professor at the University of West Attica which emerged from the Piraeus University of Applied Sciences. From 2007 to 2017, she acted as lecturer (until 2012) and then as assistant professor at the University of Applied Sciences of Central Greece. Her research interests lie mainly in the areas of information and communication technologies including (a) routing protocols and trust management in wireless sensor networks; (b) control plane technologies in broadband networks including HFC, PON and WDM metro and core networks; and (c) industrial, embedded and network system design and development. Currently she is working on blockchain technologies and IoT-enabled systems for various application sectors including e-learning and energy efficiency. Her research results have been published in more than 100 scientific journals and conferences. She has participated in several EU-funded ACTS, IST, ICT and H2020 research projects in the above areas.

Vilmantė Liubinienė is professor at the Faculty of Social Sciences, Arts and Humanities, Kaunas University of Technology, Lithuania, with M.A. in humanities and English philology (Vilnius University, 1985) and Ph.D. in sociology (Kaunas University of Technology, 1998). Her expertise is within media linguistics, media literacy, localisation and translation, digital culture and intercultural communication, system of universal values, migration and identity building. She has published around 50 academic articles and has participated in more than 50 national and international conferences and global seminars. Currently she is involved in three international research projects on digital literacy and multimodal practices of young children as well as research into migration culture. She is ECREA member since 2017.

Neus Lorenzo is co-founder of the Transformation Society and professor at the Autonomous University of Barcelona. She is an inspector of education and the former head of the Foreign Language Service in the Departament d'Ensenyament, the local Ministry of Education in Catalonia (Spain). She currently serves as chair of the Primary and Pre-primary Research and Development Community (RDC) of the Association for Teacher Education in Europe (ATEE) and co-chair of the Transformation Society and Information 4.0 Research and Development Group (RDG) of the World Federation of Associations for Teacher Education (WFATE).

Neus has also worked as a training adviser at the Council of Europe for Pestalozzi courses, as advisor for the Anna Lindh Foundation in Amman (Jordan) and Alexandria (Egypt) and Fundación Telefónica, and at the Inspectorate of Education in the Generalitat de Catalunya (Catalan government). She has also represented the Spanish autonomies before the education committee of the European Parliament.

Dr. Lorenzo is an author and co-author of many articles, books and other academic publications over many years. Her areas of expertise include communication, language learning, digital learning, ICT, organisational networking, educational assessment, international collaboration and headmaster coaching. She is currently doing research with the Jaume Bofill Foundation, several Catalan universities and the Transformation Society.

Leanne Ma is a doctoral candidate in the Department of Curriculum, Teaching and Learning at the Ontario Institute for Studies in Education at the University of Toronto. Her research interests include computer-supported collaborative learning, knowledge building/knowledge creation and innovation networks. She is currently consulting with the Ontario Ministry of Education on the *Leading Student Achievement: Networks for Learning Project* to build innovative capacity in K-12 schools and spread knowledge building across the province.

Giuseppina Rita Jose Mangione is researcher (tenured position) at INDIRE (National Institute for Documentation, Innovation and Educational Research). She holds a master's degree in communication sciences and a Ph.D. in telematics and information society. She has been postdoctoral associate at the University of Salerno, working on e-learning and innovative educational methods. Her research interests include teachers' training in small school, adaptive instruction and learning technologies for innovation. She managed several projects in the field of education and small school, collaborating with international institution and governmental agencies. She is author of several books and about 100 scientific papers.

Personal page: http://www.indire.it/personale/giuseppina-rita-mangione/

Olja Maričić is a teaching assistant at the Faculty of Education in Sombor, University of Novi Sad. She is currently pursuing the Ph.D. degree at the Faculty of Sciences, University of Novi Sad.

Her main research interests are multimedia design, early STEM teaching and learning and educational technology in K-12 and higher education. She is an author and co-author of more than 15 academic publications.

Luciano F. de Medeiros is the professor and senior research fellow at the Centro Universitário Internacional (UNINTER), Curitiba, Brazil, and assistant coordinator of the Master's Programme in Education and New Technologies.

His expertise includes artificial intelligence, new technologies in education, education at distance, computing simulations, educational robotics, learning objects, systems analysis and development, database modelling and knowledge engineering and managing and is a DIY enthusiast.

He is a professor, consultant, author and co-author of approximately 100 publications involving interdisciplinary projects in education, artificial intelligence, neural networks, knowledge management and ontologies. He is the head of the Computing Simulations and Educational Robotics research group at UNINTER, conducting educational projects joining robotics with recyclable materials and easy-to-use open-source electronic platforms, the use of 3D printing at schools, games and gamification and quantitative research methodologies for education.

Jesús Montejo-Gámez is an assistant professor in the Department of Mathematical Education of the University of Granada, member of the Andalusian research group "Mathematics, Education and Society" (EDU2011–27168) and member of the education committee of the Spanish Royal Mathematical Society. His expertise includes both applied mathematics and educational research, paying special attention to collaborative learning supported by ICT, mathematics teacher formation and mathematical modelling in problem solving, mostly in what concerns to algebraic and functional thinking.

Alvino Moser is the dean of Centro Universitário Internacional (UNINTER). He was vice-rector and professor of the Master's Programme in Education and New Technologies in which he teaches epistemological fundamentals of technological mediation. He completed his postdoctoral degree in deontic and juridical logic (1985), his Ph.D. in ethics (1973), his master's degree in epistemology (1970) and his Ph.D. in philosophy (1969) from the Université Catholique de Louvain. He also graduated in chemistry (1963) from the Pontifical Catholic University of Paraná.

With more than 80 articles published as an author or co-author, he has experience in philosophy, with an emphasis on epistemology and philosophy of sciences, working mainly in the following subjects: education, learning of digital youth and their mediation and research on philosophy and epistemology of technology and augmented virtual reality and immersive 3D virtual reality.

He is professor since 1954 and currently researches and coordinates the project of development and application of educational processes gamified in immersive virtual environments and augmented reality and immersive 3D virtual reality.

Agnes Papadopoulou is a special research and teaching staff member in the Department of Audiovisual Arts at the Ionian University in Greece. Her scientific interests include art didactics, art and technology in education, neuroaesthetics, philosophy and aesthetics of media, digital arts, performance and technology. She has been involved in many projects in primary and secondary schools in Greece. Her publications in both conference proceedings and journals are related to the teaching of art and creative technologies, the role of the arts as a means of effective learning and activation of *critical thinking*. Her writings include two books and a theatrical play. She has also been involved in book editing. She has directed many theatrical performances and contemporary and new plays.

Rab Paterson is the principal instructor of the Toyo University-UCLA Extension Centre for Global Education's Business English Communication programme. He is also the director of the Asia Association for Global Studies, a fellow of the British Royal Asiatic Society and a fellow of the Royal Society for the Encouragement of Arts, Manufactures and Commerce and holds memberships in many other educational technology/professional teaching associations. In addition he is an Apple Distinguished Educator award winner, an Apple Certified Teacher, a Google Innovator award winner, a Google Certified Trainer, a Google Certified Educator and a founding leader of the West Tokyo Google Educator Group, the first GEG in Japan. He has a B.A. (Hons.) in Pacific Asian history and an M.A. in Pacific Asian studies from London University's SOAS, a Certificate of Educational Technology and Information Literacy and an M.S. in multidisciplinary studies from SUNY (Buffalo). Currently, he is a doctoral candidate at University College London's Institute of Education on the International Education Doctorate programme, conducting research on digital literacies. His publications range from peer-reviewed academic journal papers, conference proceedings and a book chapter in an anthology on globalisation and human rights, and he has presented at over 150 academic conferences and events worldwide.

Arta Rūdolfa has a master's degree in educational sciences, and she is a researcher at the University of Latvia. Her research focuses specifically on the digital learning materials, learning management systems (LMS) and online learning. Currently, she is engaged in the development of tool for the learning platform assessment.

She has a master's diploma written and lead under the guidance of Professor Linda Daniela on the topic "Learning platforms in the context of education digitization in Latvia" evaluated with the highest mark and appreciation from the rector of the University of Latvia.

Marija Sablić is an associate professor and has participated in several research projects: *Intercultural Curriculum and Education in Minority Languages*, *Intercultural Education and European Values*, *School Culture Types and Active Citizenship: A Critical Interdisciplinary Approach*, *Intercultural Curriculum* and *European Values*. She has participated in 26 international and national scholarly and professional conferences in the field of education and is the author of books and numerous scholarly papers. She is an editor of several books and conference proceedings. She is a member of the Administrative Council of the Association for Teacher Education in Europe (ATEE). As a Montessori educator, she is the coordinator of the 2-year professional training in Montessori education at the Faculty of Education in cooperation with Montessori-Vereinigung Steiermark KPH Graz and the Institute of Montessori Education in Zagreb. She currently holds the position of the head of the Department of Social Sciences at the Faculty of Education in Osijek. She is one of the editors of ATEE 2017 Annual Proceedings.

Marlene Scardamalia holds the presidents' chair in Education and Knowledge Technologies at OISE/University of Toronto and is co-founder and director of the

Institute for Knowledge Innovation and Technology – a worldwide network of innovators working to advance the frontiers of knowledge building in various sectors. Knowledge building, a term now widely used in education and knowledge management, has been developed by her, in partnership with Carl Bereiter and team members. Marlene also led the team that created the first networked knowledge-building environment for education and is currently president of Knowledge Building International. She has been honoured with fellowships or memberships in the most highly recognised organisations in her field, including the Centre for Advanced Study in the Behavioural Sciences, US National Academy of Education, Canadian Institute for Advanced Research and Human Development Program. She has received numerous awards, including the World Award of Education and World Cultural Council, for worldwide effort to advance educational opportunity and honorary doctorate and diplomas from the University of Joensuu, Finland, the World Federation for Advancement of Teacher Education and the Michener Institute for Applied Health Sciences. Research interests include innovative learning environments; knowledge-creating organisations; digital, textual, scientific and graphical literacy; discourse analysis; and knowledge-building analytics.

Sandy Schuck is professor of Education in the Faculty of Arts and Social Sciences at the University of Technology Sydney. She was founding co-director of the STEM Education Futures Research Centre at UTS. Her research interests include teaching and teacher education futures, teacher professional learning with new media, development of mobile pedagogies and beliefs and practices in mathematics education. She has authored or co-authored over 80 publications and has been awarded over 2 million dollars in competitive research grants.

Alma Škugor is an assistant professor, teaches the courses of the *Pedagogy of Sustainable Development* and *Tradition of Spontaneous Children and Youth Culture* and conducts exercises in the course titled *Didactics of Science and Society II* and *Research in Science and Society*. Since 2014, she has been teaching the course Methodic Practice and is a head of the course titled *Practical Work in Schools*. She has participated in a number of international and national scientific and professional conferences in the field of education and has published about 20 scholarly and professional papers. She has been a member of the programme committees of scientific and professional conferences. In 2017 she successfully passed the Montessori educational training in teaching children aged 3–12 and thus acquired an international degree (Montessori-Pädagogik Diplomlehrgang) in accordance with the guidelines and the standards of the Austrian Montessori – Österreich umbrella association. She is one of the editors of ATEE 2017 Annual Proceedings.

Penny Standen is professor in Health Psychology and Learning Disabilities at Nottingham University. Her main interest as a health psychologist is in how people understand health and illness, how illness affects their lives and inequalities in health provision. In intellectual disabilities she has focused on evaluating ways of promoting independence and quality of life and assisting people in reaching their fullest potential. From this grew her main area of research which is developing and evaluating technology for people with intellectual disabilities. From early work on developing virtual environments to support independence, this work in intellectual disabilities has grown to embrace serious games, location-based services, robotics and contemporary media. Current projects are investigating the potential of a range of new technology to support profound and multiply disabled adults and young people. This expertise led to collaboration with colleagues in rehabilitation working with patients recovering from a stroke and those with long-term neurological conditions. Her research has been supported by funding from the ESRC, EPSRC, NIHR, EU Commission and charitable money and has generated over 110 refereed and invited articles, 16 book chapters as well as editorials and reports on all of the topics in which she has been involved.

Ivan Stojšić is a Ph.D. candidate (study programme: Teaching Methodology of Natural Sciences [biology, chemistry, physics, geography], Mathematics and Informatics) at the Faculty of Sciences, University of Novi Sad.

His area of research interest includes virtual reality, mobile augmented reality, technology-enhanced learning, online learning and STEM teaching methods.

As an author and co-author, he has more than 15 published papers in journals and conference proceedings. Also, he is a member of the Serbian Society of Subject Didacticians and co-author of an accredited programme (in the Republic of Serbia) for professional development of teachers: "Application of Virtual Reality in Teaching and Learning Processes".

Kevin Sullivan received B.Sc. degree in applied science (computer science and software engineering) from the Dublin Institute of Technology, Dublin, Ireland, in 2002 and M.Sc. degree in technology and learning from the University of Dublin (Trinity College), Dublin, in 2012, where he is currently pursuing the Ph.D. degree in computer science. He is the education manager at Bridge21, Trinity College Dublin.

His expertise is in 21C teaching and learning, skills development and teacher professional development.

Fabian Hadipriono Tan is a professor at the Ohio State University, professor of Civil Engineering, professor of Construction Engineering and Management, professor of Engineering Education Innovation Centre (EEIC) and director of Construction Laboratory for Automation and System Simulation (CLASS).

Professor Tan has an M.Sc. in structural engineering, an M.E. in construction engineering and management and Dr.Eng. in construction engineering and management from the University of California in Berkeley. He has worked in the areas of construction of infrastructures and buildings, failure assessment of buildings and bridges, construction accident investigations, forensic engineering, ancient buildings, ancient bridges and ancient history of science and engineering for over 40 years. Professor Tan has served as a forensic consultant with numerous law firms in Ohio as well as the United States Air Force Weapons Laboratory in Kirtland, New

Mexico. Additionally, he has also served as a project manager and engineer on multiple international construction projects such as Leighton Australia-Indonesia Construction Inc. and Mahkota-Ekman Sweden Inc. The tools Professor Tan uses for his research include fault tree analysis, fuzzy logic, artificial intelligence and virtual reality.

Bożena Tołwińska is an assistant professor at the Faculty of Pedagogy and Psychology of the University of Bialystok. She is a holder of the Academic Tutoring Certificate issued by Collegium Wratislaviense. She focuses on the subjects of school management and school organisational culture, especially the model of school as a learning organisation. She is actively involved in popularising the idea of humanistic management, based on the idea that interpersonal relations foster mutual development of the interaction partners. She has authored a number of articles concerning this subject and a monograph: *Kompetencje społeczne dyrektorów szkół* [*Social Competencies of School Principals*]. Besides, she is an assistant editor of the semi-annual *Parrhesia: Journal of the Forum of Young Scholars at the Committee of Education Sciences of the Polish Academy of Sciences* (Polish, *Parezja: Czasopismo Forum Młodych Pedagogów przy Komitecie Nauk Pedagogicznych Polskiej Akademii Nauk*), and she is a member of the Polish Educational Research Association (Polskie Towarzystwo Pedagogiczne).

Panagiotis Trakadas received his Dipl.-Ing. degree in electrical and computer engineering and his Ph.D. from the National Technical University of Athens (NTUA). He is holding the position of associate professor in Technological Educational Institute of Central Greece. From October 2001 until July 2004, he was working for Hellenic Aerospace Industry (HAI), as a senior engineer, on the design of military wireless telecommunications systems. In the past, he has been with the Technological Educational Institute of Athens as an assistant professor (September 2002–June 2004), teaching radar and microwave technology; the Technological Educational Institute of Chalkida (September 2008–June 2009), teaching digital systems design; and the National Technical University of Athens as a senior researcher. He has published more than 70 papers in magazines, journals, books and conferences. He is a reviewer in several journals including *IEEE Transactions on Communications*, *IEEE Transactions on Electromagnetic Compatibility* and *Elsevier Applied Soft Computing*. Dr. Trakadas has been actively involved in many EU-FP7 and Horizon 2020 research projects (AWISSENET, VITRO, SMART, XIFI, AgriFI, FISIS, SONATA, ARMOUR), and he is now involved in 5G-PPP 5GTANGO and SOFIE projects.

Vasiliki Valla graduated from the Department of Preschool Education of the University of Ioannina. She holds a Master of Education with her thesis in the field of ICT in education from the University of Crete. Miss Valla has worked in the private sector and in the public sector as a kindergarten teacher for more than a decade. She is a co-author of a few publications on the use of ICT in mathematics at kindergarten. Her research interests include ICT in education and teaching of mathematics using ICT.

Floriano Viseu is an assistant professor at the Institute of Education, University of Minho, and member of the Research Centre on Education.

His main research areas are mathematics education, mathematics teacher education and technologically enhanced mathematics teaching and learning.

He is author and co-author of more than 90 publications concentrating on the aforementioned research areas.

He has been involved in competing research projects focusing on issues within the scope of mathematics education and mathematics teacher education as well as on two Portuguese-speaking countries curriculum reform projects.

Nicholas Vretos obtained the degree of B.Sc. in computer science from the UPMC (Paris VI) in 2002 and the Ph.D. degree from the Aristotle University of Thessaloniki in 2012. His main interests are in machine learning, big data, learning analytics, image and video processing, semantic analysis, neural networks and 3D data processing. He has published more than 40 articles in scientific journals and conference proceedings and a book chapter. He has served as a reviewer for several journals and conferences. Moreover, he has served as chair/co-chair in several conferences and workshops in his field of expertise.

Jin Rong Yang is alumnus in Civil Engineering from the Ohio State University.

Dr. Yang also holds a B.Sc. and M.Sc. in civil engineering from the Ohio State University. He has worked as a graduate teaching associate for the Department of Engineering Education at the university, as well as a construction inspector for the City of Columbus. Dr. Yang has more than ten publications on the research areas, such as 3D modelling, virtual reality, multimedia system, fuzzy logic, Leadership in Energy and Environmental Design (LEED) for environmental-friendly construction, engineering education and history of construction engineering.

Nicholas Zaranis graduated from the Department of Electrical and Computer Engineering of the National Technical University of Athens. He holds a Master of Science in computer studies from the University of Essex. He has also received a Master of Science and his Ph.D. from the National and Kapodistrian University of Athens. Dr. Zaranis has worked in private sector as an electrical engineer for Hewlett-Packard Hellas for a few years and in the public sector as educator of information technology in secondary education. He is currently associate professor in the Department of Preschool Education of the University of Crete and is also the director of the ICT Laboratory in Education and Natural Sciences. He is an author and co-author of more than 100 publications about processes in all dimensions of ICT in education, and he has been involved in more than 20 research projects. His research interests include ICT in education, educational software and teaching of mathematics using ICT.

Irēna Žogla is an emeritus professor of the University of Latvia and a researcher of Scientific Institute of Pedagogy at the University of Latvia. Her academic and research profile includes process of teaching-learning and teacher education. Currently she is an expert at the Latvian Council of Sciences and member of the Council for Promotion in Pedagogy. She delivers classes in didactics for doctoral and masters' programmes and is scientific adviser for doctoral research.

Part I
Concept Development of Smart Pedagogy

In the first part of the book **Concept Development of Smart Pedagogy**, there is outlined new pedagogical direction using a technology-enhanced learning process that defined the idea of smart pedagogy. In this part of the book, there are included ten chapters where authors provide conceptual ideas on necessary changes in pedagogy to ensure smart learning; introduce with reality of a major paradigm shift, in the form of the Fourth Industrial Revolution; seek to update views on didactic practices in the rapidly changing field of education; aware readers of cognitive development of children in different age groups; examine the nature of smart pedagogies and their intersection with mobile pedagogies; and discuss a plethora of practical suggestions which could be considered to make pedagogy smarter. The first part of the book ends with the chapter where authors offer a toolkit for evaluating learning platforms.

Smart Pedagogy for Technology-Enhanced Learning

Linda Daniela

Abstract The progress of technology has raised challenges to the educational environment, so it is necessary to search for answers to the questions: How can one teach better? How can one scaffold the student in the learning process? What kind of competencies should be developed? What competencies do teachers need? What kind of technology should be used or not be used? This chapter analyses the role of pedagogy for education and outlines the risks for cognitive development that may result from the introduction of technology without an understanding of pedagogical principles. These risks are defined as a *centrifugal effect* that can be mitigated by integrating technology into the educational process using the principles of Smart Pedagogy.

The idea of Smart Pedagogy for technology-enhanced learning is defined, and the author explains why the term 'Smart' has been chosen to define the pedagogical aspects of TEL. In addition, a conceptual model of the educational process in which Smart Pedagogy is the driving force of technology-enhanced learning is developed. There is outlined the necessity for *predictive analytical competence*, which is emerging for TEL.

Keywords Smart Pedagogy · Technology-enhanced learning · Conceptual model of technology-enhanced learning · Predictive analytical competence · Technology

1 Introduction

Pedagogy as a science is constantly evolving and looking for ways to better teach and to scaffold students in the process of knowledge building. An important milestone in the development of pedagogy can be seen from the year 1949, when a group of scientists in the fields of pedagogy and psychology worked out the development of an educational taxonomy, which was published in 1956, more widely known as

L. Daniela (✉)
Faculty of Education, Psychology, and Art, University of Latvia, Riga, Latvia

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Bloom's taxonomy (Bloom, Engelhart, Furst, Hill, & Krathwohl, 1956). In the following years, various other taxonomies have emerged, which are based on the idea that the learning process should be structured. Marzano (2001) developed the idea that learning is hierarchically structured, where the acquisition of information, memorization, and then retrieval of this information from memory is the first step, followed by the understanding of information, analysis, and, finally, knowledge construction as the highest level. There are researchers who believe that this taxonomy is very valuable in scaffolding the learning and promoting a higher level of thinking skills (Eddy & Hogan, 2014; Toledo & Dubas, 2016), which is also an important result to be achieved in the TEL process. Marzano and Kendall (2007) offered an idea of how to separate the lower-level thinking skills from the highest level of thinking skills, where the lower-level thinking skills are characterized by knowledge acquisition and understanding, while higher-level thinking skills are characterized by the construction of new knowledge (Marzano, 2001), thus achieving a metacognitive thinking level. Anderson and his colleagues in 2001 presented Bloom's revised taxonomy, where learning is characterized by verbs: remembering, understanding, using, analysing, evaluating, and creating (new knowledge) (Anderson et al., 2001). SOLO (structure of the observed learning outcome) taxonomy (Biggs & Collis, 1982) is also often used in the learning process. In 2007, Churches adopted the idea of Bloom's digital taxonomy, which offers a hierarchical view of digital skills, from low-level thinking skills to the highest level of thinking. The lowest level is characterized by the search for information in the digital environment and its selection, operation in social networks, etc. The next level follows a targeted information search, its categorization, the addition of comments and annotations, as well as blogging. The third level is the maintenance and editing of a digital site. The fourth level involves the ability to understand how the specific digital tool works. The fifth level is the creation of reciprocal networks, collaboration with other digital tools, as well as testing them. The sixth level is characterized by programming, creating new products, testing, interacting with other products, etc. (Churches, 2007). These levels are not separate, and there are no specific indicators for when the next level has been reached, but these aspects can be taken into account when analysing the digital competencies and thinking about the pedagogical aspects of the learning environment in order to develop this digital competence to lead the student from the lower level of thinking, characterized by simple digital skills, to a higher level of thinking, which is characterized by the design of new knowledge and the creation of new products. In the context of Bloom's Digital Taxonomy (Churches, 2007), the digital competence required in technology-rich environments is emphasized but in TEL, not only digital competencies but the overall development of human competencies.

Technological progress brings about a transformation of the educational environment which happens faster than the literature can offer solutions for how to work in this environment. This puts in the focus the role of pedagogy in the context of the transformed educational environment; therefore, the present chapter will provide a vision of the role of pedagogy and its transformations in the discourse of 'Smart environment' and define the idea of 'Smart Pedagogy'. In the context of this chapter, the term *technology* is used to describe various types of information and communication technologies (ICT), digital technology solutions, educational robotics, smart devices, and so on. The term *teacher* is used to describe different kinds of educators.

2 The Role of Pedagogy in Education

In Webster's Dictionary, *pedagogy* is defined as the art, science, or profession of teaching (*Merriam-Webster.com*). Žogla (2017) has analysed the interdependence between pedagogy and the educational sciences, presenting the development of pedagogical science, which has changed direction from external influences on the learning process to the understanding of the complex nature of learning, which, from the perspective of the students, takes into account the individual needs of each student and looks for solutions with which to support the students by emphasizing and strengthening their abilities (Žogla, 2017). Different conceptions of the use of the terms *pedagogy* and *education* are to be found in the literature, but in the context of this chapter, *education* is taken as the broader process which supports the student, but pedagogy is the driving force to reach this result (see Fig. 1), where different

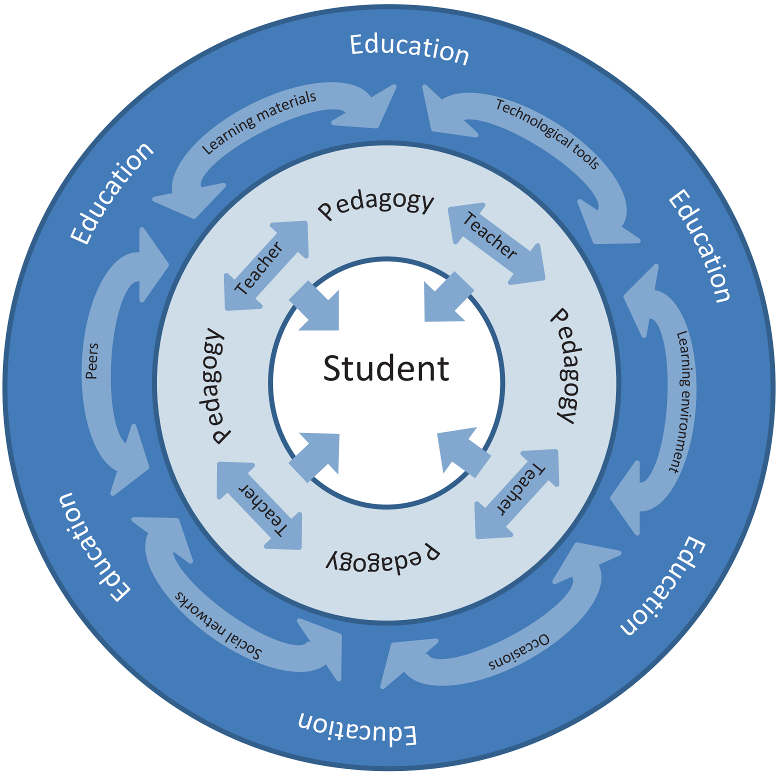

Fig. 1 Interrelations of *education* and *pedagogy*

actors in the educational process interact actively: *learning materials*, including digital teaching materials which, in the context of this chapter, are understood as materials that provide the content of the learning; *technological tools* that can include computers and smartphones, robots, smart boards, and so on; *the learning environment* which is the physical school and class environment and virtual environment; *occasions* which happen in everyday life; *social networks* which are peer-to-peer networks, family networks, as well as online social networks; and *peers*, which can be a learning resource and learning community for knowledge building. Teachers use their pedagogical knowledge to organize the learning process. In general, this is a traditional learning process in the discourse of the learning paradigm, where the student is at the centre of the learning process but the teachers are those who, using their pedagogical knowledge, plan and organize the educational processes to support all the students.

In general, education is considered to be a cyclic process (see Fig. 2), where the learning process provides the inclusion of new innovations, modifying the content of teaching, changing teaching strategies, developing new teaching materials, planning what competencies will be needed in the future, which occupations will be required in the labour market, and so on.

However, technological progress, which is becoming more rapid with the possibilities provided by digitization, poses a risk of *centrifugal effects* in the educational process (see Fig. 3), making it fragmented, where actors of educational processes operate independently, and the role of pedagogy is diminishing, which also affects the quality of education. This is due to several possible causes, and one of them that the possibilities which are provided by technology are interesting and exciting and can redirect students' attention away from the educational process, where these interesting and exciting technologies are not included. The reason why they are often excluded is because quite often technology is considered useless for promoting students' cognitive development, since there must be taken in account the regularities of student development and the need to support the development of the attention span. It is undoubtable that it is necessary to let students acquire the needed

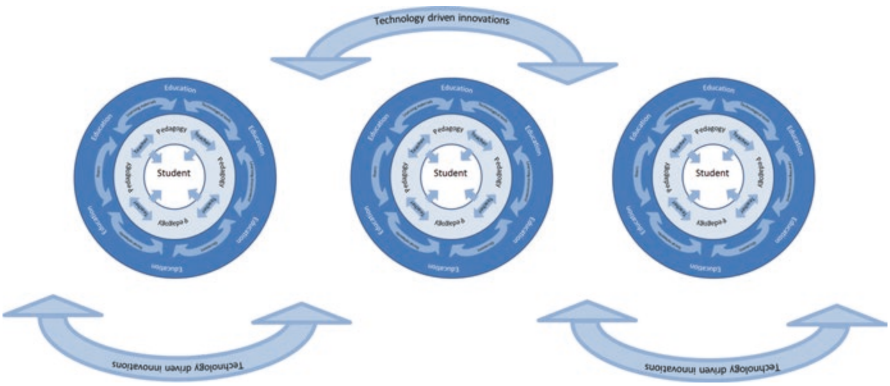

Fig. 2 Cycle of the educational process

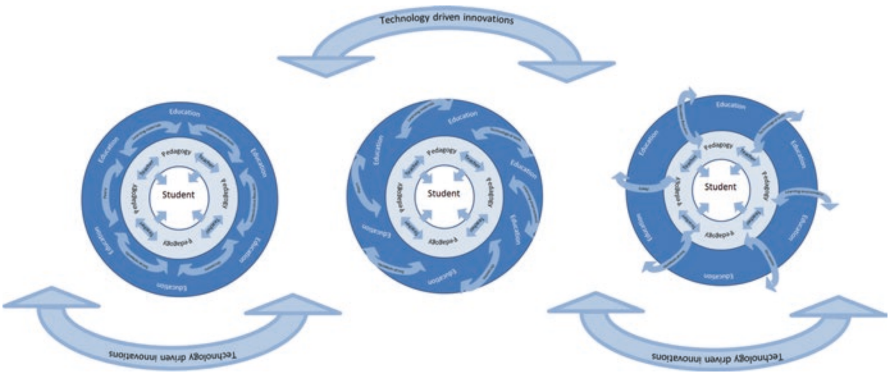

Fig. 3 *Centrifugal effect* on educational process caused by technology-driven innovations

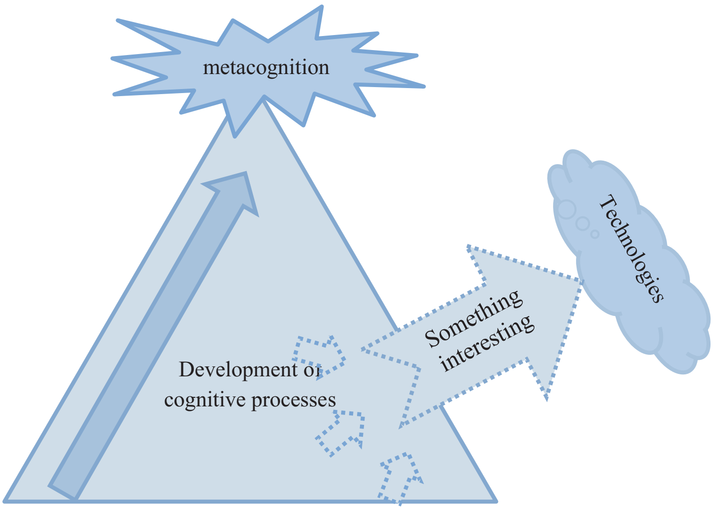

Fig. 4 Risks of interesting technologies

knowledge to analyse information, make informed decisions, and promote the development of higher-level cognitive processes in order to create new innovations. The fact that the learning process should be interesting and exciting is not new for educators. However, the fascination of technology makes it necessary to analyse the risks which can be caused by the concept ‘interesting’, as students are constantly shifting their attention to interesting technologies. This attention-shifting process can lead to the situation where long-term attention is not developed properly (see Fig. 4), which means that fragments of different pieces of information are stored in memory but do not allow being analysed as a whole picture of information, with the new information synthesized and new knowledge being constructed. This may endanger metacognitive development.

This does not mean that to support the development of metacognition what should be provided is a technology-free learning environment. On the contrary, it brings a focus on the pedagogy, which is where to find the answers for how to incorporate technology in the educational process to use the driving force of the concept of the 'interesting' in such a way as to direct the students' attention to reach higher levels of cognitive development (see Fig. 5).

It is necessary to diminish those risks which have been indicated in several investigations, where it has been concluded that the instant availability of information which is provided online can influence cognitive strategies (Mills, 2016). The possibility of such problems was indicated already by Bandura (2001), who wrote that the Internet is a tool for 'self-controlled learning', but when the information is reachable at the moment it is needed, it means that poor self-regulators can become overwhelmed and fall behind. Noncritical and unwise use of a variety of new and innovative technological and digital solutions can contribute to the development of a situation where lower levels of digital literacy are acquired without promoting a higher level of digital competence (Churches, 2007), which in the long run will affect the innovative and creative nature of digital solutions by next generations.

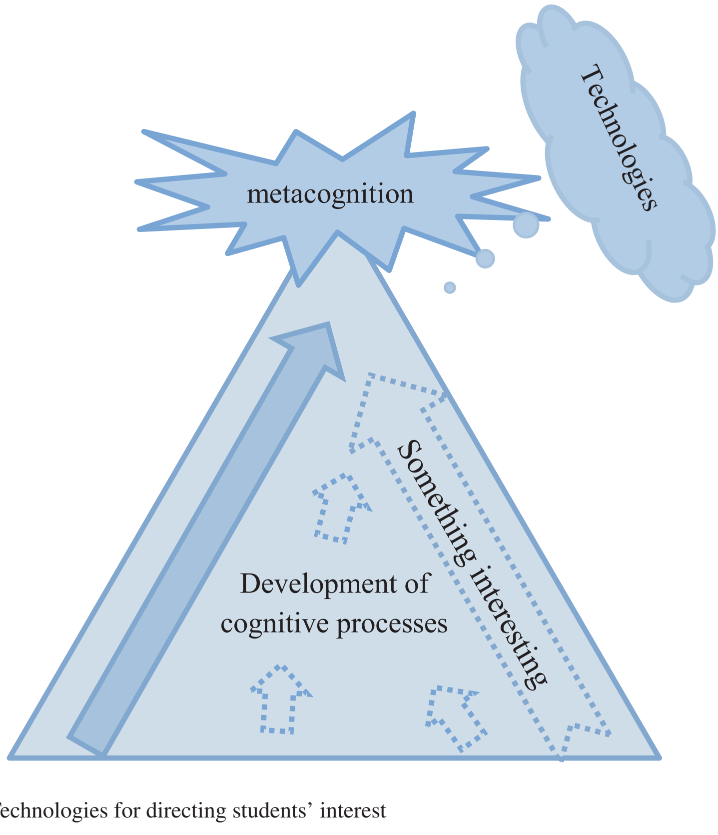

Fig. 5 Technologies for directing students' interest

This leads to the necessity to reconceptualize the regularities of the educational process, to define the teachers' competencies which are emerging for technology-enhanced learning (TEL), to ensure that fascination of technologies is used to support learning and not support the centrifugal effect on learning where teachers continue to compete for students' attention, providing interesting learning process, but students are searching for new interesting impulses on which they can focus their attention and technology provides this opportunity, thus ensuring the reduction of their attention span.

Another cause for the centrifugal effect arises from the assumption that students are 'digital natives', or what are also sometimes called 'mobile natives' (Palfrey & Gasser, 2008; Prensky, 2001). Based on this, it is then argued that therefore the students already know how to exploit the possibilities of technology and hence the teachers need not pay much attention to this: they only need to provide the opportunity to use the technology (Mancillas & Brusoe, 2016). This is a concept posing quite a high level of risk, because if students are not provided with a pedagogical scaffolding in this process, it can lead to the development of avoidance (Bandura, 1997) or handicapped motivation (Migdley & Urdan, 2001): in case a cognitive effort is needed, students can wish to avoid that and choose the easiest way—which is easy in an online environment, where it is possible to switch from *window* to *window*, exploit the capabilities of smart devices, and find quick answers and solutions. This does not provide the brain with a cognitive load. It should also be noted that in some research, it has been found that students' perception of their digital competencies is higher than it is in reality (Černochová, Voňková, Štípek, & Černá, 2018; Katz & Macklin, 2007; Turney, Robinson, Lee, & Soutar, 2009), which again indicates the role of the teacher and the role of pedagogy.

A third factor which can lead to a centrifugal effect is the conservatism of the educational system itself, which is based on the idea that there cannot be brought in new, unresearched ideas. This is in contrast to the increasing pace of technological progress, which makes it challenging to plan and implement the necessary changes. It is traditionally assumed that before the introduction of certain changes, longitudinal studies should be carried out, the findings of which can be subsequently introduced in the educational process. But while these longitudinal studies about the learning outcomes of a particular technology or digital solution are being carried out, that particular technology will become outdated and be replaced with new ones. This can cause the learning process to fall behind the innovations, whereas it should rather guide and support the development of the innovations. Already in 1980, scientists encouraged paying more attention in the preparation of future teachers to preparing them for the extensive use of technology. They pointed out that the most influential factor which prevents innovations in education is the conservatism of the educational system itself (Perusse, Décamps, & Pécot, 1980). Nothing much has changed since that time: Because there are diverse multidimensional digital solutions developed for all aspects of life, it is already accepted that these solutions can significantly improve the quality of life, reach goals which couldn't be reached before, learn in a way where students are in the centre of learning and support them, providing the knowledge outside the borders of space and time. Unfortunately, digital learning solutions enter the educational system slowly, with great caution, and sometimes they are even ignored so as to not disturb traditional learning process (a line of reasoning based on the idea that before using a technology, there should be found evidence of positive outcomes from it).

After a review of the literature on TEL, where papers from 2010 to 2016 and in the next step papers from 2013 to 2018 were analysed (Daniela, Kalniņa, & Strods, 2017; Daniela, Strods, & Kalniņa, 2018), it can be concluded that the largest amount of research is on outcomes of one particular technology. Furthermore, these studies are short term, with small samples, mostly on the use of learning management systems (LMS), but there are just a few papers on pedagogical aspects in TEL. A literature review carried out by Ying-Tien et al. in 2013, where 322 papers were analysed, concluded that more attention should be paid to the role of interventions in technology-assisted instruction in future empirical research. Moreover, they also found that very few studies have simultaneously addressed achievement, learning process, and effective outcomes. This suggests that further research on technology-assisted instruction should be conducted with various samples, different subject domains, or multiple research foci (Ying-Tien et al., 2013). It illuminates a dialectical situation, where, on the one hand, there is a need for research to find answers to various topical issues arising from the use of technology, but on the other hand, there is a need to keep pace with technological progress, which is often faster than research logic of longitudional surveys.

It is clear that technology cannot provide successful knowledge construction per se but can be a tool for widening the zone of proximal development (Vygotsky, 1978) if used according to learning objectives. In addition, pedagogy can redirect the focus from the use of technology merely in support of the learning process to creating new solutions (Kinshuk, Chen, Cheng, & Chew, 2016; Law, 2008). Together with the possibilities provided by the progress of these technologies, it is important to accept that they can be used to scaffold the learning in a digital learning environment. There are academics who affirm that pedagogical considerations are crucial in the use of technology in education (Leijen, Admiraal, Wildschut, & Simons, 2008), but, in reality, educators, although aware that technological solutions can be used, are often unprepared for their meaningful use (Burden & Kearney, 2017). A large number of studies point to the role of educators in making the learning process active in using different technologies, and most of these studies come to the conclusion that the attitude of educators towards technologies is the main influence on the decision to use or not to use specific technologies in the teaching process (Kreijns, Vermeulen, Van Acker, & van Buuren, 2014; Raghunath, Anker, & Nortcliffe, 2018). This confirms that the teacher is the one who has the pedagogical competence to organize and manage this process.

According to Jones and Binhus (2011), it is necessary to change pedagogical methods to support the needs of each student and provide what the student expects from the educational process, since the way of learning is changing rapidly (Basso Aranguiz & Badilla Quintan, 2016; Eggen, 2011; Jones and Binhus, 2011; King, 1994; O'Loughlin, 1992; Schuh, 2003; Tin, 2000) and now the fact that the student is at the centre of learning is not enough. Neither is just changing the role of a teacher when they become technology users. Now educators must facilitate learning by providing a supporting framework for the students in their use of technology (Herro, 2015). Pedagogy must search for solutions to reduce the gap between the way students learn and the way educators teach. Students of the new generation process the information differently than their ancestors did, and these differences are wider and deeper than educators conceive at the moment (Dosaj, 2004).

To reduce the centrifugal effect mentioned previously (see Fig. 3), the full potential of technology should be used, providing at the same time a structured scaffolding for all the students where they are. It must be admitted that there is an urgent necessity for changing educators' competence, to be able to plan and organize educational processes suitable for all the students and be able to predict the unpredictable, incorporate all the possibilities provided by technological progress to prepare the next generation for the world which is instantly changing. Taking into account the fact of instantly changing discourse, Smart Pedagogy should be developed by following the principles of Grounded Theory (Glaser & Strauss, 1967) where the possibilities of technology are incorporated into a Smart educational process by bearing in mind the principles of Smart Pedagogy to avoid a situation where educators agree that the use of technology is necessary in the educational process, but they are not ready to act on the principles of the pendulum foundation when the result is not clearly known but only predictable.

3 Concept of Smart Pedagogy

It has already been stated that the role of pedagogy becomes more important for finding the ways to incorporate technology in education. Here there will be explained the concept of *Smart Pedagogy*, which was developed under the logic of Grounded Theory, where the direction is defined, but not the particular methods and tools, because the technological progress is ongoing process. The concept of Smart Pedagogy is triangular (see Fig. 7), where the important cornerstones are:

1. Human developmental regularities, which include the conditions for the development of cognitive processes, the conditions for sensory development, as well as the conditions for socio-emotional development.
2. The taxonomy of the educational process, which includes the goals to be achieved and the regularities of the learning process needed to achieve these goals.
3. Technological progress, which entails the need for changes in teachers' pedagogical competence, where one of the most important components of this competence is *predictive analytical competence*.

The term 'SMART', to characterize the pedagogical principles which are appropriate for a technology-enhanced environment, has been chosen for several reasons:

1. The first is the development of Smart Technology, of which the most prominent product is the Apple iPhone, which appeared on the market in 2007, and then in

2010 also the iPad (http://www.applemuseum.com/en/apple-history), which has provided the opportunity to use the telephone and the computer not only for their already known options but for added new possibilities where these options are mixed together and also provide access to information when connecting to the Web at any place and time. As Stephen and Edwards (2018) concluded, since that time, children's engagement with technology has grown rapidly in a very short time.
2. Another reason for choosing this term is also related to the field of technology, where SMART is short for Self-Monitoring Analysis and Reporting Technology, which is a diagnostic method originally developed by IBM and introduced with the ATA-3 specification that was at the time referred to as predictive failure analysis. This technology provides advanced warning of drive failures (see https://www.computerhope.com/jargon/s/smart.htm). This predictive principle, in other words, when the system is able to analyse opportunities and warn about problems, is what needs to be taken over into pedagogy.
3. The third reason is that even though there are an increasing number of studies analysing various aspects of the use of technology in the educational process where such terms as Smart Education or Smart Learning are used, it remains unclear which pedagogical principles are being used. This produces the need to develop a new theoretical direction for pedagogy.
4. The fourth reason is based on a pun: *SMART* refers to wisdom and cleverness and so on, and the goal of an educational process is the Smart Student.

In the research literature, the term *SMART* is used to describe contemporary society as a whole, the urban environment, business, etc. Smart technologies are those that are able to adapt automatically and change behaviour to suit the environment, sense things with technological sensors, provide data to analyse, and draw conclusions from the data obtained. They are able to learn how to use experience to improve their performance (Zoughbi & Al-Nasrawi, 2015). Spector defined technology as *smart* if it is effective, efficient, innovative, engaging, and flexible (Spector, 2014).

Smart Education is also described in various ways: there are studies that associate it with learning through a variety of smart devices (smartphones and tablets), there are studies where the term is used as referring to students' wisdom, and there are those who use SMART as an acronym for various terms:

1st Option SMART – Social, motivated, anywhere, anytime, resource enriched, and technology embedded (Chun, Kim, Kye, Jung, & Jung, 2013)

2nd Option SMART – Specific, measurable, achievable, relevant, and timed (Tofade, Khandoobhai, & Leadon, 2012)

In the educational sciences, various terms are used to describe learning in a technology-enhanced digital environment. During literature review, it was concluded that there are quite a few articles and studies that use the term *Smart Education* when analysing the TEL process. Jang (2014) states that this term has been used approximately since 2012. There are articles that confirm that this term had already entered the research literature a bit earlier, starting in 2007, when the TEL process was characterized by describing it as *Smart Education* (Klichowski et al., 2015; Rothman, 2007). There are also articles in which the term *Smart Education* is used to describe learning through smartphones (Igoe, Parisi, & Carter, 2013; Sykes, 2014).

Smart Learning is also a term used in the research literature. There are articles that explore how to use personalized smart devices to learn (Graham & Zengin, 2011; Junghwan, Hangjung, & Hwansoo, 2014; Raghunath et al., 2018; Tofade et al., 2012) or analyse student learning through Learning Platforms (Caldirola, Fuente, Aquilina, Gutiérrez, & Ferreira, 2014). Spector (2014) defined *Smart Learning* as being where all philosophical and psychological aspects are taken into consideration in the learning environment and technological possibilities are added.

Digital Pedagogy also appears as a term, and there are articles that reflect on the role of digitization now and in the future (Lewin & Lundie, 2016; Turner, 2017), but at the same time, pedagogical principles have not been analysed. There are articles that analyse how to acquire specific knowledge through digital technology, for example, in music (Ajero, 2014), or mastering Victorian culture (Alker & Donaldson, 2016).

There are also articles that analyse the principles of *Mobile Pedagogy*, which highlights that despite pedagogy's becoming mobile, it is essential to remember that learning is key (Kearney, Schuck, Burden, & Aubusson, 2012; Schuck, Kearney, & Burden, 2017).

As a result of the analysis of the literature, it can be concluded that in the field of education, there is relatively high uncertainty about which pedagogical principles should be taken into account when providing learning in a technology-enhanced and digital environment, the organization of the learning process, and the competencies that need to be developed in order that students become 'smart'. So far, the pedagogical principles necessary for a transformed education have not been thoroughly analysed and defined in order to be aware of the technological possibilities, human developmental regularities, and also the principles of educational taxonomy to support the learning process. All of this points to the need to start developing a new direction of research: *Smart Pedagogy*, which is now based on the principles of Grounded Theory, and is the most appropriate in the current situation where there is no and cannot be long-term research, because the technological progress is faster than the logic of longitudinal studies.

At the centre of the educational process, there is still the student, who is becoming a *Smart Student* in the technology-enhanced environment. To reach this goal, a *Smart Education* is needed where *Smart Pedagogy* is the driving force behind a learning process which is structured and supportive. The technology-enhanced learning (TEL) for technology transferred educational environment can be seen (see Fig. 6) as a continuously changing process where different technologies are used in the learning process to support students to become smart, motivated learners who know how to construct their knowledge and are supported by competent educators, who continuously evaluate the process and carry out predictive analyses. In general, this process is driven by, and the centrifugal effects of technology are mitigated by, *Smart Pedagogy*, which takes into account the opportunities offered by technology that affect all actors in this pedagogical process. This model differs from Goodyear's (2005) conceptual framework for networked learning environments, where the use of technology was accepted as consisting of two elements: the teacher's pedagogical approach and the educational environment in which learning takes place. *Smart Pedagogy* plays an important role in the model offered in the present chapter, which is a driving force for ensuring that all the actors interact in a balanced way in the

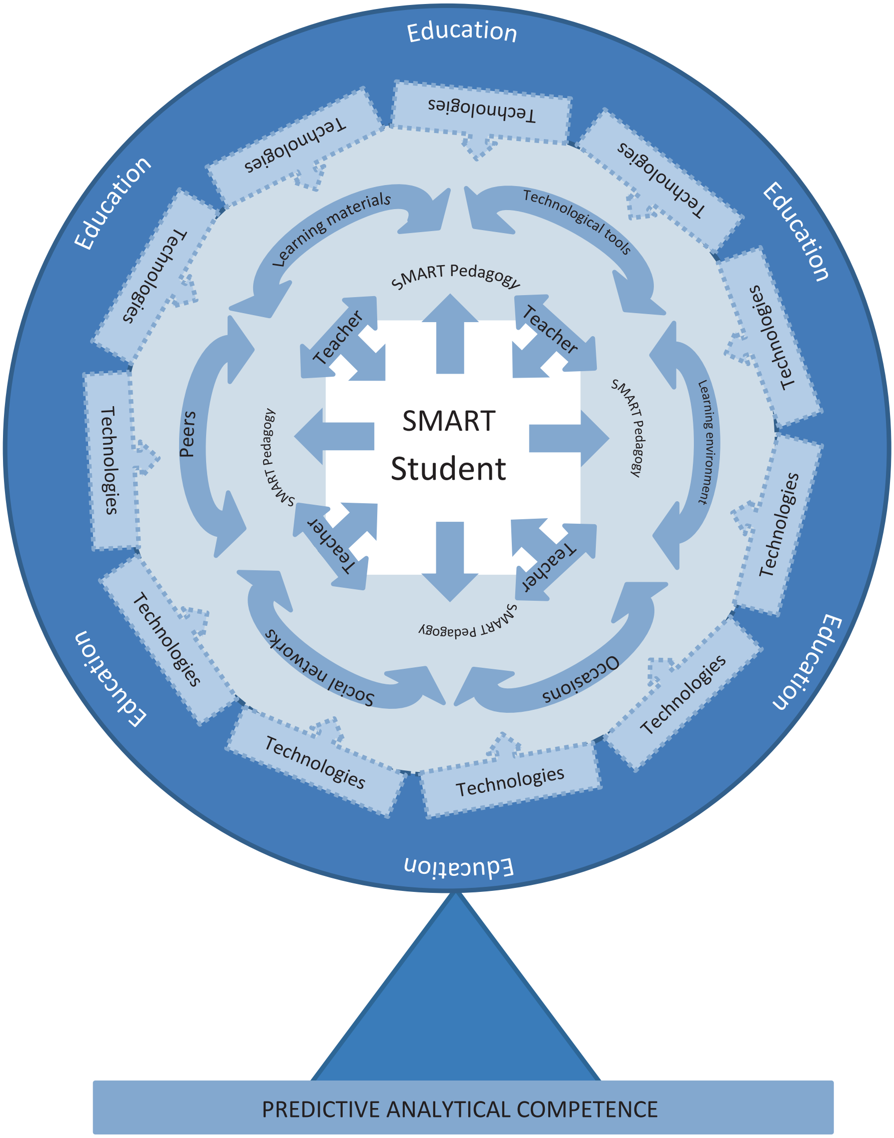

Fig. 6 The technology-enhanced learning process with Smart Pedagogy as the driving force

educational process, the technology is used to support and structure the learning, and the students are active learners who collaborate with the educational environment.

The technology that makes the circle between education and Smart Pedagogy for this model is intentionally not precisely defined, as it is constantly evolving and its progress must be taken into account in the educational process. This TEL model is put on a pendulum foundation, envisaging that the teacher not only fulfills the traditional role in supporting students in the learning process but also develops a *predictive analytical competence*, which includes the traditional competencies that educators already have (hopefully): the planning of the learning process, its organization and monitoring, support for the knowledge construction process, assessment of learning outcomes, selection of appropriate study materials, organization of peer learning process, and so on. In the transformed learning space, there should be added the ability to predict the unpredictable, to analyse the outcomes of types of technology which no one has used and assessed yet, the ability to make immediate decisions, and the readiness to use types of technology which are unfamiliar to the teachers themselves and therefore can make them feel uncomfortable in using them. This means that there are two main features of this emerging competence: the ability to predict and the ability to accept that uncomfortable feeling which, for teachers, means that they are looking for new solutions and challenging themselves and their students to reach new levels of development.

In the inner part of the circle, there are the important actors in the educational process. In the context of *Smart Pedagogy*, the following are not considered as separate elements of the educational process but as mutually interactive: the learning materials, the technological tools, the learning environment, occasions, social networks, and peers, where the ongoing process of the continuous evaluation and adaptation of the pedagogical process takes place. It also requires an elasticity of the educational environment, where these changes are possible in the actual moment needed. Although in this model the actors are referred to as separate elements of the educational process, it must be borne in mind that their boundaries are less strictly separated on a daily basis, because the technological tools can even be a supportive tool in the educational process and a tool that also contains a certain content; therefore, at the same time, it can also be considered as a learning material. Peers can be a learning source, make peer networks, and so on. *Predictive analytical* competence is one which keeps the process balanced, evaluates how and when to use technology for its general purposes and technology for specific instructional purposes, as well as understands how to evaluate the possible outcomes, support the students, evaluate the technological tools, and combine different pieces of tools, materials and content, and so on, in a pedagogically structured and supportive environment. The centre of this model is the student, who becomes the SMART student, who is an active actor of learning, co-collaborates with the learning environment, takes part in knowledge construction, and is not a mere passive observer who takes the role of an external evaluator.

4 Conclusion

All the above analysis allows making the assertion that the most important educational goal is a competent person, but in order to prevent a centrifugal effect in a TEL environment that can contribute to the fragmentation of the educational process, it is necessary to develop the principles of *Smart Pedagogy*, which becomes the driving force for the TEL. At the forefront, there is the need to supplement teacher competence with *predictive analytical competence*. In the context of technology-led pedagogical transformations, SMART can be read as follows:

S – smart (in the sense of intellectual smartness), social
M – meta-cognitively developed and motivated
A – anywhere, anytime (in the sense of a learning process that is flowing across the temporal and spatial borders)
R – rapidly changing
T – technology enhanced, which takes into account the peculiarities of human development, the taxonomy of the educational process where the next generations are using the benefits of technology, and *Smart Pedagogy* bringing the students of the next generations in front of progress to serve as developers for new levels of innovation

At the same time, 'smart' can be used as a synonym for such adjectives as clever, brilliant, wise, knowing, and so on, but with regard to the term *Smart Pedagogy*, one should not lose sight of the meaning of smart technology, which is the reason for the necessary changes.

From the student perspective, being a part of *Smart Pedagogy* means an active participation in the learning process, being someone who constructs their own knowledge in a self-directed learning process. But at the same time, the teachers must not forget that the ability to construct knowledge should be developed step by step.

Smart Pedagogy from internal perspective is the driving force of TEL, but from external perspective, it ensures that for every activity there are three cornerstones which should be taken into account (see Fig. 7), and these are:

1. Human developmental regularities, which include the conditions for the development of cognitive processes, the conditions for sensory development, as well as the conditions for socio-emotional development
2. The taxonomy of the educational process, which includes the goals to be achieved and the regularities of the learning process needed to achieve these goals
3. Technological progress, which entails the need for changes in teachers' pedagogical competence, where one of the most important components of this competence is *predictive analytical competence*

The most important principles of Smart Pedagogy are:

I. Technology should be incorporated in the learning process to use the students' natural interest in technology, as a tool for the sake of providing a scaffolding, but there should be made predictive analyses of these technologies to be evaluated in accordance with the:

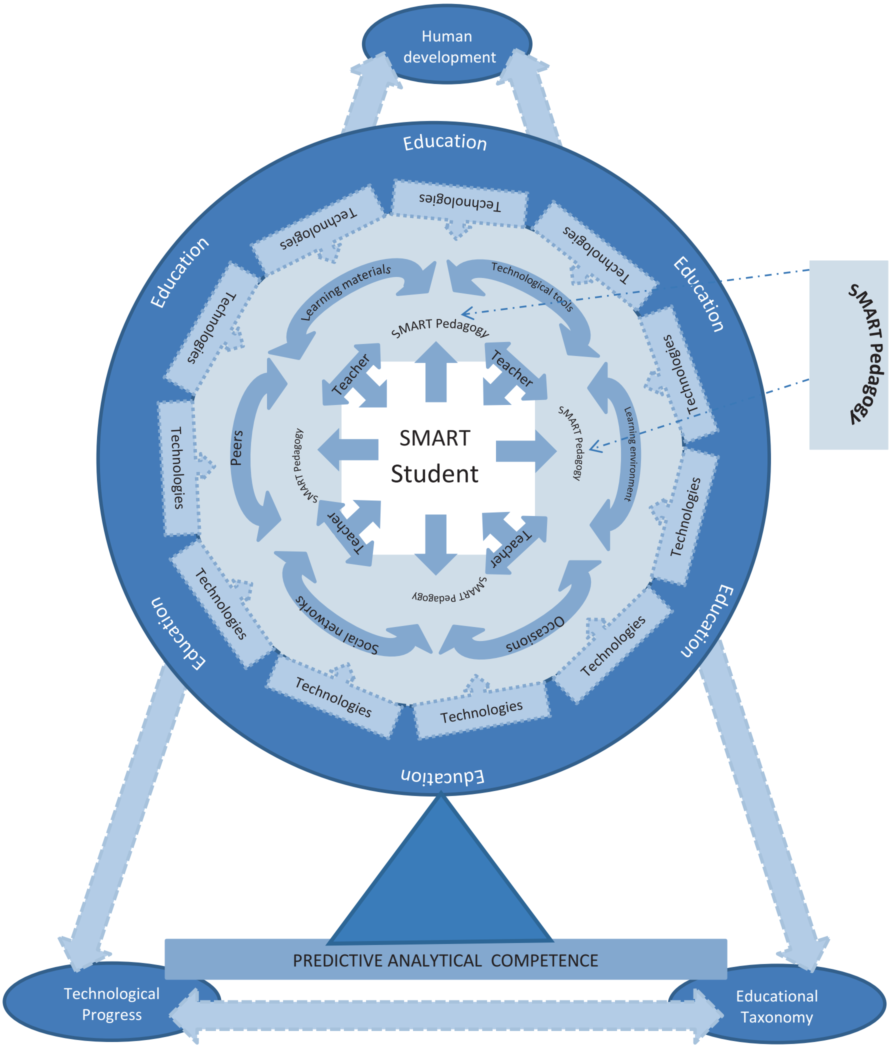

Fig. 7 Conceptual model of SMART Pedagogy

1. *Didactical criteria*:

   – Is coherent with learning content
   – Is coherent with other learning materials and learning forms
   – Helps to reach learning goals
   – Ensures self-directed learning
   – Can be used in assistive learning process as an agent
   – Is integrated/can be integrated into particular curriculum
   – Helps to develop learning motivation
   – The target group has adequate competence in their use

2. *The criteria of cognitive development:*

   - Is coherent with target group's zone of proximal development
   - Is coherent with target group's existing knowledge
   - Helps to construct new knowledge on the basis of existing knowledge
   - Prevents cognitive overload
   - Helps to focus attention, develop imagination, and processes of memory

3. *The criteria of socio-emotional development:*

   - Is coherent with the socio-emotional development of the target group
   - Ensures socio-emotional development
   - Prevents emotional overload/stress
   - Is coherent with learners' expectations
   - Is coherent with inclusive and heterogeneous learning process (special needs, different ethnical, religious groups, etc.)
   - Ensures mutual cooperation among individuals

4. *Physical development criteria:*

   - Fosters the sensory development of individuals
   - Causes no physical overload or sensory impairment

5. *Technical criteria:*

   - Visual/auditory/tactical solutions are qualitative and help to capture the learning content to be learned
   - Interactive to allow students take active part in use of them in knowledge construction
   - Easy to perceive and easy to manage
   - Teachers have guidance on their use
   - User manual easy to perceive
   - It is possible to apply to different age groups, peculiarities of pupil perceptions, and the diversification of the pedagogical process
   - It is possible to combine forms of collaboration using individual–individual collaboration, individual–device collaboration, and device–device collaboration, where the individual is the content creator, using the particular technology
   - Provide personal data protection

II. Teachers need to develop *predictive analytical competence* to evaluate possible outcomes of technologies which are not used yet.

III. Teachers are active participants in the use of the technology together with the students and accept that a discomfort in their use is part of the teachers' identity.

Smart Pedagogy is not a wonder wheel, which is offered to solve various problems that can arise in the TEL process, but more of a continuing process that respects the knowledge that has been accumulated over the ages and forms a new multidimensional knowledge based on Grounded Theory (Glaser & Strauss, 1967) principles. The proposed Smart Pedagogy vision has to be developed by identifying practices and standards that describe all the actors of the SMART pedagogical process, preparing concepts, putting concepts together to develop categories, and, for the next step, developing the theory of *Smart Pedagogy*.

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From Smart Teaching to Smart Learning in the Fast-Changing Digital World

Katarzyna Borawska-Kalbarczyk, Bożena Tołwińska, and Alicja Korzeniecka-Bondar

Abstract The aim of the article is to characterize smart pedagogy (smart teaching and smart learning) in the context of the fast-changing digital world. As part of the theoretical framework of the text, we refer to elements of the concept of network society by Manuel Castells, liquid modernity by Zygmunt Bauman and the mobilities paradigm by John Urry. They all include the thesis of the changing space-time in which a contemporary human is functioning, and that is an important frame of reference for our work.

Keywords Digital world · School learning environment · Smart teaching · Smart learning · New technologies

1 Introduction

There is social change to which we are both witnesses and originators. This has led to the formation of a new culture and different ways of experiencing relationships with the world around us. This social change creates the need to develop new methods of learning from which is standard. Transformations in the contemporary civilization force us to re-evaluate many behaviour systems and thinking patterns and to redevelop our skills and attitudes. One area in which it is necessary to thoroughly transform previous activities is education. The analysis of educational practice shows that teachers who create the educational process too often believe that the reality is made up of changing and unchanging structures. One assumption is that their traditional way of thinking about education is based on holds that teaching (i.e. teacher's activity) is necessary for student's learning. This way of thinking about education leads to the situation in which education is basically the process of transmitting information from a higher element (teacher) to a lower one (student). It is very often accompanied by one-way communication processes, the dominance of

K. Borawska-Kalbarczyk (✉) · B. Tołwińska · A. Korzeniecka-Bondar
University of Bialystok, Białystok, Poland
e-mail: borawska@uwb.edu.pl; b.tolwinska@uwb.edu.pl; alibon@uwb.edu.pl

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verbal methods of teaching (lecturing), as well as stationary and collective forms of classwork (Barnes, 1992).

We agree with the opinion of Douglas Thomas and John Seely Brown that "the kind of learning that will dominate in twenty-first century education does not only take place in the classroom – at least not in today's classroom. Instead it happens all around us, everywhere" (Thomas & Brown, 2011, p. 17). Moreover, it is based on different teacher-student relationships and requires a changed way of organizing the educational process. Further in the article, we will refer to this way of carrying out the educational process as smart pedagogy.

We assume the most important idea of smart pedagogy is the transfer of the educational process from constant, unchanging, stationary structures of transmission-based pedagogy to a fluent and flexible model with interactions between teachers and students varied in time and space. Based on literature analysis, we define smart pedagogy as the process of creating a school learning environment with high temporal and spatial flexibility, which involves students' cognitive autonomy, collaboration between both educational subjects (the student and the teacher), and making varied use of digital technologies.

The aim of the article is to characterize smart pedagogy (smart teaching and smart learning) in the context of the fast-changing digital world. As part of the theoretical framework of the text, we refer to elements of the concept of network society by Manuel Castells, liquid modernity by Zygmunt Bauman and the mobilities paradigm by John Urry. They all include the thesis of the changing space-time in which a contemporary human is functioning, and that is an important frame of reference for our work.

2 Technological, Information and Temporal Transformations of the Reality

The world we live in is the reality of continuous changes. Due to their dynamic character, they can be deemed radical. The changes are the result of some significant factors, the most important of which is scientific and technological progress, contributing to considerable economic development and civilization transformations in much of countries. The transformations occur in many areas of human functioning and are described with reference to postcapitalist society (Drucker, 2011), post-industrial society (Bell, 1973), risk society (Beck, 1992), liquid modernity (Bauman, 2000), late modernity (Giddens, 1991) or network society (Castells, 2007) and others. Currently, humans are the originators, the participants and/or the targets of all this variety of social, economic, cultural and technological phenomena. Characterizing the social context of the issues discussed in the article, we need to emphasize that the contemporary society is a new structure of socio-economic organization. It is the result of intensive development of digital technologies of information production, storage, processing and transmission, regarded as a necessary for its functioning.

The term "liquid modernity", used by Bauman to refer to the contemporary world, is its shortest but very accurate description. It points to the great dynamic of changes in nearly all areas of our life and the inability to continue unchanged for a long time (Bauman, 2010). According to Tonino Cantelmi (2015, p. 19), an Italian researcher studying the issues of Internet addiction and the influence of technology on the human mind, a new wave of technology has come within liquid modernity since the introduction of personal computers (symbolically in 1976), and it has strongly intensified in the age of the Internet (Cantelmi, 2015). Therefore, today's post-modern society is technologically liquid and characterized by the "unavoidable marriage of liquid reality and digital revolution" (Cantelmi, 2015, p. 19).

Most of discussions, analyses and studies within the aforementioned categories all focused on information society and concentrates on the transition "from a system based upon the manufacture of material goods to one concerned more centrally with information" (Giddens, 2008, p. 1). Currently, information is an important element of contemporary social structures. Castells (2007, p. 69) holds that what makes the current phase of civilization development unique is the function attributed to its two key elements: information and knowledge. Explaining that in the first and second industrial revolutions they had another more instrumental character, the author highlights the uniqueness of the information revolution, which mostly lies in the use of knowledge and information to generate new information and new knowledge. These processes have triggered important social, epistemological and even economic changes. According to Castells (2007, p. 70) "for the first time in history, the human mind has become the production force, not only a fundamental element of the production system".

Media technologies make virtual kinds of space and time and introduce more and more communication interfaces. Currently, thanks to the opportunities they offer, new forms of mobility have been developed and connected. It has improved and assisted with the changing places of residence, better working conditions and entertainment. In this context, we need to take into consideration the so-called mobilities paradigm by Urry (2009). The author uses the concept of mobility in many contexts such as tourism, the development of new communication technologies, time or consumer practices. Continuous global processes are analysed using the term "mobility", which relates to the metaphor of movement. The processes involve the movement of people, goods, ideas, services and information. As Urry observes, because of technological development and the consequences of permanent multiscreen information flow, the contemporary generation of Western teenagers can perform multisensory activities, such as receiving information from many sources at a time, following parallel multimedia accounts, or creating their own games and other contents. The author argues that "the development of such post literate 'multimedia' skills will be centrally important in the future. It suggests that humans may develop multi sensuous sets of skills combined with emerging new virtual objects" (Urry, 2009, p. 107). In the social space, there are more and more "multi sensuous places", where all senses are attacked at the same time (e.g. in shopping malls) (Szlendak, 2010, p. 81). According to Polish sociologist Tomasz Szlendak (2010, p. 81), individuals expect "to receive and generate many attractions and stimuli for all senses in one place and in the shortest time possible". This shows that an instant culture is developing, and instantaneous time is dominant, in which nanoseconds and the simultaneous occurrence and experiencing of social and virtual reality have become the priority. Urry uses the term "instantaneous time" to describe the new information and communication technologies operating in extremely short moments, completely imperceptible for humans (Urry, 2009, p. 176). The temporal framework of digital technologies in which humans are currently immersed exceeds conscious human experience. The media previously known to humans (the telephone, the facsimile) shortened human reaction from months, weeks and days to seconds. The computer has shortened it to nanoseconds. The instantaneous time analysed by the author "stems from what Negroponte describes as the shift from the atom to the bit; that the information-based digital age 'is about the global movement of weightless bits at the speed of light'. The information can become instantaneously and simultaneously available anywhere" (Urry, 2009, p. 176).

Some elements of Urry's mobilities theory go in line with the analyses by Castells, who uses the term "mobile revolution" to refer to a component of the emerging information society. We can see strong relationships between the popularity of mobile communication and the development of a new teenage culture, language transformation and cultural transformations in the organization of time and space by individuals and groups.

3 Irrelevance of Traditional Education in the Contemporary Reality

The evaluation of traditional school presented by John Dewey over a century ago is still quite true. Known to everyone image of a classroom with rows of desks made the author think that the conditions "compel the children to be dealt with *in masse* and compel them to be led in flocks, if not in hordes, without much appeal to individual initiative, judgment or inquiry. This can also be the explanation for the repetitiveness of teaching methods and curricula. If everything is based on listening, the materials and methods can be constant. Talks and books can be the same for all. Yet, it is nearly impossible to adapt to students' different needs and abilities" (Dewey, 2005, p. 29). Despite many such expressions of criticism of school in the social discourse, the fossilized educational strategies, irrelevant to the current reality, still exist. The paradigm of transmission pedagogy is strongly rooted in this school system, resulting from treating knowledge as a product that needs to be popularized at all cost (Dylak, 2009, p. 40). It is reflected in the concept of banking education, developed and criticized by Paul Freire (2000, p. 67), whose aim is "to fill the students with the content provided by the teacher, which is unrealistic and unrelated to the real world" (Kostyło, 2013, p. 88).

In the transmission strategy, it is the teacher who presents certain contents, values, assessments and choices, and the student's role is to acquire and accurately reproduce them. It consolidates students' cognitive passivity and limits their research activity in the acquisition, construction and application of knowledge and skills. In addition, it reduces the cognitive curiosity and the inclination to creative thinking due to the stress on reproducing textbook knowledge instead of autonomously constructing and implementing it. School that functions this way is oriented at forming attitudes connected with fulfilling certain proper roles and obligations, highlighting objective standards of humans' relations with the world, despite declarations of strengthening students' subjectivity. It affirms logocentrism, the culture of print and linear cognition of content, considering media messages as mere illustrations, not as independent cultural texts (Kasprzak, Kłakówna, Kołodziej, Regiewicz, & Waligóra, 2016, p. 51). It builds a barrier, endorsing the transmission provision of content and often not allowing any alternative possibilities of relaxing the rigid framework of educational negative tradition.

One element of traditionally understood educational process is the presence of teacher and students at the same time and place. School focuses on arranging their meetings in time and space, which requires punctuality, precision and predictability (Urry, 2009, p. 157). Most events taking place at school are planned in terms of time and space, to help synchronize the activity of the whole institution. Observing the temporal and spatial rules (being at the right place at the right time) is necessary to keep the order and clarity of tasks carried out by all the educational subjects. It particularly refers to the didactic process, in which the set goals need to be achieved through precisely planned activities with consideration of temporal and spatial regularity (Zerubavel, 1985). Planning and achieving the effects of education are conditional on what, when, where, in what order and how often will be done and how long it will last. This "static" time-oriented model of thinking about the teaching process taking place at a specific location is only seemingly beneficial. It did work in a reality in which changes were predictable (in terms of their occurrence, nature, direction and scope). But nowadays the changes are quick and rapid, as we have already explained before.

The analysis also involves changes in students, who need education that is organized and carried out in a different way now (Rubene, 2018a). Contemporary students were born in the age of digital media, which has a tremendous impact on them. Don Tapscott believes that a common characteristic of people of this generation is the fact that they were the first to grow up in the digital age (Tapscott, 2010, p. 38). He called them the Net generation. It is sometimes also called the generation of digital natives (Prensky, 2001) or generation Z (McCrindle & Wolfinger, 2011). Those young people live on the Internet: they obtain multiple resources from the Internet, and apart from living in the reality, they live in the social media. Having permanent contact with other members of their community thanks to mobile devices, they are becoming the "wireless" generation. The nearly constant presence on the Internet leads to changes in teenagers' cognitive, social and even biological functioning (Carr, 2013; Small & Vorgan, 2008; Spitzer, 2013). Thus, contemporary students live in conditions completely unlike those that existed a decade or two ago.

Teenagers' permanent presence in the virtual space is a great challenge to researchers and educators, because it forces them to reconstruct the traditional educational process. Its important aspect is “to know the complex and constantly evolving problem of the young generation’s interest in the media. Children influenced by the new media go to schools, which should recognize that the profile of an average student varies from that of even a few years ago” (Morbitzer, 2011–12, p. 151). The young mobile generation, so different in terms of perception of the world and information, is still educated in the system developed in the nineteenth century.

This creates the need to determine the main characteristics of the generation of digital students and to find ways to capitalize on the fact that all the students are present on the Internet to activate them in the formal educational space.

The mode of education proposed by school now is insufficient, and one reason for this is the teachers’ unawareness that the students they are educating are unlike the students they taught in the past and very different to themselves.

Since the Internet developed into a full-fledged entity, many researchers have been studying the sociocultural implications of its universal accessibility. One area of this scientific exploration is the relationships between the huge resources of information offered by the Net and the human capability of retrieving and processing it. Culture 2.0 has definitely broadened our access to information, but it has not broadened our capability of processing it at all (Szpunar, 2015).

Technologies and media have not only formed young peoples’ attitudes and system of values, but – as proved by research results – they have also effected changes in their brain structures, making the Net generation a generation of people with brains different from those of their parents. It can be proved by neurological studies, showing that contact with digital technologies (especially the Internet) alters the anatomy and functioning of the brain (Small & Vorgan, 2008). As a result, the young generation may have problems with communicating feelings, understanding others’ viewpoints and maintaining social relationships, as well as displaying creativity. Analyses by Gary Small show that constant access to visual and auditory stimuli has modified the neuronal structures of digital natives so that they expect instant gratification (Small & Vorgan, 2008). “The areas of the brain responsible for attention, assessment of profits, emotional intelligence, controlling impulses and goal achievement-oriented behaviours undergo substantial changes between the age of 12 and 24” (Tapscott, 2010, pp. 180–181). Thus, the immersion in digital technologies takes place when the brain of a young person is particularly susceptible to external influences. Intensive involvement of young minds in information technologies, computer or video games in that period may have a negative impact on the development of the frontal lobe in youths, which may lead to disturbing their social or reasoning skills. Small’s thesis is that if the maturation process occurs as described above, neuronal connections in teenagers may be permanently stuck in the concrete operational stage, i.e. at the level of immaturity (Small & Vorgan, 2008).

Scientific reports lead to the conclusion that prolonged Internet usage also weakens the ability to immerse in reading and the linear thinking ability. Moreover, the Internet may have a negative impact on concentration and contemplation ability, manifested in accepting information in the form offered by the Net: as a flow of data. Linear reading promotes the formation of one’s own structures of knowledge, concentration on creating the image and understanding the text, whereas on the Internet, we predominantly read short texts, blog entries, posts on discussion forums, etc., which involves scanning and skimming rather than actually reading (Carr, 2013). In our times, the Internet has clearly contributed much to training young people's quick reading skills, but it refers to reading of short texts which do not require any thorough insight. So we can actually see with our own eyes what Marshall McLuhan predicted years ago: the media are not only information channels but powerful tools which shape the way of thinking and modify human perception of information (McLuhan, 2004).

Living in a world full of digital media has both a positive and a negative side. The negative influence, however, is increasing due to the excessive, uncontrolled use of the media, and people with a low level of information literacy are especially sensitive to this influence. Hence, teachers cannot ignore the omnipresence of the new media and their influence on students. Besides, they should not limit the use of the media in the educational process to simply substituting other teaching materials without considerably changing their function. What we mean is that ICT should not be used for the tasks that were performed before computers appeared.

This change cannot take place without the re-evaluation of teachers' mentality regarding the process of information acquisition and learning from the perspective of today's students. An important task would be to deepen teachers' awareness of what kind of students they have in class, the awareness of differences between the generation of "digital natives" and "digital immigrants" (Prensky, 2001). Changes in the minds of the Net generation members result in the evolution of their way of learning and work. Understanding them can provide the ground for cooperation and motivate teachers to seek new ways of activating students. The need to exchange information, look for new content and share their thoughts and comments is completely natural for contemporary students, and they want to do so as they learn at school as well. Therefore, the possible ways of using digital media, which they know very well, can be applied for the very same purpose in education. According to Tapscott (2010), technologies should serve education, not the other way round. We need to remember, however, that every tool can be used well or be used wrongly. "Educators' activities must focus on minimizing the potential wrong use and maximizing the benefits of rational and responsible use of IT tools" (Morbitzer, 2010, p. 8).

Young people's permanent connection to the Internet, active participation in social networks, creating digital content, the freedom of commenting as well as fruitful, business-like collaboration with the members of virtual communities mean that digital natives are more demanding towards school. They expect "education to be relevant in the real world, the world they live in. They want learning to be interesting and fun" (Tapscott, 2010, p. 225). They expect school to meet their interests, to give them the opportunity to doubt and question what they learn, to really take part in the research and to look for answers to their questions.

Nowadays, there is a huge gap between the students' needs and the passive didactic activities of the teachers. It is hard for teachers to gain students' attention if the lesson is conducted in the traditional way. The learners do not accept their role as passive recipients of information, since they have unlimited, much quicker and easier access to it thanks to modern technologies. This may cause students' alienation from teachers. Our analysis shows the image of school which offers educational process that not very much related to what the students do out of school and at home. Immersion in the world of digital media has created considerable dissonance between the attractiveness and speed of what a student does in their free time and the slow, constant pace of what they are told to do at school, where it is often impossible to use new information technologies. The huge gap between how students (digital natives) think and act and how teachers (digital immigrants) teach is the most clearly visible in the methods of education offered by school. According to Tapscott (2010, p. 225), the generation of contemporary teenagers will not be satisfied with passive participation and listening to talks given by teachers.

Permanent, temporally and spatially unlimited access to online information opens interesting opportunities for innovative organization of education. It may occur at a place and time convenient for students and does not require meeting the teacher or working together with the group at a steady pace. In the past, the place of the educational process was physical. Today, we rather have educational areas, which due to the development of digital media are related to social networking and enable communication and cooperation in the virtual dimension. Anywhere and anytime learning may also be referred to as ubiquitous learning (Topol, 2012). "It is well understood that a ubiquitous learning environment is a situation in which even the student may be learning without being fully aware of the fact" (Gros, Kinshuk, & Maina, 2016, p. VI).

The problem we are facing is the irrelevance of school activities to the world the students are living in. The institution has become "culturally irrelevant (…), unaware of the changes occurring in culture, and hence, incompetent in perceiving them and creatively participating in them" (Klus-Stańska, 2005, p. 30). The mismatch between school and the contemporary world deepens the crisis of education efficiency and is frustrating both for teachers and students. Studies from many countries show that fewer than 40% of secondary school students are intellectually engaged in schoolwork (Fullan & Langworthy, 2014, p. 1). The contemporary school is far from students' everyday interests, so as an educational environment, it is intellectually unattractive. This translates into students' poor motivation to school effort. "The digital revolution is transforming our work, our organisations and our daily lives" but, as Sir Michael Barber observe, "it is transforming the way children and young people play, access information, communicate with each other and learn. But, so far, this revolution has not transformed most schools or most teaching and learning in classrooms" (Barber in Fullan & Langworthy, 2014).

Digital media with their temporal and spatial infiniteness and the variety of content offer students an opportunity to become active participants of the educational process, not passive recipients of information. However, in traditional educational environments, they do not have free access to computers and other information technologies and are even discouraged from using them at school (Schleicher, 2012). The world of digital natives (students) and the educational space created by digital immigrants (teachers) are two separate planes defined by completely different sets of goals, motivations or means of performance.

To sum up, changes in the sociocultural and technological context of education described above and the new model of a student strongly immersed in the world of digital media lead to the need to modify the traditional theory of education.

4 Smart Teaching: Smart Learning Environments

The use of modern technologies in educational processes is currently discussed at the global scale, but preparing students to living in the dynamically changing digital world does not only mean adding digital media to teaching. It is rather an important element initiating reflection on the need to change the assumptions concerning the educational process. Traditionally understood education, i.e. transmitting new content at a specific time and place, proves to be ineffective in the face of the need to constantly and quickly change skills and adapt information. We totally agree that the "current education crisis is first the crisis of inherited institutions and philosophies created for the needs of another reality, which it is hard to adapt to the ongoing changes" (Bauman, 2007, p. 143). So, it is fundamental to reveal the "fiction of constant (unchanging) context and place of the learning process and hierarchical relationships between the teacher and the student. We need to put more emphasis on didactic concepts that highlight the synergy of group learning and the reconstruction of the teacher's role as the moderator of the process of students constructing their own knowledge" (Bougsiaa, Cackowska, Kopciewicz, 2016, p. 483). The learning process, its structure, timing and technological infrastructure are becoming more important than the content itself (Dylak, 2013b, quoted in Bougsiaa, Cackowska, Kopciewicz, 2016, p. 483). We find these assumptions in the smart pedagogy model. In our opinion, implementing smart pedagogy is not tantamount to simply spicing the lesson up with attractive methods or digital media. It rather involves the transformation of the teacher's mental awareness – understanding the new perception of teacher's and student's roles and rejecting the traditional thinking about the teaching process (stationary transmission of information).

We assume that smart pedagogy is the process of the teacher constructing a learning environment organized in a modern way (smart teaching). Hanna Dumont, David Istance and Francisco Benavides point to seven key characteristics of such an environment: learners at the centre, the social nature of learning, emotions are integral to learning, recognizing individual differences, stretching all students, assessment for learning and building horizontal connections (Dumont, Istance, & Benavides, 2010). The problem of organizing a modern learning environment was also tackled in the OECD report on preparing teachers to the twenty-first century. "A central foundation for improving teaching is an understanding of learning. The body of evidence on how children learn has grown greatly over the past years. However, this knowledge base has not always had a profound impact on teacher practice in the classroom. Research shows that teachers, like most people, interpret new ideas through their past experiences and their established beliefs about learning and teaching. As a result, innovative ideas are often simply absorbed into traditional classroom practices" (Schleicher, 2012, p. 39). Thomas and Brown note: "learning should be viewed in terms of an environment – combined with the rich resources provided by the digital information network – where the context in which learning happens, the boundaries that define it, and the students, teachers, and information within it all coexist and shape each other in a mutually reinforcing way" (Thomas & Brown, 2011, p. 35). The learning environment understood this way is permeated by the new learning culture, in which students learn actively. It requires open-ended activities that allow for deep information processing and creativity development, based on students' autonomy and promoting teamwork. An important difference is the fact that in the traditional educational system, the students are taught about the world, whereas in the modern learning environment, the stress is on learning through actively immersing in the world. As pointed out by Thomas and Brown, "the goal is for each of us to take the world in and make it part of ourselves. In doing so, it turns out, we can re-create it" (Thomas & Brown, 2011, p. 38). In smart pedagogy, the process of creating active modern learning environments assumes the possibility of deep learning at school through the change of school practice (teaching and learning) (Fullan & Langworthy, 2014). The benefit of implementing the principles of smart pedagogy is that traditional classrooms are replaced with learning environments, digital media give access to rich sources of information and fun, and the processes occurring in these environments are an integral part of the effects.

Developing such modern learning environments based on the smart pedagogy model, we need to re-evaluate the teacher-student relationship, modernize the knowledge acquisition process and actively include new digital technologies. We emphasize that changing the teachers' thinking, resulting in the re-evaluation of the essence of traditional education, is the underlying factor of smart pedagogy.

4.1 Change of the Teacher-Student Relationship

One significant element of this change is the formation of proper relationships between teachers and students. Thus, we point to the importance of partnership in learning and the need to develop relationships with students that are based on humanistic values. The role of the teacher is more than providing educational content and explanations. The teacher should reject the previous role as the "soloist" (the provider of structured, organized information) and transform into the "accompanist", guiding the student in their search for, organization and use of knowledge. Thus, it is more important to guide the student's mind than to model it, not neglecting fundamental values as crucial life guidelines (Delors, 1998, p. 150). This transformation of the teacher's role is possible if the following conditions are met. First, students should sense the teacher's care about their well-being and learn how to build mutual trust. The time and place at which teachers do things should be determined by the students' needs (Davies, 2003, pp. 136–137). Second, decisions should be negotiated with all the partners of the interaction. Such relationships make it possible for teachers and students to learn together and from each other. In smart pedagogy students participate in deciding about the learning process, and the teacher does not have the absolute power over it. Students' interests and questions related to the educational content are not ignored (Ames, 1992). Students contribute their own ideas, experiences and knowledge to the educational process, and they feel that teachers also learn from them (Fullan & Langworthy, 2014). The latter characteristic highlights that the contemporary teenagers belong to the generation that Margaret Mead calls prefigurate (2000). This means the roles are switched, a perfect example of which is the process of using the new media, where students may become the teachers of those who were supposed to teach them.

Third, the student should receive feedback from the teacher and from peers on their activity. The aim of the feedback is to help the student better understand their work in relation to the previously determined educational goals. It helps develop the awareness of their learning process and express their way of thinking. Peer feedback is a very useful technique to support autonomous learning and clear thinking. Students learn to formulate goals, determine the criteria of success, accept feedback and evaluate their own and others' work. Doing this in practice allows teachers and students to analyse which teaching and learning strategies best contribute to progress (Fullan & Langworthy, 2014). "The learning environment operates with clarity of expectations using assessment strategies consistent with these expectations; there is a strong emphasis on formative feedback to support learning" (Dumont et al., 2010, p. 17). It is important for the feedback to include appreciation for the student's effort or the adopted strategy (in the case of success) or the expression of need to modify these elements (in the case of failure). When providing feedback, the teacher should avoid referring to the student's intelligence. Stressing the student's level of effort and the autonomous choice of the proper strategies is a way to develop in the student the craving for mastery and accomplishment (Fullan & Langworthy, 2014).

4.2 Changes in the Information Acquisition and Knowledge Production Process

In smart pedagogy, collaboration and the process of active knowledge acquisition and processing are possible thanks to community education. One example is the "peer-to-peer" model, understood as a form of learning together that highlights the value of interaction between learners. This way of learning is greatly facilitated by information technologies, which offer new methods of education support. Digital media make it quicker and more natural and allow the collective experience of participating in another dimension of time and space (Thomas & Brown, 2011, p. 50). In this model learners are encouraged to share knowledge and experience they gain. Outsourcing platforms, which enable students to establish contacts with more and more learners and to participate in the process of content production and implementation, provide good conditions and opportunities for the organization of this kind of education (Pedagogika Web 2.0). Significant advantages of peer learning are the individual engagement of each student in the learning process, the development of independence and strengthening the sense of responsibility for the produced knowledge and its application. Other benefits are higher motivation to work and the development of key competencies, such as obtaining and processing of information, collaboration, using modern technologies in studying, and teamwork skills.

Therefore, forming groups and participating in group activities are important skills to be developed. Team learning follows the model: production – production and reflection – production, reflection and sharing (Pedagogika Web 2.0). This tendency leads to changes in the learning culture: it is the culture of community, i.e. learning, teaching and exchanging experiences between the learners. It involves adopting from others and combining already known elements into new entireties, introducing minor changes in them and again sharing the results (Brown, quoted in Pedagogika Web 2.0) Taking part in this form of education, people learn from each other thanks to interaction and participation in the activity of the whole community. This specific collective ensures equality to each person: nobody is attributed the traditional role of a teacher (Thomas & Brown, 2011, pp. 50–51).

Regarding the change of the teacher-student relationship in the smart pedagogy model, we can point to the great diversity of didactic actions selected with consideration of tasks interesting and engaging for the student. The teacher should stress the purpose of didactic actions and make them emotionally and intellectually attractive for the students (the goal is to help them appreciate the value of learning). If necessary, the assignment of materials and tasks as well as their level of difficulty should be individualized (Ames, 1992). The goal of these tasks is students' deep engagement in discovering and acquiring the existing knowledge and then producing and applying the knowledge in solving real problems. Students often choose by themselves what and how they are learning, and their cooperation with the teacher includes determining clear educational goals, criteria of progress and the structure of activities (Fullan & Langworthy, 2014).

Noticing the need to transform the role of a teacher, Tapscott entreats "teachers to leave their desks and start listening and talking to students, not only to give them lectures. They need to reject the one-way style of transferring knowledge and adopt a new, interactive one" (Tapscott, 2010, pp. 230–31). The teacher organizing a modern learning environment assumes the role of organizer/animator of the didactic process. This involves strengthening the student's natural curiosity, encouraging them to do research and ask questions but also leaving ample time to find the answers. Developing the ability to independently acquire knowledge through searching, analysing and evaluating information is an important principle of smart pedagogy, promoting an active learning environment.

In an active environment, learning takes place indirectly. It is mostly the student who builds their way of finding the solution, and this activity promotes cognitive development (Dylak, 2013a). Thus, the student becomes the manager of their own cognition process. The student's role is not to remember and reconstruct the existing content prepared by another person but – using different strategies, such as combining and adding information and concepts – obtain a new element that will be used in a real-life situation. These tasks are difficult; they require initiative and endurance. To perform them, cooperation within the team is usually necessary, which shifts the stress in the learning process from an individual to a group. This way, students become the leaders of their own learning, they can achieve educational goals using available resources, tools and connections, thanks to digital access, but they also develop teamwork skills. This process of education is organized with consideration of students' interests and ambitions (Fullan & Langworthy, 2014).

Such effects are possible thanks to the well-known project method and the WebQuest method based on it. This method makes use of the Internet as the source of information and a tool of teaching purposeful and reasonable use of global information resources. Based on the theory of constructivism (Perkins, 1999), it develops students' comprehensive information competence: it teaches directed information search and processing; allows to improve problem-solving skills, critical and creative thinking and cooperation within the team; and supports students' mental process in terms of analysis, synthesis and evaluation. The WebQuest method was based on the project method, and their common features are the desire to motivate the student to independent work and activate them at different levels and the stress of creativity in thinking and action. This way of working with students is oriented at the process of information search which main (though not the only) source is the Internet. Using online resources, students analyse the problem assigned by the teacher, search for diverse information and try to verify its quality. Students use digital tools to collect, edit and prepare for presentation the obtained information and structures based on them (Dodge, 1997). This method is a specific class project, whose main goal is to create problems (tasks) that will be appropriate (i.e. especially attractive) for students and to organize teaching around certain concepts. It meets one of the basic demands of constructivism, referring to appreciating students' personal knowledge in the educational process, which is an important principle of the smart pedagogy model.

4.3 Information Technologies in Education

Such methods will not only allow students to do "old" (traditional) activities in a new way. They also allow to do new activities in the new way and to participate in another, better education thanks to information technology, making it easier to get information and learn. As Fullan and Langworthy see it, "without changes to the fundamental pedagogical models by which teachers teach and learners learn, technology investments have too often simply layered slightly more entertaining content delivery or basic skill practice on top of conventional teaching strategies that focus on the reproduction of existing content knowledge" (Fullan & Langworthy, 2014, p. 30). Using modern technologies in combination with traditional educational strategies will not create a modern learning environment, conforming to the principles of constructivism. The potential of new technologies is much greater.

It is clearly seen in the SAMR model by Ruben R. Puentedura (2003), defining the levels of technology integration in the school education process. Analysing the levels of using ICT in education, i.e. Substitution, Augmentation, Modification and Redefinition, we can see that it is only at the second level (modification) that we abandon the traditional model of teaching and technology begins to play a significant role in the classroom: it is used to solve the tasks students must do. At this point, the change in the use of technology is critical – technology becomes necessary to carry out the task. What is more, student's individual educational experiences become significant too. The student no longer learns only to communicate; now they also develop various digital skills.

The last level (redefinition) offers much greater opportunities for creative activities. Digital media enables students to perform complex activities which also include tasks that could not be predicted or imagined before. In this case, information and communication technologies are extensively used in performing the task but as tools necessary for the project to succeed. Students – not the teacher or the technologies – are at the centre of the activity. Collaboration is vital, and technology offers an additional opportunity of effective communication between the team members. If students are deeply engaged in the process of learning, the process has been transformed (Puentedura, 2003).

Mobile technologies in education and the whole digital learning environment offer the opportunity of community production of knowledge in a broader democratic perspective. Understanding the learning process as a social activity, mobile technologies are tools that enable collaboration in problem-solving and social construction of knowledge, motivate to work as a team and to share knowledge (Bougsiaa, Cackowska, & Kopciewicz, 2016), as we have already pointed out.

Modern digital technologies are used in applying various time- and space-unlimited sources of information to facilitate the student autonomously create knowledge; they make it possible to learn and perform tasks in cooperation with others out of the classroom or school, through participating in networks all over the world. Thus, digital technologies offer new opportunities to carry out the teaching and learning process, which places in the centre the student's activity in extended space-time.

5 Conclusion

Smart pedagogy restores the proper interpretation of the concept of activity. It refers to both educational subjects: the teacher, who activates students in cognitive effort, supports them in the knowledge production process and provokes to think, do research and explore the environment, and the student, who, thanks to skilfully arranged didactic situations, actively gains information and autonomously constructs knowledge. Changes mostly occur in the so-called teaching sphere: promoting the departure from the active teacher and passive student style. Classes are based on discussion and exchange of views, and the classroom is a form of community, not just a place where many students do their best to survive and go unnoticed. The modern style of teaching is successfully implemented by a group of Polish teachers called "Superbelfrzy" (*Super Teachers*). The group is made up of professionally active teachers, coaches and educators who use information technologies in their everyday work at various stages and levels (from preschool to the so-called Third Age, in accordance with the lifelong learning principle). They attempt to change education at the grassroots level, since they find traditional education boring and irrelevant to the challenges of the contemporary reality. They believe change is a constant element of life, so they call themselves "Educhangers". They are passionate about teaching and understand their role as being guides in students' journey through the world, not as infallible sources of knowledge. Their activity is based on the idea of mutual teaching and learning, sharing knowledge and experiences. They uphold the following principle: "If you want to be an effective Educhanger, first of all change the phrase: 'it's impossible' to the phrase 'how to do it?'" (www.superbelfrzy.edu.pl).

Consequently, students' activity in the modern learning environment may relate to another role: the role of active participants of designing and experiencing of their own educational situations (Prensky, 2012; Rubene, 2018b). When carrying out such didactic assumptions, considerably supported by multi-subject, multi-level and "timeless" communication in the digital space, students' cognitive activity makes them the subjects of their own learning. After all, we know for teenagers it is of key importance to "be active, evaluate, and be heard" (Dylak, 2012).

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Smart Pedagogy for Smart Learning

Neus Lorenzo and Ray Gallon

Abstract Pedagogy has been defined as the discipline that deals with theoretical concepts and practical educational approaches. A smart pedagogy for digital transformation, where artificial intelligence will provide smart educational agents, needs to consider how technologies affect perceptions of reality, cognition, and social interactions. In the second decade of the twenty-first century, several international organizations, including the OECD and UNESCO, are converging on natural learning principles for a new pedagogy focused on achieving the United Nations goals for sustainable development. At the same time, notions about learning space have evolved due to the input of specialists from many disciplines. Even the term "space" has been redefined, with the advent of personal computers and mobile devices as elements that offer a window to the world. Educators today are facing a major paradigm shift, in the form of the fourth industrial revolution, or Industry 4.0, that requires a rapid response through Information 4.0. New technologies and infrastructures enable learning to be personalized to each individual learner. Technological objects metamorphose from tools or environments into personified agents that help teachers evaluate the potential and progress of each learner and might eventually decide for them. Future challenges demand a humanistic approach to technological development in education.

Keywords Smart learning space · Virtual learning space · Educational space · Smart pedagogy · Smart learning · Information 4.0 · Digital transformation · Distance learning · Artificial intelligence · Internet of Things · Personalized learning · eLearning · Mobile learning

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N. Lorenzo
The Transformation Society, St. Etienne Estréchoux, France

Universitat Autònoma de Barcelona, Barcelona, Spain
e-mail: neus@transformationsociety.net

R. Gallon (✉)
The Transformation Society, St. Etienne Estréchoux, France

Universitat de Barcelona, Barcelona, Spain
e-mail: ray@transformationsociety.net

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1 Concepts for Building an Epistemology

Etymologically, the word *pedagogy* comes from the Greek παιδαγωγέω, a compound word that includes παῖς-παιδός, child, and άγω-ἀγωγός, leader, meaning the curator that guided a child's development and well-being during the first years of life. It has traditionally been defined as the discipline that deals with education concepts and teaching practices (Ellis, Cogan, & Howey, 1991). It includes theory (conceptual understandings of what is learning and knowledge, how humans learn, think, and interact) and practical approaches (who should teach, where, when, how, and what for) (Beetham & Sharpe, 2013).

Modern definitions of pedagogy put the emphasis on social and political aspects, reflecting on the purpose of education itself, how nations organize their educational systems, what learning technologies will facilitate students' learning, how education policies relate to the economy and labor markets, and why we humans should be shaping current education to create a better future world (Illeris, 2009). With all this in mind, researcher Cynthia Luna Scott (2015) collected, for the United Nations Educational, Scientific and Cultural Organization (UNESCO), different channels of thought about new forms of learning needed to tackle complex global challenges. She reflected on the pedagogies needed for the twenty-first century, where Smart Learning Spaces (SLSs) are expanding into the unknown horizon of extreme automation (machine learning), ubiquitous connectivity (Internet of Things), and hybrid societies (combining human and artificial intelligence). She synthesized a common consensus among several experts, notably McLoughlin and Lee (2008) and Beetham and Sharpe (2013):

> Moving towards a new pedagogy is not simply a matter of offering learners technologies they are likely to use in the knowledge society (McLoughlin & Lee, 2008)… Rather, twenty-first century pedagogy will involve engaging learners in apprenticeships for different kinds of knowledge practice, new processes of enquiry, dialogue and connectivity. (Beetham & Sharpe, 2013)

This movement toward more diversified, reflective, and interactive learning can be framed according to the three-level skill taxonomy defined by the International Tuning Project (2014), where 29 countries propose 3 general learning competences for higher education students:

- **Instrumental competences:** cognitive, methodological, technological, and linguistic
- **Interpersonal competences:** individual social skills, interaction, and cooperation
- **Systemic competences:** relating to whole systems, combining understanding, sensibility, and knowledge

To achieve this complex competence development, educational systems need to adapt to a transforming world and use existing technology to offer personalized support to every student, in school and beyond. Constraints of time, space, and roles in the teaching and learning process are disappearing from educational spaces, thanks to a deep transformation of technological resources, theoretical concepts, and practical issues. Reflecting on this evolution will provide new policy horizons and new strategical lines of action.

Technological evolution under the smart learning spaces rubric is nicely connected to the pedagogical evolution of concepts, techniques, and goals that are converging into both UNESCO's and Tuning's pedagogical approaches. Understanding how "learning spaces" have become "smart," and when "learning technology" has evolved into "smart environments" leads to methodological considerations that help identify epistemological characteristics of smart pedagogy.

1.1 Learning Space: Building a Concept from Different Disciplines

The concept of *learning* has been developed over centuries by philosophy, pedagogy, and educational psychology (De Corte, 2010) as a way of understanding the adaptive process of how people grow and live by interacting with the environment and with others, including the study of individual characteristics, gifts, difficulties, or disabilities (UNESCO, 1994).

The concept of *learning space,* on the other hand, has been the domain of other disciplines and has been studied from many different points of view:

- Architects have seen it as an opportunity to explore the effects of different environmental factors on the learning process (physical arrangements of walls, furniture, and tools), connected to how people experience light, sound, color, volume, atmosphere, or shape when interacting and interpreting meanings. Two famous examples are Josep Goday's Escola del Mar in Barcelona and Le Corbusier's Carpenter Center for the Visual Arts at Harvard University.
- Gardeners and landscapers are now producing research to demonstrate how strategically situated plant arrangements on school grounds can affect different attitudes among learners, to the point of facilitating or blocking capacities of concentration, memorization, or concept representation. Dilafruz Williams' interesting Webinars, for the North American Association for Environmental Education, debate how gardens and landscapes can enhance holistic and academic learning (Williams, 2018).
- Psychiatrists and medical doctors have researched the role of health and well-being on learners, including humidity, temperature, open air, and volume, or the effects of personal reactions to physical environments, and individual responses to the evolution of diseases in a space. The rubric elaborated by the Victoria State Government, in Australia, connects inclusion and engagement with health programs and policies (Victoria State Government, 2017).
- Anthropologists and ethnologists have been comparing educational spaces for decades all over the world, looking for connections between mental and physical spaces. They collect evidence of how adults can condition communication,

cognition, and interaction strategies by shaping learning spaces and the activities that are organized in them. Researchers such as Franz Boas and Margaret Mead started a brand-new discipline to study customs and communities.
- Teachers, trainers, and educational authorities in every country have also observed and considered learning spaces from empirical perspectives. They have produced practical suggestions on how to use, modify, and adapt learning spaces according to students' needs and teachers' methodologies to achieve better results, work more effectively, and use resources more efficiently. Research papers and policy guidelines are regularly published by global institutional organizations such as UNESCO, the Organization for Economic Cooperation and Development (OECD), or the World Economic Forum (WEF).
- Neuroscientists have recently been called upon by politicians and decision-makers to apply their discipline to justify necessary changes that need to be made in furniture arrangement, subject timetables, classroom language, or emotional education to improve innovative spaces. This type of intervention is part of a continuous tradition that dates back to medieval figures like Averroes and Avicenna, continuing into modern times with people like Nobel Prize-winner Santiago Ramón y Cajal or linguists like Paul Broca and Carl Wernicke.
- Engineers and technologists no longer limit themselves to studying the design and ergonomics of daily tools, such as tables, chairs, or students' rucksacks. They have swiftly evolved into central decision-makers in the design of learning resources, including the computers and connecting devices that access content and connect classrooms to the global knowledge network. They are the designers of devices and virtual spaces that expand concepts like augmented schools or smart learning environments.

These and other specialists contribute different concepts to the design of learning spaces and help us to understand how contextual elements can be relevant in learning processes. Future smart learning spaces will be connected to the Internet of Things (IoT) – the network of connected objects, driven by AI, which will automate many processes that today require human intervention and will make many machines autonomous. Spaces equipped with this technology will be able to identify, quantify, and modify environmental factors (e.g., light, screen color, humidity, temperature, air pressure) to meet physiological and personal needs or preferences.

> Smart pedagogy will have to be developed collaboratively, by cross-disciplinary teams, finding consensus and negotiating environments through plurality and diversity, to produce collective educational proposals.

1.2 Classroom Space: Evolution of Active Learning

The evolution of educational spaces is connected both to technological and social complexity. Originally, it responded to policies designed to prepare the generational renewal of citizens for whatever cultural and socio-economic roles were prioritized: soldiers, workers, or simply responsible adults. The school we know today is still the primary common educational space where knowledge is supposed to flow for systematic, structured learning for everyone.

Specific teaching and learning technologies have been used and reused in schools for decades, but the most common methodology is still explicit instruction led by the teacher in a classroom. Classrooms are widely known as the traditional learning space, where teachers apply specific techniques to help students to understand and practice certain activities, to achieve the required educational goals. These goals change according to social needs and have evolved from providing accumulative data (school syllabus) to procedural information (learning strategy) to globalized knowledge (core curriculum). Institutional classroom equipment has also evolved from utensils for student practice (e.g., pencils) to teachers' implements (e.g., books) and classroom supplements (e.g., connectivity devices). Simply placing computers in a classroom is not going to change teachers' performance, but they can change information-access habits and modify students' learning dynamics. The school's learning space is now open to a network of complementary spaces (e.g., social media platforms) where teaching and learning is not a list of activities, but a continuous interaction of interpersonal connections and social interdependencies (Beetham & Sharpe, 2013).

There is a long list of innovative experts who have promoted changes in the traditional school space (where teachers fully supervise students' activities) to make the student's role more active in the classroom and reshape the teacher's role from authority figure to more of a facilitator (Dewey, Montessori, Rosa Sensat, etc.). Others have reorganized the physical space to create unique scenarios, where learning processes have their own technological environments. Ferrer i Guàrdia (1913) used printing machines to offer a creative space to students, shaping both professional skills and critical thinking. Freinet (1927) created specialized corners to allow students to experiment. He separated classroom spaces for learning with different technologies and offered students autonomy and self-access. Decroly (1929) based school spaces on the cognitive itinerary in his method of observing, associating, and expressing conclusions.

In their classroom spaces, teaching and learning is redefined by approach and technology. Structured education at school becomes a system of interactions and creates a more transparent space of self-access and self-regulation of agreements between the learner and the teacher, between the learner and the environment, and between the learner and the other learners in the group. Under this paradigm, learning spaces are more associated with their educational *teaching and learning* function and their associated technologies than with the traditional classroom space for teachers and students where subject matter education was dispensed in just one rigid direction. Today, the concepts developed by these pioneers remain valid:

> A learning space should be able to motivate learners and promote learning as an activity, support collaborative as well as formal practice, provide a personalized and inclusive environment, and be flexible in the face of changing needs. (JISC Development Group, 2006).

It seems that the more complex a *technological learning space* becomes, the more personalized and self-regulated the learning activities need to be, to offer advanced learning strategies and to promote autonomous learning processes (Heo & Joung, 2004).

1.3 Expanding Knowledge: Evolution of School Technology

At present, when digital transformation and virtualization are reaching ever deeper into society to drastically transform every economic and social activity (Winthrop, McGivney, Williams, & Shankar, 2016), formal education systems will also need to be fully integrated into a technological context where schools and classrooms are widely connected with the outside world, and into the IoT, using computers, phones, tablets, and other new devices (Lorenzo & Gallon, 2015).

In this new context, most of the academic literature related to smart spaces emerged initially from the concept of a technological learning space, enriched with computer-based connectivity and ubiquitous retrieval. This space is commonly understood as a digital setting or a virtual place in which “teaching and learning” occur, fully supervised, or semi-supervised, through structured methods or from emerging and self-regulated processes (Cook, 2010).

The concept of smart space is still connected to the idea of platforms and technological environments, but it is evolving with increasing technological complexity into a more virtualized and contextualized ubiquitous space. It is becoming a personalized sphere of activity that can be performed with the support of wearables, detached devices, or even internal implants. The current concept of smart learning space is becoming so open and transparent that physical boundaries between formal learning at school and informal learning outside the school almost totally disappear (European Commission, 2012). Smart schools are transforming into hubs of personal and social learning processes, where students, teachers, families, and the whole community can learn and participate in real events (Rellis et al. 2009).

2 Learning Process: Toward Smart Learning

In 1999, Mark Weiser suggested that technology was going to evolve from the initial “tool to do something” to a more unseen, invisible context in which “to extend your unconscious” as part of future technological evolution into a world of calm and continuous experiencing of life (Weiser, Gold, & Brown, 1999). Leaving aside the “calm” part, he was ahead of his time.

His vision of a ubiquitous dimension to digital learning environments enhanced our understanding of computer-based learning. Such a widened, open, transparent learning space can make it easier for actions and activities to be shared by all members of the educational community. Transparency becomes essential for collective cohesion, increasing the possibilities for synergies, motivation, and the feeling of belonging to the educational community (Freire, 1970). This idea of nonstop lifelong learning continuum (both in physical and temporal space) evokes a net of interactive relationships that can be seen, identified, and quantified. Specific data increases the information that can be analyzed to understand the learning process and its interdependencies. The study of the flows supported in these networks, and recorded in smart learning spaces, provides essential metadata that widens the scope of teachers' roles as instructors, evaluators, advisors, facilitators, and educational decision-makers.

Innovative smart pedagogy should consider the opportunities that such metadata produces for designing a more professional, accurate, efficient, sustainable, and equitable educational system.

2.1 Learning Process in Virtual Learning Places

For centuries, pedagogy has been delegated to modular systems led by an adult of reference. For our ancestors, it was a conversation near the cave fire; for our parents, it was a lecture in the school classroom. Learning in this type of dialogic space requires listening, understanding, and reproducing to show effective results from the training. Students are assessed by their ability to replicate the model of the teacher.

The incorporation of computer technologies into these spaces for educational interaction introduced a new "communicative" competence (digital skill), but it continued to reproduce the same question-and-answer models, maintaining a linear discursive narrative between teacher and learner.

The introduction of word processors to classrooms in schools and universities had a major effect on written assignments. They generated a first meaningful mental

> In almost 40 years of computer-based learning, it is difficult to detect a real paradigm shift in education related to changes of approach and technology.

change in teachers' understanding of knowledge, correction, and assessment in digital spaces, especially when applied to foreign language learning (Lee, 2000).

2.2 Computer-Assisted Learning Spaces: A New Learning Process

The advent of screens for human-machine interaction helped project a new cognitive learning space and transformed the student-machine relationship. The computer was then identified as an extra school "place" more than a "tool." Students were asked to "go to the computer" instead of going to the library or to the study room. Everything started to change when the computer itself started to "act" and "interact" with the student. Learners' and teachers' roles were affected, and the concept of learning process evolved.

While Computer-Assisted Learning (CAL) models were gradually gaining popularity in foreign language teaching, they also brought progressive enhancements to educational spaces in general (Brumfit, Phillips, & Skehan, 1985). Some scholars considered that the conceptualization and development of these computer-based learning spaces at school were tied to psycho-pedagogical movements that were in fashion at different moments during the past 40 years. For Warschauer and Healey (1998), the combination of technology and pedagogical theories led to three initial stages in Computer-Assisted Language Learning (CALL) models that we can identify as behaviorist, communicative, and integrative:

- **Behaviorist CALL:** In the 1960s and 1970s, the first form of computer-assisted language learning reproduced repetitive question-and-answer models, translation, and lexical drilling. It offered a digital interaction (student-machine) very similar to that of the traditional classroom (student-teacher). One of the most popular tutorial programs, PLATO, combined educational needs and technological means to generate a new learning space without teacher intervention at school (Ahmad, Corbett, Rogers, & Sussex, 1985).
- **Communicative CALL:** In the 1970s and 1980s, those who rejected behaviorist pedagogy started to focus on language usage rather than on language form. Grammar learning was implicit, while students were encouraged to generate communicative messages instead of manipulating given forms (Phillips, 1987). CALL tutorials in this era started to implement constructivist theories and included software for dialogue building, situational communication, and multimedia support for conversational simulations (Jones & Fortescue, 1987).
- **Integrative CALL:** In the 1990s, with the emergence of the World Wide Web, computer-based learning made a major revolution. It moved away from its focus on individual learning and opened to a socio-cognitive approach. This put the emphasis on collaborative activities, authentic social context, and meaningful cultural content (Lorenzo & Noguera, 1997). The Internet started to be more popular than any specific learning software, and the opportunities for connectivity in education started to generate a whole specific pedagogy that led to collective action and role-based inquiry sessions on the net. Most of these have become classic examples of early gamification, such as Treasure Hunting (Gates, 1993) and Webquests (Dodge, 2001).

Since the beginning of the twenty-first century, as the number of schools connected to Internet has increased, the expanding concept of learning spaces has included the image of “the computer” or “the screen” as classroom furniture – part of the set of common educational resources. Schools have installed computer rooms as the symbol of the new millennial pedagogy, where the teacher has had to become a facilitator, a strategic leader, and a guiding coach more than a subject matter expert (Ellerani & Gentileb, 2013). Computer corners were brought into the classroom where encyclopedias and dictionaries had been before, to become part of the usual equipment of modern connected schools.

Schools incorporated digital tools as extra learning spaces by trying to integrate them without changing the basic instructional, structured educational system, as they usually do, with innovative ideas, which can be viewed as threatening for the institutional organization (Florio, 1975).

2.3 Building a New Knowledge Concept: Distance Learning Evolution

At the same time, the Internet was being associated with the idea of having a “window to the outside,” open to the real world. It brought students to museums, monuments, zoos, or libraries that could be visited during or after class, as part of school learning itineraries.

In the last 15 years, many schools have become enriched environments, with digital extensions where students can manage content and data quickly and efficiently if teachers and learners have the appropriate digital skills. Most students can easily find the answers to almost all their exam questions (as currently generated by their classroom teacher) by asking Google or Siri.

The school subjects that require simple, low cognitive abstraction (identify, remember, isolate) started to be seen as “memorizing disciplines,” almost useless “silos,” because they managed complex reality in arbitrary fragments that could be easily found on the Internet. Learning started to be considered as a dynamic, integrated flow. Interdependent socio-cognitive processes were presented as progressive levels of abstraction (Bloom et al., 1956), continuously revised (Anderson et al., 2001), adapted to the digital environment (Fisher, 2009), and linked to High Order Thinking (HOT) processes (Resnick, 1987). Mastery of knowledge building required social interaction (Vygotsky, 1978), and globalized project-based learning (Kirkpatrick, 1996) was seen as good practice for developing it.

Computer-based learning appropriated practices from existing distance learning methods to create a structured, expansive educational model. Use of the Internet meant the possibility of delocalized instruction and competence transfer across different experiential spaces, resources, and learning techniques. Massive Open Online Courses (MOOCs) became popular and widened the scope of SLSs into Virtual Learning Environments (VLEs). In a virtual environment, learners have the ability to reach distant and remote territories and connect with each other through different media via real-time or time-shifted technologies.

But despite the excitement over new forms, distance education is not new. It has occurred throughout history, using media such as carved wood, knotted cords, painted leather, or written documents. In the modern educational community, it was the systematic structured intention of transmitting instructional content that has shaped virtual learning environments (Brown, 2010):

(a) **Before the twentieth century:** VLEs had their conceptual origins in correspondence and home study courses, common in ancient China, popularized in Europe in the 1700s among monasteries, and generalized in the USA after the late 1800s, thanks to the development of affordable public postal service.
(b) **Beginning of the twentieth century**: Radio facilitated the organization and dissemination of correspondence courses (Lambert, 1963) that could be segmented into small tasks and coherent chunks of learning material, which was used to create virtual classrooms (Volkan Yüzer & Kurubacek, 2004).
(c) **Late 1960s and 1970s:** Schools explore educational opportunities from television, audiotape, and fax, in combination with printed study guides and local libraries, to bridge geographic distances and provide education to remote students.
(d) **1980s and 1990s:** With mass expansion of electronic connectivity, educators in the USA, Canada, USSR, and Australia experimented with distance teaching via interactive television, electronic networks, and computer-based multimedia systems, both sending and receiving synchronous (real-time) and asynchronous (delayed) audio, video, text, and graphics. Interactive interfaces were available to both students and instructors, and included facilities for editing content, case studies, and email discussions.[1] The teacher's job started expanding to include measuring connection efficiency, counting process data, and analyzing test results, timing, link accesses, and other meaningful metadata that would be included in next-generation web-based systems.
(e) **1991–1999:** The rapid development of the Internet created a new global dimension for distance learning, and schools developed online projects that shaped the international access process as an extension of the school learning space (Lorenzo & Noguera, 1996). Building online communities brought new, unexpected teaching and learning challenges focused around intercultural engagement, personal motivation, and strategic media communication (Zimmer, Harris, & Muirhead, 2000).

[1] The authors participated personally in the Kidlink social learning project, started in 1989, using fax to link children around the world. That project evolved to the web, now at https://www.kidlink.org. Another relevant project, Big Sky Telegraph used fledgling bulletin board systems from 1988–1994 to connect rural schools in the U.S. state of Montana to some of the great minds then working at Massachusetts Institute of Technology (MIT). For a narrative of this experiment, see http://www.davehugheslegacy.net/files/PDFs/odazhist.pdf

In the twenty-first century, VLEs enriched this virtual eLearning space with interactive tools and metadata measurement that could be accessed by the instructor to know about individual and collective test results, forum discussions, completion of assignments, email usage, etc. Courses merged self-teaching, interaction, and team collaboration – three personal learning spheres that reproduced existing school spaces in the new smart learning environment.

2.4 Smart Learning Environments: Personal Networks for Smart Learning

Entering the new millennium, everything changed with mobile telephones, when eLearning became mLearning (Buchem et al., 2012). This portable device allowed everyone to communicate and to access learning spaces wherever they might be. Digital education was finally institutionalized as a right by international organizations like OECD and UNESCO, when they called for equity and universal education (European Commission, 2017). They have high expectations for the twenty-first century from massive open online platforms, evolving out of learning management systems, collective Wikis, etc. and based on the connectivist approach that this globalization can offer to facilitate real educational change (Siemens, 2004).

Many schools are moving away from initial strategies of technology accumulation, toward new personalized spaces and flexible options. Computers have started to be replaced by wireless devices, both provided by the institution and by the learners under a Bring Your Own Device (BYOD) program: smartphones, tablets, watches, and other wearables are now widespread in many countries and have generated a long list of international Information and Communication Technology (ICT) projects under the European Erasmus+ programs and their education action keys (European Commission, 2014). On the other hand, the overwhelming need to adapt schools to this accelerating change is also producing an opposite educational reaction in many schools and countries. Smartphones are officially in the process of being banned from the classroom in countries like France, in favor of a closed, controlled ICT regime that maintains the existing educational paradigm (Anderson, 2017).

The big shock has been not only the creation of an international virtual space for education that is now institutionalized by global initiatives at all educational levels (UNESCO, 2011), but the need to adapt methodologies, or even create a new, specific pedagogy, for teaching and learning in this unexplored global virtualized sphere. The virtual world becomes a continuous extension of personal space and the extension of local and global cultural development to a wider horizon. It can be a useful environment where educational systems can rethink needs, challenges, and possible solutions.

Virtual learning environments become Smart Learning Environments (SLEs) when the emphasis is not just on “what new learning content” a particular virtual space is offering to students, but on “how the knowledge building process” can be personalized. Knowledge is not storage, but flowing in networks of interactions.

A smart pedagogy for SLEs needs to take into account how every student responds to learning sequences, activities, and interactions. It must offer more effective access for each learner (adapting to special needs and individual capabilities), make strategic learning more efficient (focusing on individual talents and interests), and turn competence development into a lifelong process (providing personalized strengths and individual coaching).

3 Education Models in Smart Learning Spaces

The digital transformation has the effect of moving more and more of our interactions into the virtual realm, and it generates a need for rethinking educative roles in the digital age. For the first time, learning spaces are not places where students go, but global networks of flowing information that offer ubiquitous access in endless streams of knowledge. Smart learning spaces become opportunities for rethinking learning processes and learning purpose, in a major paradigm change, toward a more effective, personalized, and sustainable education.

3.1 Educational Technology: Acquisition Models

The combination of desired education outcomes, students' personal capabilities, and learning environments should determine what resources will be most appropriate in every case. This acquisition process follows different steps or phases of technology incorporation that different authors have correlated with learning theories.

The potential impact of technological evolution in smart learning spaces has been analyzed according to the SAMR model, in parallel with Bloom's taxonomy (Puentedura, 2014), to provide a progressive framework for understanding the role of technology in education:

- **Substitution:** Technologies that replace other tools without adding anything significant
- **Augmentation:** Technologies that replace other tools and add new functionality
- **Modification:** Digital tools that replace other tools and add new functionality that also affects learning in a significant way
- **Redefinition:** Digital immersive environments that change fundamental relationships and pose cognitive (and sometimes ethical) challenges

Evidently, the added value of SLSs is not just focusing on technologies, but on the synergies that help teachers and learners modify or redefine solutions for every singular and contextualized situation (i.e., helping to transform and not just enhance learning), therefore being able to modify and redefine roles in teaching and learning processes in virtualized spaces. As early as 1998 Robin Mason was proposing different models of eLearning that also correspond to different levels of the SAMR model (Mason, 1998):

- **Content + Support Model** is a substitution model, where content is prepackaged in a more or less traditional way and is separate from online tutorial support which can be provided by teachers who may not have authored the course content. The teacher's role is not knowledge provider, but access/knowledge facilitator.
- **Wraparound Model** corresponds more to the augmentation pattern, similar to the "flipped classroom" model. Course material is still prepackaged, but about half of the course consists of online interactions between tutor and learners. More of the course is dependent on what interactions occur between the various actors on line, which can include mutual problem solving using screen sharing software and other similar collaborative tools.
- **Integrated Model** enters the realm of modification. The boundary between content and support is almost totally gone. The course is made up of collaborative activities that can be initiated by anyone and can include different transmedia elements such as videos, audio, texts, lectures and conferences, fora, etc. In order for this to be successful, a genuine learning community needs to be established.

It is easy to understand a classroom as a shared learning space, where learners come together to join in common efforts using common resources. It is more of a stretch to imagine how learners accessing information on mobile devices while on the bus or in a cubicle at work are sharing a common learning space. Yet more and more people are thinking of the social media they participate in as communities where they develop social skills for creating Personal Learning Networks (PLNs) for lifelong learning in formal and informal learning environments (Camacho & Ferrer, 2012). Research on the so-called "millennial" generation shows that they are comfortable with forming virtual communities of interest around various goals of social activism and mixing them with more traditional forms (Achieve Agency, 2017).

> Smart Education Models will have to include social dimensions and collaborative approaches, and expand them to real global problems, institutional challenges, and goals for the human species.

3.2 Student-Centered Models: From Students' Abilities to Individual Awareness

Our informational and learning environment is becoming increasingly complex, and there is no one-size-fits-all technological solution. Learners need to be able to select from an array of tools, to best fit their preferred learning styles. This is not possible without a self-driven learning itinerary founded on individual awareness and personal self-regulation. When using smart learning spaces, the student is at the center and becomes the protagonist of the whole process. Classroom work is delocalized and conceptualized differently, and both teacher's and learner's roles change drastically, creating a learning community based on real personal interaction for learning achievement, regardless of the locale of its members:

> Assimilation of learning space and collaborative learning experiences should go hand-in-hand with re-conceptualizing technologically enhanced learning spaces that complement paradigm shift. It is essential to have flexible classroom environments that support integration, engagement and collaboration among instructors and learners, without regard to location. (Ochola & Achrazoglou, 2015)

It is difficult to understand the personal mechanisms that incentivize engagement and motivation, as they are tightly connected to individual learning interests, styles, and priorities and need different stimulation and support. Smart learning spaces can be a useful element in this personalized approach. Smart learning tools help us to incorporate data analysis from student behavior and generate personalized contexts, simulated or real, for each student to stimulate learning engagement.

Integration and personalized student support have been widely treated in special needs education (Biklen, Ferguson, & Ford, 1989) and with regard to classroom organization for managing diversity at school (Stainback & Stainback, 1989). For decades, since empirical studies of psychology started to categorize learning processes and abilities at school (Binet & Simon, 1911), pedagogues have studied and classified learners according to their needs and their capabilities. Several models have gained a certain acceptance because they encourage teachers to prepare different activities for students to help them feel comfortable according to their learning profiles: the traditional triad VAK, for Visual, Audio, and Kinesthetic learning styles (or VARK or Visual, Audio, Read/Write and Kinesthetic sensory modalities), has been used all over the world to provide initial support for reading and writing literacies and to help students struggling with their difficulties in academic achievement (Fleming & Mills, 1992).

Other models have emerged to describe learners' performance in new technological environments. Honey and Mumford (1992) have proposed four learning styles focused not on personal capabilities, but on individual preferences and learning behaviors:

- **Activists:** like trying things out and participating.
- **Reflectors:** take a thoughtful approach before acting.

- **Theorists:** pay attention to details and prefer a sequential approach to problems.
- **Pragmatists:** appreciate the idea of applying what they have learned and solving practical problems.

For many years, these and other classifications tried to diversify teaching and learning techniques, but they could never provide enough personalized support with individual granularity until smart learning spaces appeared, with their potential for metadata analysis. The common approach was that some of these people had special needs to perform adequately. The concept of universal diversity and personalization for everybody, and the commitment to establish inclusive schools where students are not classified by profiles, abilities, or categories, is quite recent (Ainscow, 1999). Connectivism and non-evolutionist theories, like multiple intelligences (Gardner & Hatch, 1989), have strongly contributed to generalizing the concept that singular differences are essential to human nature. Every student is unique and responds differently to dynamic communication flows and is organically connected to the others and to the world.

What we have learned from the CAL and VLS experiences mentioned previously is basically the need to recognize the value of every student's learning process as his or her personal strategy to adapt, grow, and evolve in his/her own lifelong learning process. Since UNESCO institutionalized a global approach for education in 1999, learning has been based on competences and literacy skills (Delors et al. 1996). The emphasis has not been on content nor on strategies, but on a more integrated concept of adaptation and interaction: learning, learning to do, learning how to be, and learning how to be with others.

In a more recent revision of educational needs for a sustainable world, the OECD has now put the emphasis on a collaborative problem-solving approach (OECD, 2013) that helps every student to manage problems collectively and to transfer competency knowledge to other situations so as to be able to act sustainably in different contexts. The OECD sees global competence as being shaped by three principles, equity, cohesion, and sustainability, and defines it as these capabilities:

- **to analyze** global and intercultural issues critically and from multiple perspectives,
- **to understand** how differences affect perceptions, judgments, and ideas of self and others,
- **and to engage** in open, appropriate, and effective interactions with others from different backgrounds on the basis of a shared respect for human dignity (OECD, 2018).

To achieve this sequence of global engagement, understanding, and capability in the digital era, learners will have to interact in formal and non-formal spaces, creating their own meaningful transmedia learning space together with others (Josefowicz, Gallon, & Lorenzo, 2017).

3.3 Building Digital Skills for Developing Collective Responsibility

Students, as smart learners, will need digital skills to access information, process it to select whatever content/procedure can be applied to solve any particular problem, and change attitudes accordingly. International educational policy guidelines are available for encouraging and assessing social responsibility in school projects. Education is designated as one of the most important vectors for raising social awareness among youngsters (Open Working Group on Sustainable Development Goals, 2014). Dr. Mmantsetsa Marope and her group at the UNESCO Global Curriculum Network have provided a framework for curricula transformation in technological environments that can also be useful for participating in virtual learning spaces and communities (Marope, Griffin, & Gallagher, 2018). The authors have correlated the technological components from Marope's proposal with the cognitive learning processes proposed in Bloom's pyramid, as shown in Fig. 1. The objective is to obtain a hierarchical framework that illustrates how activities and exercises can be planned in an SLS.

According to Marope's team of experts, learners should be able to develop seven *stable macro competences* for lifelong learning in the digital age by combining cognitive processes and digital transversal skills:

Inner Strength

1. Lifelong learning: curiosity, creativity, critical thinking, etc.
2. Self-agency: initiative, drive, motivation, endurance, grit, resilience, responsibility, etc.

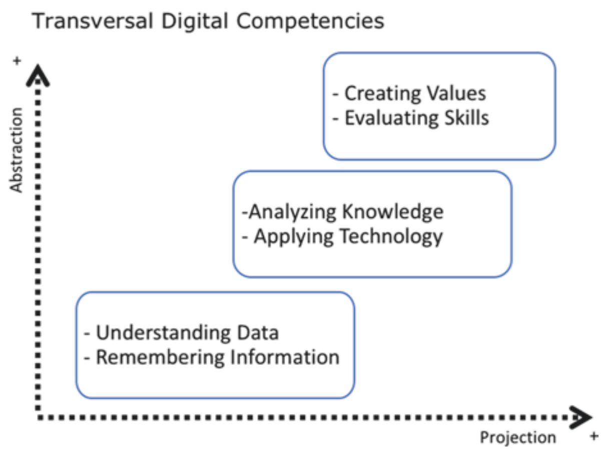

Fig. 1 Associating Bloom's taxonomy with UNESCO digital skills. (Chart by the authors)

Interactive Action

3. Impactful use of resources: efficient use of resources, responsible consumption, etc.
4. Interacting with others: teamwork, collaboration, negotiation, etc.
5. Interacting in and with the world: being local and global, balancing rights with privileges, balancing freedoms with respect, etc.

Transformational Knowledge

6. Trans-disciplinarity: STEM, humanities and social sciences, etc.
7. Multi-literateness: reading and writing, numeracy, digital literacy, etc.

To meet these goals, smart learning spaces must be able to empower learners according to their needs and capabilities. They should offer a wide variety of real, gamified, and simulated activities that can be modulated for individual response, self-agency, and resilience.

Using transmedia resources, inside and outside formal structured courses, individual achievement can be detected from personal and collective performance during real interactions with technology, with others, and with the world.

Knowledge levels and personal progress can be tested during daily interaction in nonformal education. It can be certified by either preparing personalized authentic challenges for solving problems in real life or proposing complex project-based learning sequences.

Under the Marope team paradigm, individual performance cannot be fully mature unless it is also integrated into social development and oriented toward the common good. Smart learning spaces can provide opportunities to explore and participate in real events to demonstrate engagement and motivation for common well-being:

- Awareness, Adaptability, Agility to Adapt
- Innovation Empowerment, Social Justice,
- Productivity Sustainability, Efficiency
- Justice Democracy, Good Governance
- Social Cohesion, Equity and Inclusion, Citizenship
- Domain Specialists, Human resources, Human Capital
- Functional Literacy, Digital Society, Health and Well Being (Marope et al., 2018)

Considering the importance of personal and interpersonal digital skills for empowering common good, an effective pedagogy in smart learning spaces needs to be able to accommodate instructional learning, strategical collaborative skills, collective community organization, and knowledge building.

4 Information 4.0: Toward a Smart Learning Epistemology

Today, the initiative called Industry 4.0, also known as the fourth industrial revolution, is just getting under way (Schwab, 2017). It is built on the combination of cyber-physical systems, the Internet of Things (IoT), and cloud computing. In the first industrial revolution, humans built machines. In the second industrial revolution, machines built machines. In the third industrial revolution – the cybernetic revolution – machines help humans decide. In the fourth, machines are deciding for humans in a hybrid society. We could envision a fifth revolution where machines decide for both humans and machines in a kind of "cyber-symbiosis."

The German Government Initiative specifies four essential design principles for industry 4.0: interoperability, information transparency, technical assistance, and decentralized decisions (Hermann, Pentek, & Otto, 2016). In response to this environment, a consortium of information specialists and technologists designed Information 4.0 to ensure the human dimension in the development of digital transformation technologies. Information 4.0 is a fluid concept, and its definition is evolving. At the time of this writing, the characteristics of Information 4.0 are defined as:

- **Molecular** – no documents, just information "molecules" – small chunks of information that facilitate the rest of the characteristics
- **Dynamic** – continuously updated and recombined with other molecules
- **Offered** rather than delivered
- **Ubiquitous**, online, searchable, and findable
- **Profiled** automatically
- **Spontaneous** – triggered by fine-grained contexts (Information 4.0 Consortium, 2018)

Smart pedagogy largely corresponds to these same principles that motivate Information 4.0. The technologies to implement them will depend to some measure on artificial intelligence, and students and teachers will need to learn how to interact with nonhuman intelligent agents, in hybrid interactions.

The authors developed a study in 2014 to compare the attitudes of people over and under the age of 40 to different aspects of digital transformation technologies (Gallon & Lorenzo, 2015). In 2018, a second study (still in progress at time of this writing) is putting some of the same questions to secondary school students to see if the younger generation's attitudes are changing. We present here some preliminary results in the area of human bionics from the Escola Virolai in Barcelona, Spain, which habitually collaborates in studies of humanistic technology.

Figure 2 shows that new generations seem quite comfortable with the idea of an electronic tattoo, but as soon as implants are connected to the Internet, they are more cautious today than the 2014 sample that included people up to 40 years old. One might imagine, then, that these youngsters would also be concerned with questions of security and control when presented with the idea of digital prosthetics. But as Fig. 3 shows, it is only the question of being hacked that worries them more than the 2014 sample.

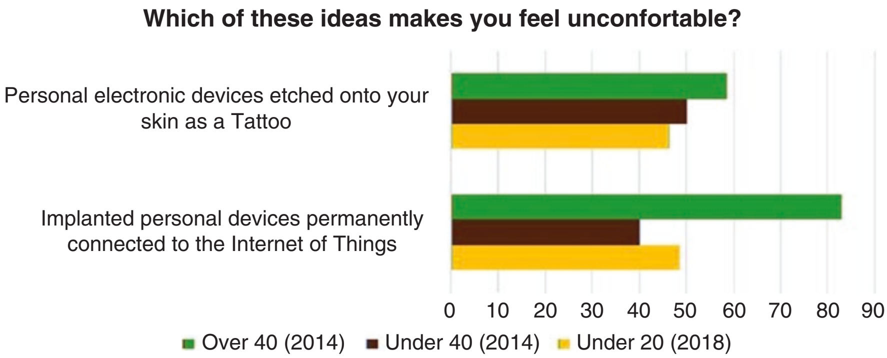

Fig. 2 Comparative levels of discomfort, by age group, with different types of bionic device. (Research by the authors)

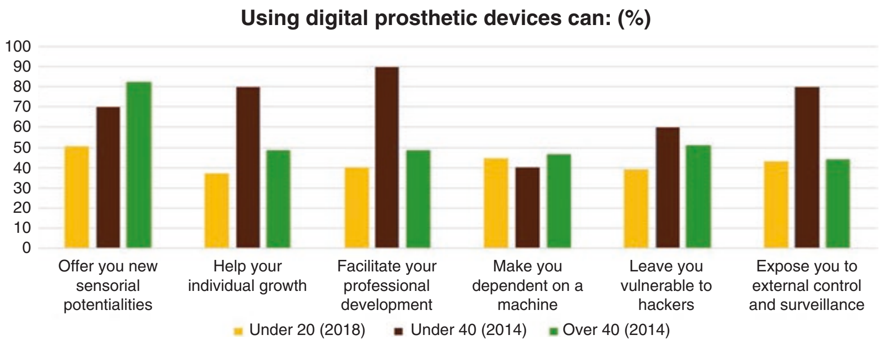

Fig. 3 Comparison, by age group, of perceptions about digital prosthetic devices. (Research by the authors)

At the same time, they are less optimistic about the value of such prosthetics than any of their elders. In other words, some commonly held ideas that teenagers have no understanding of the security risks or dangers of online life may be exaggerations. We need to examine the results from the rest of the study before we have definitive conclusions, but these first results are thought-provoking.

4.1 A New Agent: Smart Conversational Learning Systems

Today's smart learning applications often feature conversational interfaces. This technology, which includes "chatbots," is gaining popularity in contingent learning situations like e-commerce sites, product help desks, and software tutorials, as well as in formal instructional settings. These automated conversational interfaces are characterized by an interaction with the learner based on natural language. They can be used to facilitate a conversational learning model. Interactions can be written, spoken, or transmedia – as, for example, a combination of signed and written text.

Conversational learning is based on the idea that the fundamental unit for investigating complex human learning is a conversation involving communication between two participants in the learning process, who usually take the roles of learner and teacher (McCulloch, 1965).

Pask (1976) posits that learning takes place by interpreting formal relationships, which should be understood in a context (societal, electrical, mechanical, statistical, etc.) and appear as sets of connected propositions (physical laws, social theories, etc.) that he calls topics.

The topic is a way of satisfying the coherence of relationships, rather than simply storing descriptions. Similarly, the memory of a topic becomes a procedure which reconstructs or reproduces concept relationships. Within conversation theory, learning develops through agreements between the participants, which subsequently lead to understanding by the learner (Pask, 1976).

The notion of relationships within a topic can be correlated with Roger C. Schank's notions of generalizability of "scenes" from one "Memory Organization Packet (MOP)" to another (Schank, 1995). A chatbot can be designed to help reinforce the learning of a topic and then guide the learner through a transference process. By incorporating this teacher's role, it becomes an actor, more than a tool or a virtual space. Educational complexity is growing with the addition of new AI agents, and their "personification" is going to be a major change in classroom dynamics.

Traditionally chatbot systems answer questions by using pattern matching and heuristic processes to navigate an informational tree-structure. Such systems require programming with many variants of the same question in order to correctly parse the learner's input. The responses available are limited, and in general, the narrower the domain treated by the chatbot, the more successful it will be (De Leon, 2017).

The use of chatbots as learning aids for users of software and other technological products has led to the creation of conversational systems built around guiding learners through use case scenarios. These systems ask, as well as answer questions, and take optional branches at various points along the way to personalize the learning process.

Each response from a chatbot represents an Information 4.0 molecule. Because it is small, it can be updated quickly and easily in a very short time. It can be reused in a variety of situations and contexts, but one revision will serve for them all. Beyond its simple content, an information molecule has metadata attached to it that enriches its value. It can include semantic tagging for its structural role and information type. It can include information on its tone and register (is it directive, conciliatory, severe, etc.). It can include information on the contexts where it is applicable or situations where it would not be valid. It can even include feedback based on performance, helping the system to learn about itself.

With the advent of AI and Natural Language Processing (NLP), chatbots are beginning to have the ability to learn about the learner and to develop new responses to questions they do not expect. These systems can also formulate their own questions (not previously stored) to elicit information from or guide the learner. As these abilities develop, conversational interfaces will gain new dimensions in their capacity to adapt to a learner's individual context and will be seen as active interlocutors in education.

For repetitive tasks involving multiple-choice responses from the learner, a chatbot has a few advantages over a human instructor: it never has a bad day, never loses patience, and is thus completely neutral when a student has problems and makes repeated errors. But if we really want to move into the transformative domains of the SAMR scale (modification or redefinition), we need to apply a wider vision to the added value these tools can provide.

The chatbot is capable of recording all the learner's responses, and thus capturing errors that might not be detected by the teacher. Not only that, but software can produce different analyses of errors produced by the whole group. These analyses can expose problems of understanding at group level or for a given individual relative to the group. If data is anonymized and shared with results of other groups, we are able to study trends in self-similar organizational units at a variety of micro, meso, and macro levels – from an individual classroom to an institution to a community – and on up to global level (Josefowicz et al., 2017). We can compare a class's performance to national or international scores on standard tests and see how the group is doing. This kind of information helps us in two directions: we can focus on specific problems of a single learner in a given context, and we can use it to help develop new methodologies and policies on a wider scale that improve educative practice for everyone.

In the near future, this metadata will not only reveal past tendencies, but predict prognoses for specific students or identified groups. Knowing in advance the statistical probability of success or error will definitively change the education model we use today. Recursive analysis of results at macro (global), meso (community), and micro (individual) levels can be used to create future disciplines (e.g., smart assessment, smart educational planning, etc.). Artificial Intelligence agents will not only be students' guides in the learning process, but also teachers' collaborators and valid interlocutors for policy makers. A truly smart pedagogy will have to frame the humanistic dimensions of these new fields of study, to optimize its benefits and avoid its dangers.

4.2 Future Components, Mechanics, and Dynamics: Three Challenges to Consider

Researchers such as Stephan Sigg (2018) are working on ways to describe very fine-grained contextual information so it can be used by AI applications. This type of contextuality becomes even more important in a mobile learning context. The work of designing learning spaces empirically (by architects, psychiatrists, landscapers, etc.) is now complemented by access to a font of data so immense that no human can parse it but is readily exploitable by AI.

> Sensors in wearables and other mobile devices are already collecting information such as our location, movement activity, ambient temperature, etc. Soon they will also recognize our emotional state via measurement of heart rate, respiration, and pulse, or through facial recognition. They can correlate this information with the enormous stock of Big Data that is available on the Internet already, and offer the learner information molecules that are not only tailored to a contingent knowledge need, but conditioned to when, where, and in what state the learner is at the moment.

We can envision a learning space where an application detects signs of stress in a learner's facial expression and changes the lighting and the tone of its interactions to help the learner relax, all automatically. The technological components necessary to do this are already largely in place[2].

Fine-grained personalization is a way to motivate learners to persist in their explorations, without the need for an external authority figure. By adapting, not only to their profiles and learning styles, but to their condition at the moment, an environment is created that encourages the student to spend more time pursuing a learning task. Adjustments to screen lighting, vocal timber, choice of which information is presented at what pace, etc. can all be adjusted to the learner's personal rhythm and contribute to more sustained attention.

The agency role taken by AI transforms virtual smart learning environments into smart learning agents. Instead of "going to Google" – or Wikipedia or any other locale – learners will "ask Siri," or Alexa, etc. AI agents will become learning buddies for us. This personalization can be attractive and a motivating force for interacting and networking. The natural language interface of a chatbot or any other AI agent can be engaging to learners, but it can also generate new unexpected problems and dependencies. Some research is showing that constant stimulation through human-machine interaction based on focused interest can have a tendency to shorten attention span. This can also affect learners' ability to analyze information and motivate avoidance behaviors, as they become more sensitive to frustration (Daniela, 2018).

Today's conversational agents don't do much more than traditional CAL did – paying more attention to the content than to the student. But the very nature of learning is altered when tools become "active friends." AI agents will not only be able to predict learners' needs based on contextual information and condition the environment, but they will be able to modify the interactive discourse and the content itself (Gallon & McDonald, 2016).

In a very short time, artificial intelligence in smart learning spaces will be able to react to learners by suggesting extra work or authentic, real-life challenges. It will

[2] For an example of a real-world product doing this, see the Affectiva Emotion AI product, a software development kit which claims to have analyzed 6,464,370 faces of all types from all parts of the world. Their site is at https://www.affectiva.com

adapt to their interests as they arrange and rearrange material themselves. Combined with various kinds of game strategies, students can find themselves very quickly solving real-world problems collectively and in record time. This happened in 2011 when gamers using an application called Foldit developed a model of a retroviral protein in just 3 weeks – a problem that had been puzzling scientists for over a decade (Khatib et al., 2011). The social mechanics to organize these innovation projects is already in place and functioning.

Eventually, the intelligent combination of AI agents, game theory, and teacher guidance just might mean that secondary students could solve some of the world's most difficult problems, while gaining new digital skills and learning to apply them.

Machine learning programs might join these games and play together with human learners to solve problems, using processes analogous to Schank's scenes and MOP's. AI researchers are already looking for ways to generalize machine learning from one context to another (Perez, 2018). The technology in learning environments evolves from being a digital tool to a personal extension of the teacher, and eventually, such agents might officially become certified alternative educational actors.

Teachers, AI agents, and students, acting together in SLEs, will change the roles of student and teacher. The distance between them will diminish and vanish. By turns, they will take on roles of coach, technician, personal assistant, etc. In this milieu, teachers learn as much as the students (although what they learn will be different).

> The notion of SLE not only as "smart" learning environment, but "shared" learning environment means that one common fear teachers have about technology – that students will know more than they do about it – becomes completely irrelevant. Students will contribute their knowledge of the technologies, which will be different than the teacher's. The teacher (either human or AI agent) will guide the students in learning how to use them effectively, and applying critical thinking to avoid pitfalls and judge the reliability of information retrieved.

The educational dynamics required to empower students to participate in building their own personal curriculum can be applied to proposing solutions for their school's challenges or for real environmental problems. At UNESCO's Mobile Learning Week, in Paris, March 2018, a proposal was made to create an Olympics for secondary students, challenging them to meet the UN's sustainable development goals, by directly solving problems (UNESCO, 2018).

The interaction of AI agents with students and teachers will be just one manifestation of the creation of hybrid communities in society, where machines and humans collaborate on a variety of levels, seamlessly, each performing tasks that they are best suited for. This will be necessary to navigate the hybrid world but also to meet the needs of the future job market.

From the human point of view, if we are to prepare our children to live in a world of these hybrid hyper-connections, we will need to help them develop emotional intelligence skills, critical thinking, design thinking, and other skills related to working together collaboratively.

In such a complex and dynamic smart learning space, where smart learning AI could end up physically embedded in or connected to learners' bodies, our definitions of learning processes will again need to change. Until now, our definitions have largely been based on identifying profiles, and oriented to understanding how people receive knowledge. Going forward, learning might be seen essentially as the capability to communicate, relate, and act in different contexts, regardless of the technology implanted. We are now interested not only in how we receive knowledge, but in facilitating proaction and social engagement on the part of learners. Collaborative learning in our hybrid communities needs to include ethics, and attitudes for the common good, as elaborated in the UN-adopted Sustainable Development Goals for 2030 (United Nations, 2015).

5 Conclusions

To meet the mentioned challenges, a smart pedagogy needs to take into account the emerging elements and agents that will participate in innovative education. It also should consider the new relationships and roles that educational protagonists will discover in this new hybrid ecosystem. Intentionality is essential to enrich our educational actions toward the common good.

The implementation of neural systems facilitates the development of connectivism and other social self-organized autopoietic approaches (McMullin & Varela, 1997). This leads to fundamental changes in knowledge theories that modify learning and teaching practices. Today, traditional pedagogical components, teaching techniques, and learning dynamics are being reshaped into a new understanding that must include a change of mindset so that smart learning spaces are not seen as just another tool or learning space. With artificial intelligence, they are becoming active educational agents with decision-making capabilities. An eventual smart pedagogy for hybrid human-machine interaction needs to integrate principles of Information 4.0 that enable flexible, contextualized, personalized learning.

Structured and unstructured learning activities are enriched by technological communication and continuous digital transformation. Existing CAL systems, VLEs, and SLSs were initially seen as diffuse spaces where knowledge could be housed, but AI agents, together with the Internet of Things and Big Data are bypassing this notion. In present and future smart learning spaces, knowledge becomes an activation of individual cognitive competences to develop interactive, collaborative skills. Learning should be seen as student-centered, empowering, participatory, transformational energy. Information does not reside in the single person. Rather, it is connected to learning's transformational capability, and it can be technologically traced at different meta-levels through transmedia channels.

The digital age has delocalized knowledge, diversified scaffolds, and opened the door to contextual learning situations. An eventual Smart Pedagogy connected to Information 4.0 should promote the humanist and ethical approach for common good, as an essential part of educational goals for everyone. Therefore, educational technology should ensure students' engagement and school responsibility for participating in global knowledge networks. Smart pedagogy should stimulate this participation by ensuring that interactive social dynamics is systematically injected into educational transmedia spaces. These hybrid interactions between humans and intelligent virtual agents provide real learning experiences in a collective lifelong learning continuum.

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Principles of Learner Learning-Centred Didactic in the Context of Technology-Enhanced Learning

Irēna Žogla

Abstract The article seeks to update views on didactic practices in the rapidly changing field of education and addresses the timely problem of paradigm transition when shifts in deliberate education have been imposed upon by at least three factors: increased access to digital technologies in the learners' everyday life and teaching-learning; reform of educational content towards the acquisition of competencies valid for the twenty-first-century social developments; and, in response to these, appropriate changes in teachers' professional competence to maintain a learner's learning-centred didactic with learners who, if compared to those of 25 years before, cooperate and communicate differently, are mobile and like taking matters into their own hands. The conceptual core of the didactic principles has been updated in the context of teacher didactical competence to allow for the existence of a deliberate process of teaching-learning that is penetrated, challenged and enhanced by the digital technologies. The didactic principles are described to help teachers maintain the congruity of a dynamic didactic process and remind teachers that they may have achieved a good level of digital readiness but they might reveal limited activities due to their inconsistent conceptualisation of digital competencies. These principles are focused on the teacher competently maintaining learner learning-centred processes.

Keywords Didactic principles · Learning-centred didactic · Digital learner · Challenges for education · Teacher didactical competence · Possibilities of didactic improvements

I. Žogla (✉)
University of Latvia, Riga, Latvia
e-mail: irena.zogla@lu.lv

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1 Introduction

The article does not aim at a complete analysis of principles to create a single list; it offers a discussion on the essence of didactic principles and their updating in order to facilitate teachers' creative work in the changing educational environment and therefore mobile educational settings. Three major forces – influence of the digital technologies, changing qualities of the "digital learner" and contradictions within the educational process – introduce the description of the didactic principles. The focus is on reflecting the dynamics of a deliberate didactic process; therefore the principles aim at maintaining conformity with the logic of didactic design by appropriate teacher and learner cooperation and communication which strengthen the dominance of the learner's self-managed learning.

The method is theoretical analysis of the literature and documents that includes reviewing, analysing and synthesising literature on the theme "in an integrated way such that new frameworks and perspectives on the topic are generated" (Torraco, 2005, p. 356). An integrated review is especially useful when the research object is scattered across publications and is viewed from different aspects (Hamilton & Torraco, 2013) like didactic principles are. The findings of the theoretical analysis address the current influences of the modern digital technologies and the changing state of teaching-learning, as well as introduce shifts in providing the deliberate didactic processes which lead to learner success, and recall the foundations for the professional philosophy held by teachers which underpin their choice of digital tools to create appropriate pedagogical techniques.

Challenges of the changing world are characterised by their breadth, speed and impact on deliberate educational settings at all its stages and components. At least some peculiarities of the most influential forces should be addressed to understand shifts in teacher professional philosophy which in its turn underpins the essence of improvements of pedagogical provision chosen by teachers, as well as didactic principles for their targeted response to these challenges. Formal education experiences pressure from (1) the social processes of the mobile world like rapidly changing labour market and technological opportunities; (2) demands and expectations of the "technology-made" learners, their mind-set and attitude to life and the deliberate educational process; (3) and also, by the paradoxical situation caused by the education itself, its inability to function in a qualitative manner to overtake social development and succeed in preparing learners for their future life.

In this paper didactic principles are addressed which stress the critical usage of evolving practices and conceptualisation of teaching, learning and assessment enhanced by digital technologies, the interplay of which makes up the core of pedagogy appropriate to meet the current external influence on teaching-learning. The influences of the external agents are mentioned here to illustrate some of their impacts that change didactic processes and need to be addressed by didactical provision.

2 Today's Challenges for Shifts in Education

"Tomorrow's graduates, by and large, won't assemble cars; they'll design the computers that drive them. They'll be tasked with tackling climate change, food shortages, and inequality. They'll be asked to solve problems on a global scale – problems for which, unlike on the assembly line, there are no set standards" (Chand, 2018). To reach these qualities, they need the appropriate pedagogical assistance of adults which gives them the tools they need to cope with these problems.

It has been acknowledged worldwide that young people are deeply interested in seeking a meaningful life beyond the connectivity that technology brings (Dingli & Seycehll, 2015). A large variety of these tools previously used in industry is knocking at the doors of schools ready to offer new tools and environments as learner options, for instance, 3D technologies like many others are now becoming common in educational settings (Aliev, Kozov, Ivanova, & Ivanov, 2017).

The digital revolution has changed learners. Investigations by *the Rapid Learning Institute* distinguished the features of a modern learner, and they found the following: 94 percent of learners prefer modules less than 10 min in duration; 65 percent said most online training modules contain too much information (Cited in Penfold, 2016b). Learners prefer skimming rather than careful reading. They also do not like learning only from digital technologies (Thomson, 2012, p. 107). They suggest some statements like "…internet is designed in such a way that it encourages skimming and discourages deep reading" (Carr, 2010, pp. 137–138). These data might change from country to country; still these and many similar findings which interfere with current modes of teaching-learning and its didactic design must be considered as a serious challenge for restructuring the educational content towards teacher and learner competencies in a learning-centred process.

The new media and digital devices make learning increasingly self-directed and distant, more and more under the control and choice of the learner, which is often poorly aligned with the standards set forth for education; therefore learner choice is more difficult to predict. "Independent inquiry, thought, knowledge production and self-assessment will become more prevalent. The learning persons will gradually share space and role with the teaching persons…" (The Gordon Commission, 2012, p. 36); teaching and learning roles are becoming interchangeable.

Digital technologies (electronic systems, tools, multimedia, online games and applications, cloud computing, mobile devices like computers, calculators, compact disc players, cellular telephones and resources that generate, store or process data in the form of numeric code) enable learners to meet their desire of taking control of activities, and schools come under pressure because previous approaches to modernise teaching and minimise risks are becoming ineffective, out-of-touch or even obsolete. Learners, familiar with the e-environment, know what they want from online learning. These are operating with multi-device equipment; learning at their individual pace; qualitative, timely and relevant knowledge; and clear objectives. They have less time to consume training, hold shorter attention spans and prefer mobile learning to meet their needs (Penfold, 2016a). They also cooperate and communicate differently, have a different sense of authorship and use different languages (Gibbons, 2007). The current generation of learners has been so deeply affected by digital technologies that we must consider them as "digital learners" (Gallardo-Echenique, Marqués-Molías, Bullen, & Jan-Willem Strijbos, 2015; Rapetti & Cantoni, 2010) because this term suggests a global vision of the twenty-first-century learner. Investigations in neurosciences (Schachl, 2013) alongside with developing technologies remind teacher and learner that even this new knowledge is not enough (Ball, 2012; Rubene, 2018); other skills, visions and attitudes are needed. These modern learner characteristics do not exclude using traditional sources of knowledge and skills, and psychological principles for learner-centred learning (McCombs, 2003) remind teacher and learner of new accents of learning; they allow for focusing on how to apply digital tools in teacher-assisted learning and how to direct learners towards developing their human qualities even if they spend much of their time among avatars and other virtual images. All this is about how teachers might turn digital technologies that are designed for industry into effective learning tools (Becta, 2015).

Serious social processes, changing the attitude of learners towards educational provision and the culture of mutual relations are recent issues under discussion. Digital devices continue demonstrating new and unpredicted interventions that highlight several essential problems for school processes. Among these there is a need to accentuate the development of the individual qualities of learners (European Governance, 2001) by targeted usage of the educational content and process so that their individual qualities allow for motivated learning and constant self-fulfilment. Evaluation of the didactic capacity of the digital devices is promising, and this should be addressed to make their usage more effective by closing the gaps between the recognised possibilities and their implementation by teachers. Actually, a new period in the development of didactic is marked by the essentials which follow and are based on already introduced innovations by the acquired new level of digital skills. This has triggered the learners' sense of freedom and autonomy in life and pedagogical process; therefore the previous experiences of teaching should be amended towards greater independence and ownership of learners by addressing their individual qualities, feelings, values and needs. Meeting the learners' desire for freedom and autonomy means learner and teacher understanding of the essence of these qualities, how they can be achieved in today's mobile world, as well as how to make use of a deliberate educational setting and teacher assistance to develop the individual experience of asserting these qualities through cooperation and communication. In other words, redefining of didactic principles might help teachers redirect their assistance and pedagogical provision to the learners who are used to e-environments.

Globalisation of social processes accentuates changes in the perspective taken by deliberate education through paying attention to teacher re-conceptualisation of individualisation in teaching. This means the assumption that while individuals or groups might view life differently, the open world, especially the Internet, makes learners and also teachers adapt to at least some common needs and wishes, as well as a need for reflecting these realities in curricula that are impacted by "… worldwide concerns, cross-cultural exchanges, cooperative programs, and international order" (Pinar, Reinolds, Slattery, & Taubmann, 2004, p. 800). Alongside with this and due to this, learner individual experiences differ more and more.

Educational content aimed at the learner's competence – knowledge, skills and attitudes – is among the most powerful factors that impact on pedagogical provision and didactic design. The educational content is constantly being reformed, currently with accents on learner general and digital competencies, as well as their self-managed learning. This introduces the most substantial and complicated transitions and challenges targeted improvements in teacher-learner cooperation and communication in order to implement a learner learning-centred paradigm by shifting (1) content-centred teaching-learning to an activity paradigm, (2) knowledge acquisition to knowledge creation and competent usage, (3) accentuated individual learning to learning as a social affair and success for individual achievements (The Gordon Commission, 2012, pp. 101–105), (4) "more hours for learning" to "quality learning time" (OECD, 2018, p. 6) and (5) isolation of learning subjects, teaching-learning and assessment to educational unifying (Furlong et al., 2003), integrating educational content and the whole process with self-evaluation at the core.

In response to the challenges of modern transformations in education including even wider usage of digital technologies, the OECD project (2018, pp. 5–7) suggests several general design principles for transformative, digital technologies' assisted school education systems: (1) for the educational content design (agency, rigour, coherence, alignment, choice) and (2) process (design, authenticity, interrelations, flexibility, engagement). A balanced pedagogical system would be consistent in developmental and learning theory across curriculum, teaching-learning and assessments to accentuate the following basic principles of school curricula design well-known by every teacher: comprehensiveness, coherence and continuity. These in a period of changing reality also need updated ways of implementation.

Crucial changes in education trigger a growing workload for teachers because they often lag behind in their professional competence in making learners capable of capturing different aspects of contexts and understanding, instead of memorising overwhelming amount of facts and reflecting the exactness and precision characteristic of the pedagogy of modernism. Some discrepancies appear in the area of tools used in teaching and learning – learners use digital technologies of all kinds, while still many teachers prefer traditional didactic methods. A shift in teacher understanding of current differences in the learning content and aligned with this, teaching, becomes a crucial precondition for targeted and successful didactic processes that should integrate the traditional experiences with the digital tools. Teachers who are used to observe their learners' activities now have to trust their mental processes while operating with the digital devices. Updating of the didactic principles attempts to suggest ways of closing this gap and provides suggestions that should warn teachers of serious mistakes that may occur and may cause obstacles to the successful development of learners.

"The central argument is that the most basic educational goal of human flourishing cannot be achieved today as long as the main criteria of 'best practice' in the classroom foreground pupil enjoyment rather than endurance of suffering. The paradox is that any call for the latter is now largely heard in a way cultivated by the culture of the former: namely, poorly and vulgarly, associated only with bullying authoritarianism, rather than the devoted care of teachers who want to awaken their pupils to self-responsibility" (Glendinning, 2018, pp. 81–96). Improvement requires radical changes; they "… speak to a distinctive and new social condition: the integration of powerfully de-localising, dis-placing technological devices into traditionally localised forms of life, rooted in a place. The challenge for educators in this tensional situation is how, if at all, the basic goal of education might still be attained: of whether a new rootedness might be cultivated, even in the technological age" (ibid.).

The scientific validity of traditional education had privileged "objective" knowledge which had to be taught and controlled, the acquisition of which followed precise criteria. Teachers have been educated according to these preferences. In spite of current positive changes, school still remains an institution which sets forth demands and standards rather than prioritises assistance to the learners' human qualities. "We have tended to examine cognitive functions independent of their contamination or being influenced by human biases and feelings. Yet, modern social and psychological sciences are pressing us to examine or assess human performance with greater respect for the influence of affective, emotional, situative and social processes" (The Gordon Commission, 2012, p. 37). Learner human qualities have to be prioritised in deliberate educational settings, and if needed appropriate shifts in teacher professional philosophy and didactic design should be made to help learners make their learning meaningful.

Consequently, the exploration of changes in the deliberate processes of teaching and learning shifts in the ways in which people think about the nature of the knowledge and techniques, prioritising the qualities of learners and self-managed learning, as well as self-evaluation rather than evaluation – all these introduce new modes of teaching-learning which can be modified or created by teachers following appropriate logic of didactic design and its basic principles. This means that the fundamentals of didactics, as a theory and practice of formal and non-formal deliberately organised pedagogical process, should be defined and described by using renewed, or new, assumptions at a conceptual level that are relevant for the new reality. This positivistic orientation should help teachers develop their professional philosophy for the twenty-first-century schooling to counteract the fact that "even when teachers have achieved good digital readiness, their activities are often limited by inconsistent conceptualization of digital competencies" (Blayone, van Oostveen, Mikhailenko, & Barber, 2017). This also means making internal regularities of a didactic process comply with the set of changing external agents and circumstances and by doing so describing pedagogical approaches and the effectiveness of the didactic process, communication and cooperation specific to learner learning-centeredness in the digital environment that can provide better learning opportunities, as well as obstacles when there is a lack of appropriate didactical provision.

In e-environments learners use their sensory input along with information processing in the brain to digest the flow of information in the mind. This is an unusual information flow through sensory inputs which often results in the so-called cyber-sickness experienced by learners as nausea, headaches and dizziness (Rebenitsch & Owen, 2016; Virtual Reality Society, 2018). The new and unknown phenomena both to learners and teachers also have impact on their emotions and behaviour caused by the loss of awareness about their surroundings and therefore experiencing feeling of anxiety and stress. To avoid cyber-sickness, the application designers and teachers must place special attention on information flow, learner behaviour, evidence of well-being in communication and group activities (Rebenitsch & Owen, 2016; Saballe, Le, & Dirin, 2018, pp. 10204–10213), as well as acquire how to maintain harmless dialogues between humans and digital equipment (Robb et al., 2015). Reflection of this phenomenon in teacher and learner understanding can better be achieved by learning together, based on collective cognitive responsibility (Scardamalia, 2002), suggesting the use of problem-solving, a joint venture leading to a meaningful deliberate educational process and to softening this tension.

The above listed realities attract the attention of educators and teachers and their acceptance of the complexity of education that challenges appropriate shifts in defining modern didactics, its assumptions, principles and their implementation. Literate persons in the twenty-first century will be able to navigate the world of digital technology and have a depth of understanding, have rational thought and emotionality and be knowledgeable and educated for change (Bereiter & Scardamalia, 2012). Therefore identification and understanding of changes must be accentuated in the aims and processes of school education.

"One of the major responses to these challenges is gradually redirecting the missions of the school: accent on learners' competencies and no longer just on their knowledge. The focus on competencies aims at equipping learners with tools which are adequate for meeting the demands of daily and professional life, and sometimes also its contradictions" (UNESCO, 2016, p. 9). The digital tools are introduced to provide new pedagogical approaches and didactic designs to assist learners meeting their "… need to think critically, work collaboratively, and communicate effectively across countries and cultures" (Chand, 2018, p. 11288); the virtual environment is being designed "… to get every student to prepare for every class using a new social learning platform that uses a combination of intrinsic and extrinsic motivation factors to get every student ready for every class in a course" (Mazur, 2018, p. 11287).

These and many other modern phenomena invite teachers to accept the role of a learner, be knowledgeable and constantly brush up their skills in the use of innovative pedagogical practices.

3 Background of Updating Didactic Principles

To answer this question, several research-based considerations are addressed here which encourage redefining didactic principles to meet the challenges of the digital technologies and the learners' changing needs; these also invite teachers and educators readdress the traditional pedagogical settings to be contextualised with the possibilities and effects of the digital tools; in other words, digital technologies should be conceptualised by educators and teachers as an important component of their professional philosophy that determines the pedagogical approach, the corresponding to its design of the didactic process, the attitude towards their learners and work as well as further self-education to enable competent shifts in pedagogical paradigms.

The changing role of digital technologies, from a subject to be learned or their random usage, has shifted to technology as a full-size didactic tool and a considerable component of teaching-learning which allows for wide access to the content and contexts of learning and meets the learner's need for freedom to learn. This now requires appropriate classroom equipment, recognition of these tools for their popularity among learners, as well as a shift in the professional philosophy of teachers. The differences between the previous and current generations of learners are marked by easy access to digital tools and e-environments almost all the time and everywhere. Latvia is among those countries which have thick net coverage with a high access to the web on its territory. This introduces at least two more peculiarities related to school didactics: (a) teachers have to keep up and even overtake the pace of technological change; (b) along with the group of learners operating with multiple digital devices in e-environment, there are learners with limited access to modern devices for their private usage. Therefore teachers have to meet different, even opposite needs of their learners; digital tools are a powerful means to individualise and personalise teaching-learning.

The nature and capacity of digital devices and combinations of digital properties open new possibilities for understanding, exploring, simulating and recording teacher and learner activities leading to their new capabilities. Meanwhile digital equipment should be perceived as didactically valid tools only if they are used in a didactically appropriate way (The Gordon Commission, 2012, pp. 101–105) – traditional and usually well-known methods of instruction and learning obtain added value when empowered by the qualities of the digital devices. Some of the impacts are recalled here to create a foundation for teachers to better understand the background for readdressing didactic principles and, more importantly, to enable them to describe the specified didactic principles in details for creating a targeted didactic process:

- The extension of human ability by providing data storing and speedy symbol manipulation functions at the core of human thinking, meaning and activity; learners have "to trust" the digital devices without a possibility of observing the processes. Acquired basic skills underpin the learner's understanding of the outcomes (the first phase of learning, obtaining the result which is suggested by standards, when external component might dominate). The outcomes provided by a digital tool should be conceptualised to come to understanding of the learner's individual achievements (the second phase of learning which addresses the learner's individual qualities); be that facilitated by individual or preferably team-based learning, these qualities empower motivation and enable learning and higher-order thinking.
- Digital technologies allow for the organisation and processing of information that supplements the capacity of human memory and mental capabilities. These are activated by didactical provision of deep learning – organising the content to initiate creative thinking, problem-solving, etc. Learners' mental control is being changed while operating with data without direct observations, expanding thinking about evidence. This needs to be addressed through appropriate theoretical

statements, regularities and abstractions which allow for interpreting and discussing of information regarding the nature of data and ways of processing – such an objective is seldom included into classroom settings. Computer-assisted interaction with the physical world and flexible manipulation with symbols allows for reflection on key representations at the core of human communication, inviting learners to reflect, analyse, conclude and operate with abstractions and notions.

- Communication and cooperation is rooted in the social nature of learning, boosted by digital technologies and designed to give learners rich experience of shared practices of learning by using a large variety of activities. Learning not only takes places in groups but is a group phenomenon (Stahl, 2006), that is considerably accentuated by the web and digital technologies and allows for creating unlimited teams, groups, constant or even random partner associations in the open world. Group learning is something beyond the learning undergone by members of the group. It is something only definable and measurable at the group level. There are legitimate and important senses in which groups understand (or fail to understand), develop expertise, act, solve problems and demonstrate creativity (Sawyer, 2003). The digital possibilities provide teacher and learner access to wide and easy usage of the web and digital technologies in creating partnership for communication and cooperation and trigger their sense of belonging and sense of being accepted in a wide social area. Teachers also can follow learner activities in the web. Cooperation and teamwork due to the learners' individual search for information on the network lead to more productive activities and synergy, new or even unexpected ideas to be discussed and developed.
- As well, virtual worlds provide opportunities for experiencing elicitation of presence and realism and contribute to successful verbal and practical interactions that lead to achievements in acquiring communication skills (Mennecke et al., 2011). The perception and feeling of "being there" in familiar surroundings trigger learners' sense of freedom and allow them to communicate with more confidence. Freedom for operating with data sets up the foundation for learning anywhere and at any time. Learners use this opportunity often to deal with the information which is not related to school programmes and standards, and the didactical value lies in the additional information to be, therefore, discussed or otherwise used in teaching-learning. This allows for personal choice and individualisation of learning should be practised on a regular basis.
- The sense of accomplishment in its turn promotes self-efficacy (Lee, 2013). This association helps learners feel they are in a place other than their usual and sometimes annoying classroom. Mediated by digital technologies, global-wide communication makes local cultural differences less restrictive in choosing conceptual approaches of education at all levels.
- Research around the creation of an immersive educational environment beyond the computer screen demonstrates a powerful interactive medium. For instance, the Hybrid Environmental Projection Platform is a collapsible, transportable installation that supports open-ended educational opportunities and challenges

through interactive projection-based systems that facilitate meaningful learning experiences for the learners as well as for the teachers by connecting physical input measured with sensors to a visual output delivered by content-creation and image-layering design that can virtually "teleport" a whole group into any projected environment applicable inside the classroom space. This also helps the pupils feel another space rather than feel them to be in a traditional classroom or simply learning facts by heart. Thus, the digital devices can increase the learner capacity to understand and remember the content of the projections (Oungrinis, Liapi, Christoulakis, Paterakis, & Manoudaki, 2018, p. 8215).

- Researchers conclude that the learners use the digital tools (such as e-mail, WhatsApp, Facebook, Skype, text messages, forums at UAb Moodle, synchronous conferencing) for educational purposes; the authors also acknowledge that the learners prefer not to use social media for contact with the teacher. On the contrary, they opt to do that predominantly by the forums at the UAb learning management systems, the Moodle platform, followed by the e-mail (Cardoso & Bastos, 2018, pp. 529–534). Virtual reality has been used to assess user experience or as a multi-method of virtual reality to organise a virtual conference environment. Virtual environments are used as empirical research tools as well (Kuliga, Thrash, Dalton, & Hölscher, 2015).
- Some researchers (Afanasyev, Afanasyeva, Bochkov, & Voit, 2018) have indicated the most popular devices (helmets and glasses) of virtual reality. These are HTC Vive, Sony Play Station VR, Oculus Rift, Samsung Gear VR and Microsoft HoloLens. "The training curriculum based on virtual reality technologies are universal in the software and hardware context, they are easily 'built into' the traditional educational process and allow educators to substitute real objects for their interactive simulation models that help trainees immerse themselves in a professional environment" (p. 10224). This is one more reminder for teachers to become diligent learners to keep being qualified and recognised first of all by their learners but also by professionals and partners in learning.
- Configuring digital tools into compact mobile personal computing devices personalise data selection, processing and exchange even during classes by combining with an access to wide database and distance usage of information by teams or individuals. This makes information a significant factor in strengthening learners' self-awareness and self-confidence by transmitting data ubiquitously and opening wide possibilities for interacting with information and other people (The Gordon Commission, 2012, pp. 101–105), as well as experiencing belonging, recognition, participation, involvement and responsibility – all of which facilitate further development of values and attitudes.
- Renz and Meinel (2018) conclude that often websites face difficulties in providing the right images for the user; on the one hand, selection of images is time-consuming; on the other hand, since there are many different devices on the market, the image needs to be available in different resolutions to suit each of them. This invites the learner and also the teacher to develop prior skills in using the chosen technologies to find and select appropriate items of visualisation and

by doing so meet the corresponding peculiarities of perception of digital learners.

- Different forms of recording the physical world allow for the transmission of physical objects often needed in teaching-learning like printed texts, pictures, graphs, etc. into electronic representation for further processing by machinery or inclusion into a set of didactic tools, as well as producing digital programmes which follow logic of data search, sort and information connections in ways that, if used appropriately in pedagogical settings, create new rules and reason for creative thinking and learning. These function in addition to the traditional pedagogical means of insight and intelligence. They also facilitate teacher and learner reflection and analysis of learning processes, outcomes and achievements – an unlimited possibility to be used in a didactic process.

To initiate and support learning, teachers usually need to know and at the same time are unable to precisely predict or be concerned with what knowledge learners use or why they select particular skills in uniquely created classroom situations. Teachers can take into consideration evidences which their learners demonstrate by using digital tools and the environment. This allows them to anticipate the identified personal importance of the assignment to each learner and therefore its critical evaluation and motivation.

Learning to use digital technologies by making them an effective didactic element is a complicated but achievable target; therefore this must form an important and special part of pre-diploma and even post-diploma studies. A recent investigation at Sheffield University (UK) concludes that implementation of technological innovations in education must be a planned step-by-step affair to successfully prepare the staff and the learners by discussions, consultations and listening to each other's views, needs and considerations so that those involved make this a meaningful part of their activities (Robson & Clow, 2018). Though the experience of the introduced master's programme by Halmstad University (Sweden) addresses the need of tertiary students, the pedagogical approach and conclusions are also applicable with modifications for innovations within school process as well. Teachers will need to acquire skills and develop their ability of digitalisation, as well as the use of digital resources for value creation and designing innovative digital services; the research supports a step-by-step or year-by-year process covering the following goal: conceptualisation and design of digital services that lead to the opportunity of applying theoretical knowledge through interaction with companies and public authorities (Åkesson & Thomsen, 2018, pp. 6317–6323). The programmes are expected to improve the students' skills and understanding of how digital innovation is connected to educational requirements and how to help them identify new digital provision or applications towards preparing students for working professionally.

These allow for focusing teaching-leaning on synthesised and contextualised goals of knowledge, skills and attitude that are closely related to the synthesised goals of didactics – educational (knowledge, skills), developmental (physical, intellectual, emotional abilities) and educative (attitude).

The peculiarities and capacity of the digital tools should not be used as standing alone modern signs of traditional teaching-learning. These should be coupled and synthesised with a balanced pedagogical system and be consistent with developmental and teaching strategies chosen by teachers in order to initiate learning environments which are across teaching and learning.

4 Understanding Didactic Principles and Their Context Adequate for Each Learner

Why are principles necessary? The list of approaches to the concept of principles is vast. Any deliberate process needs regulations to make it targeted, especially if the processes undergo serious developments like paradigm shifts in education with serious changes of the educational content and the design of the didactic processes when the wide usage of digital devices have made them develop the qualities of didactic tools.

In textbooks, handbooks and instructions for teachers, didactic principles are usually defined as the fundamentals of teaching-learning, and by doing so this introduces to didactics some uncertainty, initially by expanding the list of principles where the essentials, general pedagogical principles and even statements of teacher professional philosophy are partnered with very detailed instructional recommendations (for instance, Parvathy, 2017). To make it clear, the concept of educational knowledge and skills, pedagogy and didactic should be addressed (see Furlong & Whitty, 2017, pp. 13–57), as well as differences between natural and social sciences identified and taken into consideration:

– In natural sciences the essence of phenomena is expressed by their essential components, structure and fundamental regularities; principles are defined as a "… fundamental source or basis of something" (Oxford English dictionary: https://en.oxforddictionaries.com/definition/principle).
– A definition of principles, which therefore corresponds to the category of didactic fundamental regularities, is as follows: a principle is "…a basic idea or rule that explains or controls how something happens or works…," something that "…really means a lot of processes of very different spheres of human activities" (Cambridge dictionary: https://dictionary.cambridge.org/dictionary/english/principle).

Didactics as a theory and practice of teaching-learning investigates deliberate educational settings which follow its most important general aim of human physical, mental and social development. This means that pedagogical science and didactic as its component does not investigate the very essence of human development; it investigates how to better follow the fundamental regularities of human development by using pedagogical/didactic means. Therefore teachers' and educators' competence must include understanding of human development and its fundamental background of multidimensional activities and communication that for their competent professional activities are included in didactic principles. More precise, these fundamentals denote the essence of changeable didactic principles; they have to define an appropriate balance between the learners' developmental possibilities and the facilitating environment. Through centuries education, from a priority for individuals, has been developed into a compulsory, comprehensive affair for society and teachers to follow. Digital technologies have changed teacher and learner organisational activities and mutual relations. These therefore have gained new qualities along with preserving the essential qualities of deliberate teaching-learning that make a didactic process an effective environment for the learners' personalised development.

The didactic principles become specialised rules. They make a targeted didactic process happen and at the same time serve to implement characteristics of the chosen aspect or sub-branch of teaching-learning. "The didactic principles relate to an applicative, concrete dimension of the system and process of education". These reflect the specific features of the educational activities which "become concrete at the level of the formative – informative correlations". They are characterised as a variable component of the didactic process and are formulated to implement the chosen professional philosophy, approach or paradigm: "systemicity, generality, dynamism, and pragmatism of the didactic process" (Eşi, 2010, pp. 27–33).

Appropriate for the paradigm change, current shifts identify a new quality of *dynamic didactic* that integrates teaching and learning, moves the accent to self-evaluation and makes this interaction instrumental for learning; these are "…multiple interactions which we call *instructional dynamics* – a defining feature of education" (Ball & Forzani, 2007, pp. 529–540). The notion of a *dynamic didactic* is initiated by the notion of *dynamic pedagogy* (Armour-Thomas & Gordon, 2012). This in compliance with the current paradigm change and triggered shifts resulting from digital technologies connotes the essence of the complicated character of the new approaches.

The principles should be addressed also by taking into consideration two notions, those of *didactic* (theory and practice of teaching-learning) and *curriculum* (what societies envisage as important in teaching and learning) which are related to each other; therefore their principles also partly overlap in spite of a large number of *curriculum* definitions that often make these two notions difficult to compare. These terms are sometimes used interchangeably in spite of differences introduced by historical developments – emphasis on what is worth teaching, rather than the goals of instruction (Klafki, 1971). "With the introduction of the concept of *curriculum* in the mid-twentieth century (with specified objectives and evaluation criteria), an interest in systematically developed learning aids has emerged" (Pinar et al., 2004, p. 810). This makes teachers readdress didactics and its categories to identify regularities in a changed reality, currently these are general didactic principles modified to meet the challenges of the digital tools, and therefore they are applicable also in the areas where the notion *curriculum* is used.

The social context of readdressing the didactic principles is highlighted by the OECD project for Education 2030 (2018, pp. 5–7) that has identified three further categories of competencies to enable learners navigate through uncertainty across a wide variety of contexts, those of time, social and digital space. The three "transformative competencies" – *creating new values*, *reconciling tensions* and *taking responsibility* – being complex, interrelated, integrated and developmental in nature, are thus learnable. They address the growing need for young people to be innovative, responsible and aware. These are the qualities which are nominated to respond to the learners' interest in the digital devices and their usage in education. The essence of the transformative competencies should be observed as a landmark for the general transformative didactic principles adequate for introducing new qualities of digital teaching-learning like sustainability and their ability to create new values and empowering learners for self-managed and lifelong learning:

– Current and future social processes being oriented towards sustainable development, innovations and high living standards expect *creating new values* which demand new ways of thinking and doing. Innovation springs not from individuals' thinking, but through cooperation and collaboration with others to address the existing knowledge in order to create new knowledge. This competence is underpinned by adaptability, creativity, curiosity and open-mindedness, and these become possible on a higher level due to the extension of human abilities by digital devices.
– *Reconciling tensions* and dilemmas leading to tolerance, understanding of equity and its practical implementation that is being strengthened by local and global cooperation, team building and value exchange alongside, and due to, the digital connectivity.
– *Taking responsibility* for nature, other people, products of human activities, etc. shared by digital technologies through the web. These coupled with the experience of belonging, experiencing positive emotions of being recognised as well as the possibility of participation and involvement – all that allows self-evaluation and further development of values and attitudes as a widely provided possibility by the use of digital devices.

5 The Didactic Principles in Details

To follow the logic of a didactic process, five basic principle groups are suggested; the content of these can be expanded by teachers within the framework of developing competences through their lifelong, non-stop learning. To follow the didactic principles, teachers have to consider priorities and limits of at least several digital tools and environments to start with. They should identify priorities for these tools and online environments to meet the needs of "digital learners" and peculiarities (the most important ones are mentioned earlier in this article or can be learned from many other sources). Based on teacher identification of the peculiarities of digital learners, changing learning environments and growing possibilities for the use of digital technologies, didactic principles for targeted development of digital competence are grouped by considering the suggested structure of teacher “key competences” – knowledge, skills and attitudes – adopted by the EU countries as the basic issue (https://ec.europa.eu/education/policy/school/competences_en):

1. Teachers develop their *analytical abilities*; an essential condition is identifying and upgrading their professional philosophy by understanding learning and teaching theories, acquiring deep and strategic knowledge and the ability for knowledge creation and using didactic fundamentals to assist learners to become self-managed learners, as well as teachers themselves becoming “digital learners” eventuating “digital teachers”. These abilities invite teachers to shift their attention from what is being taught to who is going to learn and why and what and how to further develop learner and teacher human qualities and by doing so gradually redirect the missions of the school (UNESCO, 2016, p. 9). Teacher analytical skills and competence will improve teaching-learning by implementing several principles of didactic:

Teachers should analyse the current situation including recent investigations related to the profession and effective experiences of digitalisation in education that means getting appropriate knowledge and skills to specify teacher attitude and be more knowledgeable or competent before making a decision on why and how to design current or long-term didactic processes.

Education standards preserve their centrality for goal setting, but what we want learners to know about educational aims and to be able to do when meeting the standards are instrumental to the responsible participation by learners leading to their complex achievements.

Based on analysis the choice of pedagogical strategies and didactic design, continuously following the development of digital technologies and their possible use in education to create e-environments together with the learners for speeding up data processing and the targeted use of the system-making functioning of digital tools in knowledge and skill creation that empower further advanced operating with the structure of knowledge.

Teachers identify what digital knowledge, language, skills and preferences are appropriate for digital environment which learners hold in order to consider their participation in creating a didactic process and practise interchangeability of teaching and learning to make teacher-learner learning teams, be this in the long-term or for a lesson – this provides learners with opportunities to experience their sense of ownership, inclusion and freedom to learn.

Teachers analyse learner attitude to learning, empower their activities by involving them in digitalisation of the didactic process, by doing so boost their participation and improve their understanding of the demands of programme and/or standard to close the gap between the aims and objectives set forth according to the level of education on the one hand and the learners’ needs and preferences on the other hand, as well as helping to ensure their learning targets, content and didactic mode are meaningful and congruent.

Teachers analyse successful local and worldwide experiences and computer programs related to education that might significantly improve teacher and learner research-based didactic, investigations or problem-solving leading to critical thinking, as well as to substitute or speed up hands-on activities, inviting learners to use their digital competence in data collecting and processing.

Together with learners teachers analyse the emotions and feelings, their experience and their well-being, satisfaction with their involvement and recognition due to their digital competencies, critical mind-set, creative thinking, activities and communication.

Teachers evaluate how and why their analytical competence can be boosted by digital technologies and used in decision-making, planning, running the didactic process and constantly practising feedback and assessment with peer and self-evaluation as a priority at all stages of education and as a component of the didactic process.

2. Teachers should learn how *to design* a learner-centred, research-based and technology-enhanced didactic process which includes several subcomponents and makes a unique didactic system; the essence of personalised didactical provision empowered by digital tools and environments belongs to the basic part of professional philosophy and the application of general pedagogical competence:

The didactic design reflects its logic and inclusive character and demonstrates teacher deep and strategic knowledge of the essence of educational aims and objectives which, if specified for the given level of education and presented by appropriately chosen digital design, affirms teacher ability to respect the complex character and possibilities of integrated didactic process as with harmonised teacher and learner aims, objectives, incentives, didactic tools and evaluation for selecting, modifying or creating a didactic design towards the anticipated success of the learner.

The created structure of the didactic process should describe its logical functioning in a way that it demonstrates compliance with learner preferences, perspectives and vision for the creation and usage of e-environments, as well as provide opportunities for choosing digital tools according to the preferences of the learner or experience of the teacher in order to create a comfortable setting for current learning activities.

Learners should be acquainted with the design of teacher and learner activities to motivate and engage learners wherever it is possible and in a way how the use of digital technology can create teaching-learning initially based on teacher and learner digital competence; it is possible to make the process attractive and enjoyable for learners and lead to their sense of ownership.

The design of a didactic process should demonstrate teacher readiness to cooperate and share responsibility and activities with the learners, functioning in several roles that are empowered by digital competencies in accordance with learner preferences and needs, and by doing so to demonstrate the inclusive character of the didactic process and provide possibilities for the learners to anticipate their participation which help them to experience a sense of belonging and shared responsibility.

Learners, when being asked to comment on the priorities of the most preferable digital tools and the suggested didactic design, need to understand that their significant achievements and the benefits of learning start with the meaningful aims that are implemented on the foundation of learner learning activities of all kinds; this includes those outside the deliberate process – competent use of effective digital tools and e-environments allows for advanced content and appropriately selected material.

The design demonstrates teacher and learner digital skills for creating content for authentic learning and shows consideration of possible ways for constant improvements by using appropriate and multiple digital sources according to the choice of the learner and/or acceptance of reasonable choices which strengthen meaningful participation of the learner in a deliberate process.

The design should assert a targeted synthesis of the traditional didactic methods and appropriate digital tools, discussed with the learners duration of the whole process and/or of each component to make teaching-learning a personalised, contextualised and individually meaningful affair and to introduce an effective shift in learning from memorising to deep learning and experience meeting the need of being "now and here" in real and online space.

A didactic design demonstrates teacher competence in using possibilities and the transparency of digital technologies in their pedagogical capacity for creating a process which is accessible to learners and which, being based on learning by doing, helps the teacher and learner to develop understanding of the nature and functioning of digital devices in teaching-learning and creates a background for creative usage of digital tools in designing and managing a didactic process.

The didactic design demonstrates teacher skills of encouraging and supporting learners and facilitating their motivation and engagement boosted by the offered or learner selected complex of digital tools which are used at the learner's individual choice and pace, therefore supporting their emotional, cognitive, physical and social development with the major accent on the development of the learner's individual qualities which empower their learning, inclusion, cooperation and communication.

The design of the didactic process should demonstrate learner possibilities and the significance of their participation and control over the process as far as possible such that it "breaks down the classroom walls" and triggers identification with peers or other people outside their classrooms, as well as makes them join processes outside a school leading to a release of the learner's sense of freedom in a deliberate didactic process.

3. *Implementation* should be considered the most important phase of the designed course or school subject to shift paradigms and implement learner learning-centred process. It must be based on teacher-learner cooperation, communication and teamwork, based on or by wide usage of web links; face-to-face or distance communication and cooperation in information searching; and discussion of findings and sharing considerations with colleagues and learners. The leading pedagogical strategy will follow the assumption that learning is the basic

and meaningful learner activity and that the teacher can only assist this process, suggest, prompt, advice or support. This phase puts teacher competence into practice and improves it:

In the digital age, the most important roles should be shared with learners in accordance with their needs and abilities to implement a pedagogical paradigm shift to a learner learning-centred process; teachers and learners become partners in their respective capacities, facilitators in digital teaching and learning – as well as in other activities – supporters in overcoming troubles, advisors and counsellors in using digital technologies and analysers and evaluators of the didactic process and its outcomes and of learner and teacher achievements.

Teachers and learners consider and effectively implement the interchangeability of roles and productive modes of teaching-learning in the digital era and acquire and improve skills of navigating in the web – teachers cooperate with the learners and are taught by them how to select and operate digital tools and environments to make a deliberate process successful.

Teachers acquire cooperation skills together with learners and colleagues in the goal setting process and in adjusting the selected digital tools of teaching-learning, involve learners in discussions on the criteria of achieving the desired success and suggest and ask learners to participate in creating a digital system of observations, data recording and processing so that they demonstrate their digital skills through the didactic process and learn how to self-manage learning as a core component of a didactic design.

Teachers ask their learners to speak on the advantages of the most preferable digital tools, as well offering opportunities for learner assistance in using digital tools or operating in e-environment – by doing so teachers improve their digital and pedagogical general competence.

Teachers implement plans and continue learning how to create/choose the digital and nondigital pedagogical tools so that they are mutually reinforcing, are appropriate for the didactic goals and discuss them with the learners so that the goals and tools conform with their priorities and preferences.

Teachers acquire pedagogical ways of using digital learning environments and social networks to strengthen the learner experience of inclusive cooperation and communication, participate in creating opportunities to use digital tools in acquisition and demonstration of higher-order thinking and by doing so experience satisfaction with the effectiveness of learning experiences and the learners' desired autonomy.

Teachers and learners prioritise peer and self-assessment, especially in the formative phase to identify the level of learner achievements by comparing them to the aims, feedback and assessment and thus leading to strengthening personalised learner self-managed learning – this should not be limited to learner observable performance but demonstrating their achievements in developing human qualities like attitude, motivation, responsibility, care, support, etc.

The chosen digital tools for collecting data and assessment should be informative for the teacher and the learner, reliable and valid and comprehensive and accessible to those involved in education, but findings and conclusions remain private provided that the learners like to discuss them with peers, teachers or parents.

Implementation of the didactic design demonstrates and further develops teacher and learner understanding of the innovative usage of digital tools and their peculiar capacity to introduce innovations by their specific design and the possibilities that empower their functioning in a capacity of a didactic tool as well – this depends on a teacher's professional approach based on strategical digital knowledge, skills and attitude to the usage of digital tools.

Modern didactic processes become impossible without the appropriate teacher skills in creating and/or choosing an online platform or social networks which provide target-oriented possibilities for constantly changing dynamic didactics, allow for experimentation together with the learners and support their experimentation with digital learning tools and their creative usage.

The professional philosophy of teachers and development of their competence to meet learner needs and their mode of thinking, along with a sense of freedom, ownership and usage of other preferences of the digital learner should be based on a step-by-step improvement of teacher digital skills through implementation, thus helping teachers become "digital teachers".

Teachers should systematically improve the basic skills of integrating learner and also teacher knowledge and skills, thus enabling their shift from the isolation of learning subjects, and similarly teaching-learning and assessment to educational unification through the use of digital technologies; the ability to critically analyse, assess and work with complex issues and mobile digital design for innovative pedagogical provision also needs to be systematically improved.

The digital skills of successful team-based cooperation and communication introduce a specific power of synergy which does not appear in individual modes of learning in classrooms or in distance education that develops social skills and practises collective responsibility in teams of all kinds, even those created for a distance activities – these strengthen the belief that consolidating digital competence is a collegial effort to improve individual practices.

Teachers' sharing knowledge, understanding and views with the team members on better usage of digital technologies in education, recent and current investigations of e-learning environments and digital tools in education, theories and practices of innovation and digital provision studies add to the innovative capacity of teachers that strengthen learner trust and value of the identification of a deliberate didactic process.

4. *Summative evaluation* in a modern didactic process prioritises self-evaluation; it starts from goal setting and motivation of teaching-learning to assessment and evaluation of the appropriateness of the goals, selected tools and possibilities for self-managed learning of the learner:

The online platform or the teaching-learning e-environment should provide an access and option of evaluation schemes for learner, peer and self-evaluation, collecting feedback, easy data processing and making conclusions and improvements, as well as for teacher evaluation – these develop teacher strategic thinking and learner skills of self-managed activities.

Learners and teachers use the same criteria; understanding of these by the learners is central to self-evaluation, autonomous goal setting and managing of the process for further learning and development of individual human qualities.

To help learners test their skills of self-managed learning, discussion with the learners needs to take place about the practices of feedback and the role of teacher assessment and formative assessment during classes and other activities teaching them how to conduct self-observation, data collection and processing, drawing conclusions and decision-making leading to the learners' ability for lifelong learning and teacher pedagogical skills to prioritise the learners' peer and self-assessment over the teacher assessment and discussing the role and practices of teacher conducted assessment.

Teachers ask learners to participate in creating digital tools for data collection, feedback and types of assessment while ensuring that self-assessment will help to reach synthesis of the components of teaching-learning and to strengthen the learners' experience of ownership and autonomy.

5. The vision of *further educational development* empowered by rapidly progressing technical possibilities should be iterative for the qualitative learning of learners, and every component and subcomponent of the didactic process should be considered. Collective cognitive responsibility is essential in building a future vision of school and educational development. It is becoming even more important and more possible due to the growing contacts among specialists and connectivity of scientists and learners who are involved in different cross-cultural projects:

The vision of the current and long-term development of didactics should be developed by taking into consideration analysis of the current situation, tendencies of global and local social developments and needs to be empowered by the learners' ability to use digital technologies, asserting the value of these technologies in their professional growth and development of human qualities.

Teacher pedagogical provision of educational progress therefore depends on the development of their navigation skill in the web and competent selecting of effective approaches, didactic design and strategies.

Teachers will need to learn how to design a didactic process so that it facilitates further development of learner digital competence and creativity appropriate for solving current and long-term problems, by acquiring human qualities to be able to live, meet the challenges and experience the satisfaction of being involved with the local and/or global social progress.

Teachers need to make assessments and judgements on the digital pedagogical provision and innovations with regard to relevant theoretical, technological, cultural and ethical norms and evaluate the contribution of the didactic process to equality, inclusion, participation, cooperation, ownership, sense of freedom, recognition and other needs of the learners related to their well-being.

Further development of educational provision and appropriate teacher education is a matter of the development of teacher intellective competence, professional philosophy and competent implementation of these leading to flexibility, effectiveness and efficiency of their classes and school educational settings.

Teachers should plan self-managed deep and strategic further learning, initiate and participate in research to acquire breadth and in-depth knowledge of the educational possibilities of digital tools and environments and capture innovations in informatics and digital services to reach professionally appropriate competence marked by visions of future developments.

- Conception and practices of teacher pre-diploma and further education should be changed towards the teachers' ability of following the modified didactic principles and also specified these for particular areas of education according to learners' needs and teachers' abilities, as well as their growing intellective competence and school and community possibilities, therefore enabling the implementation of shifts in general educational along with those in particular teaching-learning paradigms.A Final Note

Currently the minimal kit of e-tools which is being constantly boosted alongside with the teacher growing digital competence in today's online learning environments, as well as activities of "digital learners", should include at least these from the suggested ones by the LearnUpon (https://cdn-web.learnupon.net/blog-downloads/ebook-36-elearning-tools.original.pdf):

- The popular package of Microsoft Office with Word, Excel and PowerPoint, to create the content of teaching-learning, presentations, feedback and data collecting. This kit can be easily used to create links and integrate with other learning platforms.
- Social nets like YouTube, Instagram and others which can be used as sources of information, creating discussion teams, sharing views, etc. and which are popular with the learners.
- Google Docs allows multiple team members to collaborate on the creation and improvement of shared texts. With all files stored in the cloud, team members can give feedback and make edits in real time.
- Cloud-based and other e-learning tools which empower communicating, receiving feedback, improvements of created digital learning materials and assignments shared between multiple team members which also involve the learners.

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Using Technologies to Teach Different Age Groups Meaningfully

Liena Hačatrjana

Abstract Increasing use of technologies in schools is inevitable as technologies provide new opportunities for innovative ways of learning and naturally attract students' attention as modern and even playful tools. However, use of technologies can be most effective if the tasks are suitable for the specific age of students. It is necessary for teachers to be aware of cognitive development of children in different age groups in order to offer teaching methods and tasks that can be well-perceived by students and that foster the development of their cognitive abilities. This chapter provides a brief overview of cognitive development of children at different school ages, including development of executive functions and cognitive abilities, and gives examples of how information technology tools can be effectively used for different age groups. There should be at least two advantages for appropriate use of technologies: (1) age-appropriate technology use should enhance learning experiences so that students gain deeper knowledge, comprehension, and competencies in school subjects; and (2) appropriate tools help to maintain students' attention and motivation, as well as foster their cognitive development, not impede it.

Keywords Cognitive development · Executive functions · Technology use

1 Introduction

OECD reports that 96% of students assessed in their PISA (*Programme for International Student Assessment*) 2012 study had access to a computer at home, but the percentage of reported use of computers at schools was significantly lower—only 72% (OECD, 2015). Most children are getting familiar with and using technologies earlier in their lives than ever, making technology a natural way to experience and get to know the world. Therefore, it is necessary to discuss what happens when children enroll in a school system where ICT (information and

L. Hačatrjana (✉)
University of Latvia, Riga, Latvia

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communication technologies) use in terms of smart pedagogy is only evolving and where the aim of ICT use is learning and developing skills, not entertainment. In a recent study in science classes in Latvia, it was concluded that technologies are often used ineffectively or in a passive form, e.g., students are only watching a demonstration of study material but are not actively using the technology—in only 22% of cases were students active users of ICT tools (Dudareva, Namsone, & Cakane, 2015). Another problem with some ICT tools that are aimed at teaching new skills is that they do not foster deeper learning but teach low-level thinking skills (Papadakis, Kalogiannakis, & Zaranis, 2018). Despite such issues, the overall current debate is not "if" technologies should be used in classrooms but "how" it can be done in the most effective and meaningful way.

Another problem is that a lot of literature that covers topics on effective ICT use (e.g., using technological devices, smartphones, or specific applications) in classrooms does not touch the subject of using age-appropriate ICT methods that meet the demands of cognitive development of children. Instead, some literature tends to focus on teachers, their effectiveness and confidence in ICT use (e.g., Ghavifekr & Rosdy, 2015; Morley, 2011), not focusing on actual cognitive development and readiness of the children to use such tools. Some research focuses only on links between ICT use and educational outcomes (e.g., Higgins, Xiao, & Katsipataki, 2012) but not cognitive abilities that are involved in this process. In addition, there is a tendency for reports to be based on self-evaluation questionnaires rather than experiments or cognitive testing. The problem of methodology also includes the fact that most students nowadays are native ICT users, and it would be impossible to implement a methodologically clear experimental design while using a group of ICT-illiterate students. Taking all this into account, it is necessary to investigate whether research indicates significant links between ICT use, cognitive development, and learning outcomes at different ages and to suggest what tools should be used in teaching different age groups effectively and meaningfully.

As already mentioned, the problem is with an effective way to use ICT (both pedagogically and technically). We can speculate about the reasons for low results in effective use of technologies. Are technologies used because it is trendy to do so, but there is no theoretical framework for when and how to effectively use them? One report suggests that teachers often lack confidence in how to best use ICT (Morley, 2011). This may lead to ineffective use of ICT (e.g., fragmentary, non-systematic, or not age-appropriate). Thus, it is a question of educating teachers, not just equipping them with computers and other tools. This also raises the question whether ICT tools are used age-appropriately, since the child may not gain any positive effects of ICT use if the technology is not age-appropriate, even if the teacher is confident in using technologies. Age and cognitive development as factors for effectiveness of ICT use in classrooms are rarely discussed in literature. To conclude, the aim of this chapter is to briefly highlight results from developmental studies of cognitive psychology and studies of ICT use and to link these findings to real examples and suggestions of how ICT could be used in classrooms. Some examples are from experts involved in a recent competence-based curriculum development project, "Skola2030" (*School 2030* in English), that is currently ongoing in Latvia (www.skola2030.lv).

2 Cognitive Development: A Brief Overview

One of the ways to promote effective and age-appropriate use of ICT is to foster understanding of cognitive development of children at different ages and use this knowledge to conclude what kinds of technological tools in classrooms would be effective at different ages. Cognitive development covers a broad range of cognitive functions and abilities that are widely studied and discussed in the literature, but not necessarily with the aim of providing the necessary understanding to teachers, so they can use this knowledge in practical classroom settings. It is crucial that the most recent findings of developmental psychology are explained to teachers and students in the education field so that there is no gap between the latest scientific discoveries and the practical approaches that are used in classrooms.

The psychometric approach in psychology offers extensive and scientifically based ways to assess the level of cognitive abilities. There are tests that are used to assess intelligence of children, and norms for each age group are created based on standardized tests that are used in large populations, so researchers can get to know the mean levels of development for each ability (e.g., Wechsler, 2014). For a teacher or parents, this information can give insights into which abilities of a student are developing "normally" and which abilities are late in development, though the test results do not say anything about how to develop the lacking abilities in an effective way. Child cognitive development is assessed not only through perspective of reasoning but also other abilities, such as development of theory of mind (e.g., Premack & Woodruff, 1978; Schneider, Schumann-Hengsteler, & Sodian, 2013) and executive functioning, which is described in detail in a later section of this chapter. Another approach of cognitive studies that has recently opened a whole new perspective in the field is research using neuroimaging techniques, offering insights into the actual physical development of the "brain" (e.g., Paus, 2005).

It is argued that the development of a child's theory of mind, which can be briefly explained as understanding the perspective of another person and understanding that other persons might have different thoughts (Premack & Woodruff, 1978), is an important milestone in a child's cognitive development (Towse & Cowan, 2013). It usually develops from preschool age up to the beginning of school age (approximately from age 4 to 7) and keeps strengthening later on. During this process of development, a child begins to understand that other persons do not share the same thoughts, experiences, emotions, and expectations that one has (Baron-Cohen, 2005). These realizations are important for a person to function in society, both as a child and later as an adult. But theory-of-mind abilities are not just about social functioning; they are related to language and executive abilities (Schneider, Lockl,

& Fernandez, 2013). Working memory may play a very important role in the development of theory of mind (Towse & Cowan, 2013), meaning that young children should be encouraged to do such tasks that can improve development of memory and attention, including when they are offered the use of technologies. Here again, we can talk about the distinctions between passively watching content or, quite the opposite, being an active participant in games or tasks that require reacting fast, keeping some information in mind, keeping attention on certain stimuli, or actively creating content.

It is crucial to understand that memory and attention abilities keep developing through childhood and adolescence up to adulthood, as neuroimaging studies show (Casey, Giedd, & Thomas, 2000; Paus, 2005). Brain functions and regions that are responsible for relatively simple, low-level, motor and automated capacities develop faster than those responsible for higher-level functions (Casey, Tottenham, Liston, & Durston, 2005). Thus, what can be seen by watching a child's development from any nonspecialist's perspective (first, the child learns to reach objects, then crawl, walk, talk, and think in abstract terms) is proven by neuroimaging studies. This also means that teachers have to keep in mind the sequence of brain development, for example, that higher-level abilities mature later, and therefore, we cannot ask young children to independently plan, execute, and reflect on their actions. Young children need help and guidance with this, and gradually, teachers can change their role from active manager to a supporting role in children's planning, action, and reflection processes. Young children may benefit a lot from guiding questions and examples from the teacher that stimulate their thinking. The supporting role of a teacher also applies to the use of age-appropriate technologies—older students may use planning tools that are available online, for example, tools that are useful for planning and managing projects, and they can do it independently or in groups. But for younger students, higher-order thinking skills should be gradually taught one by one. For example, they can use some tools that support planning—students first have to think and develop steps that they have to take (using thinking) in order to achieve a goal, and then they can arrange these steps and actions in a planning tool (using ICT). Most importantly, ICT use should not replace tasks that require deep thinking, planning, and reflection processes. Instead, these tools should support the implementation of these processes.

Language development is another important indicator of overall cognitive development. Language is crucial for the development of thinking, as the processing of thoughts is of a verbal nature, and cognitive development occurs in the process of internalizing language (Vygotsky, 1978). Early years of infancy are especially important for the development of language as the rapidly developing brain has all prerequisites for this. Studies show that language ability at the age of 3 can predict metamemory at the age of 5 (Schneider, 2008), and for 3-year-olds, language (sentence comprehension) is significantly related to their development of theory of mind and executive functions (Schneider et al., 2013). In addition, a huge number of neural synaptic connections are formed until the age of 4 (Nelson, 2002), making this a sensitive time for development. Language development is both about the communication (the active and social part of language) and representation and construction of concepts in the brain (the cognition part of language) (Nelson, 2002). Based on this research of language and brain development, it can be concluded that at preschool level, very young children (about 2 to 5 years old) should be encouraged to be active language users, expressing themselves verbally. This is an argument against extensive use of ICT tools during this period because, at such ages, children can mostly be passive users of technologies. Technologies can also be used to foster reading skills, and with older students, it is even advisable to read at least some part of study material digitally because it can enhance students' ability to read and grasp digital information. Younger children should first of all learn how to read, write, and count properly, and only then include ICT tools in the process. However, some applications may serve as aids for better learning of reading and counting if the child is having difficulties.

Research shows that adolescence is also as important a period for the developing brain as the early days of an infant, making this a very sensitive time for development and reorganization of regulatory systems (Steinberg, 2005). Most humans spend most of their adolescence at school, making it an important responsibility of the school system and each teacher to choose such methods (pedagogical, technological, etc.) that support the necessary development at this age by stimulating students' thinking processes, including fostering higher-order processes such as metacognition, as well as social-emotional development that is not covered in this chapter but is also a crucial part of development. For adolescents, ICT tools could be used to improve and teach social and cooperation skills, e.g., using tools that help to manage teamwork, assign tasks to each member, etc.

To sum up, different kinds of technologies (devices—tablets, interactive boards, applications) should be gradually introduced in classrooms based on children's age and cognitive development. Generally, for younger children, ICT use should be extensively supported by teachers, and for older students, ICT use could be more independent and self-managed. The overall conclusion is that technologies have to be used to support the developmental processes of cognitive abilities, such as language, memory, attention, and specific skills—counting and number comprehension, writing, and reading. Cognitive abilities are enhanced if the child is actively participating and communicating and is challenged to think critically.

3 Executive Functioning and Cognitive Development

In a later section, additional insights into cognitive functioning will be addressed. Cognitive processes are driven and managed by executive functions which can be defined as a set of mental processes that guide an individual's activities to attain a specific goal (Goldstein, Naglieri, Princiotta, & Otero, 2014) and control thinking and behavior (Friedman et al., 2006). "Executive functions" is an umbrella term for several individual abilities, each of which has its own distinct meaning and function. For example, inhibition (stopping an action) and arousal (initiation of action) will have opposite effects, but both of these abilities are essential for people to reach their goals (Barkley, 2012). Executive functions, if properly developed, aid in development of crucial skills, such as mathematical comprehension (Cragg & Gilmore, 2014), language, and science (St Clair-Thompson & Gathercole, 2006), making it an important developmental factor that needs to be considered by educators. Most of today's research is based on the three-factor model of executive functions (Miyake et al., 2000) which includes these executive functions: updating of working memory, inhibition, and set-shifting. It is widely accepted that these three are crucial for effective human functioning and are described further.

Updating of working memory is the ability to temporarily keep information in mind and manipulate it by constantly replacing the old stimuli with new incoming stimuli (Toplak, Sorge, Benoit, West, & Stanovich, 2010) that is important, for example, in the learning process. Working memory updating is sometimes called simply "working memory," thus fostering a discussion on the overlapping of executive functions and cognitive abilities (e.g., Hacatrjana, 2017). However, the "updating of working memory" is defined more precisely as a continuous observation and monitoring of the situation that includes constantly updating information from time to time. It means that each stimulus that is being kept in short-term memory is constantly replaced in the mind with new incoming stimuli (Garon, Bryson, & Smith, 2008). The development of this function is crucial for successful functioning as an adult. Thus, it is clear that children's learning activities both without and with technological tools should foster, not slow down, the development of working memory updating. For example, interactive games that include memorizing numbers, pictures, names (such as "memory block games"), and other stimuli could be helpful in the development of this function. It could be concluded that working memory manifests if all the information is not available at all times but has to be stored in and retrieved from memory.

Inhibition is the ability to control automatic impulses and delay the manifestation of action. During inhibition tasks, it is necessary for the human mind to recognize the situation of cognitive conflict in which the dominant (automatic) answer or reaction, which would be typical in such a situation, should be stopped or delayed. For example, in the classical Stroop task, the word "red" is written with green ink, and the person must call out the color of the ink, not the written word, thus creating a cognitive conflict (Scarpina & Tagini, 2017; Stroop, 1935). Inhibition is an important function in the life of an individual because it provides the ability to regulate one's impulses, and it has been discovered that inhibition begins to develop in the first year of life when it is possible to observe the first signs of the ability to stop oneself. Faster improvement of the ability can be observed from 2 to 5 years of age (Garon et al., 2008), which is usually the preschool period. This means that activities that are organized in preschool, such as games, socializing, and focusing on precision and reaction, are very important for the development of this function. At school inhibitory skills support general ability to learn (St Clair-Thompson & Gathercole, 2006).

The *set-shifting ability* is characterized by the individual's flexibility and the ability to switch attention from one task to another and back or from one type of stimulus to another type of stimulus. In executive function tests, this ability is usually measured by tasks where images, symbols, or shapes must be grouped according to certain characteristics, such as color, shape, or number, and these features change all the time, which forces the individual to shift focus from one feature to another. It is often necessary to change the link between the initially established stimulus reaction to another new conditional link (Garon et al., 2008). Different studies have shown that executive functions are related to and can predict several aspects of intelligence and problem-solving (e.g., Hacatrjana, 2017; Brydges, Reid, Fox, & Anderson, 2012; Miyake et al., 2000). Healthy development of executive functions is necessary for a child to function successfully at school, to learn the necessary skills, as well as to become ready for school requirements, for example, focusing attention on doing a specific task (Fuhs, Nesbitt, Farran, & Dong, 2014). In author's opinion, technological tools could help students focus attention to specific details of the task when it is required and changing the focus to another detail when it is necessary.

Researchers have found that executive functions are closely related to attention problems—such problems in the early years of development were associated with lower executive functioning (inhibition and working memory updating) and intelligence in adolescent years (Friedman et al., 2007). The study comprised 866 children, and their abilities were assessed in periods from ages 7 to 17. Studies like this lead to conclusions that it is especially important that students in early school years and in preschool learn how to focus on specific tasks for a specific amount of time that is appropriate for their ages. This means that for preschoolers and early childhood students, ICT tools, which naturally draw children's attention, should be introduced or available only when the actual task is to use them. The previously mentioned study showed that attention problems were most tightly related to inhibition, which is responsible for controlling and stopping impulses, and this suggests that if young children use ICT, for example, to play games (also in their time outside school), then these games should include activities in which one needs to react fast, to switch between stimuli, and to increase their attention spans.

In a study of 11-year-old children ($n = 255$), it was discovered that of all executive functions, only working memory updating showed a statistically significant relationship with solving mathematical problems (Lee, Ng, & Ng, 2009). Based on these results, it can be assumed that inhibition develops at a younger age compared to set-shifting and working memory updating, which mature later. Also, a study with 7- and 9-year-old children showed that the older ones had significantly higher results in executive function tasks, except for inhibition (Brydges et al., 2012). This suggests that inhibition ability has already developed at the age of 7 and improvement after this age is moderate, compared to other functions, meaning that teachers of preschool children should be aware if their students can inhibit their actions properly and offer necessary help if a student is lacking such an ability.

To conclude, it is important that teachers understand the overall sequence and tendencies of development of executive functions, such as inhibition, set-shifting ability, and working memory updating ability, and cognitive abilities, especially at early ages when their development is most rapid. Teachers can offer adequate tools and technologies for children so that these abilities develop successfully, fostering better learning outcomes.

4 ICT Use, Cognitive Development, and Learning Outcomes

To understand the relation between technology use and cognitive development, we need to analyze results from studies that have included cognitive measurements or measurements of learning outcomes and their relation to specific ICT use. This is a rather broad field of study, and researchers are focusing on different technologies and different cognitive processes or abilities. For example, researchers might study using the Internet, computer games, using interactive presentations in class, and using technological devices or other kinds of ICT. Furthermore, an overview is offered of results and insights of such studies and suggestions about how these findings might be interpreted and integrated into the practical classroom environment.

A report by Mills (2016) that focuses specifically on the use of the Internet and cognitive processes suggests that constant access to online information could affect cognitive strategies and aspects of memory, task switching, and other cognitive processes. For example, students might learn and remember where to find specific information but not remember the exact facts and information, and it may lead to problems with adopting and using strategies if the solutions are easily available. Therefore, it should be necessary that ICT tools be used to deepen students' learning and comprehension about a topic, but not merely for finding facts online or finding easily available examples of some problems. Adolescents are currently growing up in environments where it is natural to use technologies and the Internet almost constantly, thus making this generation used to constant access to information and the Internet. Therefore, in the study process, it is necessary for teachers to shed light on information resources that are trustworthy and to promote critical analysis of each source that is offered online. It might be hard to prevent students from constantly being online, but the teacher can guide them regarding what kinds of information should or should not be used.

The author of this article suggests that each use of an ICT tool in classrooms should be done meaningfully: either to promote in-depth learning so that students can use and train their cognitive abilities and develop thinking skills, such as analyzing information based on specific criteria, or synthesizing information from different sources to create new valuable information, or to develop specific technological skills. However, the main concern that has been addressed is that extensive use of technologies might result in quite the opposite—shallow information processing.

Thus, if students are asked to use Internet resources in the study process, the focus should be on the quality of the resources they find, not the quantity. In addition, for younger children (e.g., 7- to 10-year-old students at primary schools), a teacher should be the one who guides and leads the process of information sourcing online, teaching students about criteria to evaluate whether the sources and information are reliable. For older students (e.g., 12- to 15-year-olds), the teacher can manage the process in which students independently develop criteria for evaluating Internet resources and analyze them independently. Such an approach is suggested so that students develop their critical thinking skills in the process of using technology in the classroom.

In a study with a large sample of adults, Tun and Lachman (2010) found that frequent use of computers is associated with higher cognitive abilities and executive abilities, such as the ability to switch between tasks, even when age and other factors are controlled. However, if such results are analyzed critically, there is a question about causality, as it is possible that individuals with naturally higher cognitive abilities are more likely to learn to use new technologies faster and adapt to them more quickly. Also, one might argue that for younger generations, this association might not be the same, taking into account that children nowadays are so-called digital natives (Prensky, 2001) who are all growing up with technologies around them. Therefore, today it is more important to study how technology use might impact cognitive development for these digital natives (compared to the development of intelligence of generations that were not growing up with such a broad use of technologies) and what kind of technologies specialists would or would not suggest using to foster the cognitive development of children.

A report by Durham University offers an analysis of a large number of studies, and the overall conclusion is that there is a positive link between using technologies and learning outcomes (for more information, see Higgins et al., 2012). However, it is not a causal link, since the conclusion is not based on experimental design studies. In addition, it is suggested that the main focus of teachers should not be on the use of technology itself but rather on the pedagogical approach and setting clear goals for the teacher's use of one or another technology. Each use of technology in a classroom should be meaningful and with a clear aim in mind about what effect it should bring to students. Therefore, a common understanding of smart pedagogy practices should be necessary (see Daniela & Lytras, 2018). Also, other sources emphasize that ICT use per se is not going to enhance learning results only because it is a modern tool and might attract students' attention. Instead, the most important emphasis should be on the pedagogical methods and reasons why each tool is used (e.g., OECD, 2016).

There are indeed a lot of positive relations that are found between cognitive abilities and ICT use. For example, frequent ICT users show faster reaction speeds compared to rare ICT users (David et al., 2015). But this may also be due to a sort of learning effect that occurs during the use of technologies, for example, playing online games. Taking into account that frequent ICT users already have an advantage (previous natural training with ICT tools), it seems logical that they can better perform on tasks that require similar activities as they seem naturally familiar with such tasks, especially when the testing is done by computers.

Another question that is discussed in literature (Heinz, 2016) is the effect of children's demographics and ICT literacy on their ability to effectively use these tools in classrooms and whether there is a gap in learning results between students with different levels of ICT skills. As was already discussed, most students nowadays have access to technologies, and at very early ages, but does it necessarily mean that all students are equally able to use ICT effectively? Some studies suggest there are no gender gaps in self-reported ICT use (Umar & Jalil, 2012), though other studies show a tendency for males to be more confident in their computer skills as their self-ratings of such skills are higher (Hacatrjana, 2017). As the recent PISA results show, variations in the results in science, reading, and mathematics are broader for 15-year-old males compared to females, though the average results are similar (OECD, 2016). Thus, such aspects as gender and previous experience with ICT use should be considered by teachers to avoid interfering with learning outcomes.

To conclude, increasing ICT use both in classrooms and at home is inevitable, and it probably would not be smart to try to restrict it. Quite the opposite—students have become technologically skilled to be competitive globally, as technological competence is an important area of life in everyday actions, the workplace, and in scientific development. Based on the research presented in this chapter, the overall conclusion is that adequate use of technologies is positively correlated with learning outcomes and cognitive abilities. Experimental design research can also be found that supports positive effects of ICT use on learning, for example, in fostering early numeracy competence (Zaranis, 2016). But one important aspect has to be taken into account: technologies in the school environment should not replace processes that encourage students to think, write, use language, remember things, and use other very important functions of their mind. Technologies have to stimulate these processes and support their development.

5 Suggestions for Meaningful Technology Use in Classrooms Based on Children's Ages

In another section of this chapter, several suggestions and examples will be discussed where ICT tools are used in classroom settings with a specific aim and meaning. Most of these examples were gathered from experts involved in the new curriculum development project *Skola2030* that is aimed at fostering the competence-based learning approach in schools in Latvia (www.skola2030.lv). Experts pointed out these examples as stimulating meaningful learning and deeper understanding in the specific study domain, at the same time using modern (and mostly widely available) technological tools. The examples are not meant to explain the use of one specific application or device; the emphasis is more on the pedagogical approach and what the students are learning in each case. As will be seen, the use of ICT tools should increase with students' ages, and the older the students get, the more active users of ICT they should become (e.g., they can learn how to program or create visual data representations independently).

Suggestions can be found that ICT tools should not be introduced in preschools or should be kept at a minimum level, and if they are used, then it should be done by interacting with an adult (e.g., National Association for the Education of Young Children, 2009). Studies have shown that children today are becoming familiar with technologies at a very early age at home (Plowman, 2015), and it is mostly a passive use of technologies (e.g., watching videos, playing simple games on smartphones, etc.). The research shows that by the age of 5, children have gotten familiar with all common technologies and have become both passive and active users of these technologies (e.g., they are both watching some content and creating some content using technologies). It is suggested that at early ages in preschool settings, students should focus on activities such as physical activities, language development, learning drawing or writing skills (and other motor skills), socializing, and managing one's emotions and actions, and technology use should not replace these activities (National Association for the Education of Young Children, 2009). However, some research confirms benefits of using technologies in numeric comprehension already in preschool (Zaranis, 2016).

Technology use in a more active form appears when students start primary school (approximately from the age of 7). At this age, students can increasingly become active users of technologies and use them meaningfully, understanding the value of experience and knowledge that such technologies may give to both foster ICT skills and to develop competencies in a specific domain of studies. In one example in third-grade (age 9–10 years) mathematics, students are asked to develop and draw models of geometric shapes in a special computer program where they can easily change the size and other features (such as length) of the shapes and analyze how such changes affect the whole shape and its parameters (www.skola2030.lv). They also have to compare their measurements to similar shapes that are drawn by hand. In this example, the emphasis is on deeper learning and understanding mathematical concepts (such as depth and area) from several points of view.

In seventh-grade mathematics (at the age of 13), students have to study degrees and angles that are created by crossing two or more lines. They initially have to do the drawings and measurements of angles by hand and afterward compare them with measurements that are done by digital tools (www.skola2030.lv). When solving mathematical equations, students can independently check if the solution is correct by using special programs, which is especially helpful for students who finish tasks quickly, and there is a risk of them losing motivation, making such applications very helpful pedagogically. Students in seventh grade also construct spatial models of shapes digitally, thus gaining a deeper understanding of geometry. These digital constructions may be their first experiences with skills such as 3D modeling and technical drawing. These examples show how the student becomes an active user of an ICT tool, not a passive watcher, which is one of crucial prerequisites for effective ICT use in study processes that foster thinking and cognitive development.

Another suggestion for ICT use comes from the field of biology. In seventh-grade biology, students have to study cells. They have to take photos of cells (e.g., the cells of plants or fruits) with their smartphones which they bring to school, but they also learn how to represent a cell by technically drawing it by hand (www.skola2030.lv). Then they have to analyze and compare in which cases the schematic drawing by hand is a better and a more useful option and in which cases a photo of a cell is more representative. In this way, students learn that the goal of a task is a very important factor, and based on a goal, different tools can be chosen as the most effective ones. In addition, they sharpen their thinking skills by selecting criteria and evaluating their opinions about each method.

In eighth-grade physics (at the age of about 14 years), students are asked to film any motion that can be observed close to their school (example based on Skola2030), and they can film it by using a smartphone or other device while working in groups. Then they have to assess what factors that characterize "motion" can be seen in the video (e.g., time and distance). In this case, students become active observers and researchers, and they create content using ICT tools, not just passively using the content. They can also work in groups prior to the filming. For example, before the actual filming, they have to make a list of indicators and features that should appear in the video, based on the topic "motion." This is a very different case compared to a case in which the students are shown a given video film and then asked to characterize motion in terms of physics.

Different tools can be very widely used for visualization of graphs, charts, and tables—this can be done in a variety of school subjects. It could benefit students' understanding of how to present data and how to arrange the data they have. For example, if students have made a survey and they have a vast amount of data, they have to choose wisely which data and in what forms they should present it to give a better overview of the topic. With guidance from a skilled teacher, this could be the sort of task that develops students' critical thinking and ability to analyze data. With ICT tools, such as spreadsheets and graph creators, students can model different kinds of visual representations of their data and assess their effectiveness. Based on the fact that chart or graph creator tools can be an efficient and a very fast way to create visual materials, students could keep their attention on the task and even see it as playing with the data, modifying the aspects of presented data, and instantly seeing the results. Most importantly, the teacher should retain the leading role and reflect on what the students are doing and why or initiate a reflection session if students are older (e.g., 13-year-olds).

In another example, portfolio gathering tools are used in arts classes, where students attach all their sketches, research, and inspirational sources for a specific topic and their plans for implementation of the art project (www.skola2030.lv). Such a portfolio can help students track their own progress, thus fostering their metacognitive skills, and it is helpful for the teacher in the process of evaluating students' work. In arts, students are asked to actively create content, for example, making a brochure of historical places in the areas where they live. They have to take photos and learn how to complement them with descriptions. The teacher has to keep students clearly focused on the main aim at each stage of production, whether it is coordinating colors or shapes in the brochure, choosing fonts, or critically developing short texts and descriptions for the brochure.

In fourth-grade Latvian (native) language classes, students have to create a photo recipe for baking bread as they cover the topic of traditions and language (www.skola2030.lv), but it could also be any other traditional food. The task is to both photograph and describe the whole process so that any reader would understand how to recreate this recipe. Then they have to send the photo recipe with a description as an e-mail to classmates, thus learning how to write a digital document and add attachments. Next, students read all the recipes and evaluate them based on criteria such as whether the descriptions were easy to understand and what makes the text easy to understand for other readers. In such a task, students experience formatting digital documents and writing e-mails, as well as develop their analytical skills when they reflect on the task afterward.

Similar examples of meaningful ICT use can be created in all study domains. For example, the Internet could be effectively used to broaden children's knowledge and perspective on different topics, and this can work in a broad range of ages. Younger children can find or create interactive biographies of authors whose books they are reading, thus learning how they looked, getting to know information about their families and in what environment and historical settings they lived, etc. They would broaden their general knowledge and gain a more holistic view of education. In addition, older students may search for information about scientific facts and research that support or reject some common beliefs in science or history. Proper and meaningful use of ICT tools is possible in every school subject and domain of studies, taking into account at least two factors: age-appropriateness and meaningfulness.

6 Conclusions

On the one hand, children are using a lot of ICT today, starting from the early years of their lives. Therefore, one might question whether teachers should foster even more indulgence in ICT, especially in the preschool years. On the other hand, the classroom can be the exact environment where students get to know meaningful and motivating ICT tools that can help them do things more efficiently and increase their technology skills that are especially crucial. Most importantly, the use of technologies can be an effective way to maintain students' motivation and attention and help them gain deeper knowledge in school subjects.

One conclusion that comes from analyzing previous research is that teachers should not encourage aimless use of Internet resources and social media that might affect the depth of information processing. Teachers should discourage "scrolling" through loads of media material or search results without critically evaluating it. They should encourage students to critically examine the source of each material, thus fostering media competency and critical thinking. If students have to use the Internet for any purpose, the goal of the use should be very clear. For example, students might analyze and compare what kinds of information about a specific topic they can find in traditional resources (such as books) and on Internet resources. Students have to become increasingly active users of technologies by creating the content, not just using it. And students have to become increasingly independent users of technologies (critically planning and deciding what technologies to use in each situation), based on the development of their metacognitive abilities.

Technologies could be used by a teacher to work more effectively with students with above-average or low cognitive abilities. For example, ICT tools might aid teachers working with students who are faster than others and always seem to finish tasks first, leaving room for boredom. These students can use ICT tools to check if their solution to a task is correct, for example, in mathematics, or to try additional and more advanced features of a certain application. It usually takes more time resources of teachers to attend to students who need extra help and explanations to do tasks. However, it is crucial that quick learners do not lose their motivation and get attention in some form. Also, ICT could serve as helpful tools for children who have some specific learning difficulties or disabilities (Adam & Tatnall, 2008), such as vision problems and attention or reading problems. Specific tools could help these children understand topics efficiently and work in a way that their disabilities have less effect on learning outcomes. All this may seem to put a lot of pressure on the teacher who has to become a master of all possible technologies. Therefore, proper informational and technical support is of course necessary, as some research already shows (Ghavifekr & Rosdy, 2015).

Based on the research in cognitive psychology and the pedagogy field, it can be suggested that teachers offer students such ICT tools and exercises that stimulate use and development of executive functions, focusing attention and thinking, in order to foster the development of students' cognitive abilities and learning outcomes in general. Technologies have to contribute to the developing brain, not hinder the development of any function. Another important factor is that each use of technology in an educational context has to be meaningful and have a specific aim that is clear to the teacher and students. In addition, more ICT tools have to be used in a way that the student becomes an active user and content creator. It has to be concluded that studies in the field of technology use and cognitive abilities have focused a lot on specific factors, such as connections between Internet use and cognitive abilities or gaming behaviors and cognitive abilities. Yet, there are various other ICT tools that are used in classrooms, such as interactive equipment, specific applications, and so on. Additional research on each of these tools would be necessary to determine their precise effects on learning and cognitive development of specific abilities.

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Why Should I Play This Game? The Role of Motivation in Smart Pedagogy

Polyxeni Kaimara and Ioannis Deliyannis

Abstract Human behavior is very much based on motivation. For decades, researchers have been trying to describe motives in biological terms, or physiological ones, while others are emphasizing on their cognitive aspect in people's behavior and hence in learning. Motivation and learning can affect one another. Contemporary research recognizes the importance of prompting students to engage in learning activities by creating links between what they already know and what they are asked to learn, creating meaning through game-like experiences. The most positive element of playful activities is the child's engagement, as games give pleasure, motives, and excitement. Researchers and educators have also found the interest of students with special educational needs for digital games, and they are looking for alternative ways of teaching complex skills to solve problems. This chapter focuses on the role of incentives in the new educational environments, which are flooded by cutting-edge technology, and the value of the gamification in learning process. Students with different learning styles, interests, motivations, and cultural background coexist in classrooms, and the multisensory approach supported by technology seems to serve the principles of differentiated instruction, providing teachers with the opportunity to adapt the process to the needs of each child.

Keywords Digital game-based learning · Gamification · Modern learning environments · Motivation · Smart education and learning

1 Introduction

Information and Communication Technologies (ICT) are spreading to every aspect of our everyday life at such a speed that it is almost impossible to keep track of all developments. ICT affect and reshape most parts of society, and human creation, and action, as well as formal and informal education. Teachers and parents work and communicate with young people who are nowadays accustomed to being called

P. Kaimara (✉) · I. Deliyannis
Department of Audio & Visual Arts, Ionian University, Corfu, Greece
e-mail: a16kaim@ionio.gr

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"digital natives". Prensky (2006) admitted that he was not the first to introduce the term "digital natives" but is the one who uses it systematically and has citation. The term is also referred by others, such as Douglas Rushkoff, *kids are natives in a place that most adults are immigrants,* and John Perry Barlow (1996) in his Manifesto "A Declaration of the Independence of Cyberspace": *You are terrified of your own children, since they are natives in a world where you will always be immigrants*. But why is it so important to mention these terms? Because they focus precisely on transforming aspects of our lives into a world, where young people speak another language. The "digital natives", the "net generation" young people, are growing up with digital technology and are familiar with the language of computers, video games, and the Internet as a native language/mother tongue (Prensky, 2009). Their skills, attitudes, aspirations, and learning styles reflect the environment in which they are raised, an environment that is clearly different from what existed when their teachers grew up (Oblinger, Oblinger, & Lippincott, 2005). Young people have been immersed in technology, which cultivates them with specialized technical skills, and learning preferences for which traditional education is unprepared (Bennett, Maton, & Kervin, 2008).

Why traditional education cannot support the modern school reality? Why do our schools predominate in teaching, not learning? These questions involve many researchers, teachers, and students alike. Nowadays, students are used to speed, graphics, energy, entertainment, imagination, and video games, and so their current education seems boring. The 21st century is provocative, and our schools must adapt to a new pedagogy that will offer new learning environments combining content with innovative technologies so that students acquire the necessary skills such as participation, initiative, creativity, and innovation, strategic thinking, and collaboration (Amar & David, 2017). *Do they really think differently?* (Prensky & Berry, 2001). Perhaps, ultimately, we need to look back at the initial question of how human learns.

2 Human Learning

The study of human learning focuses on how individuals acquire and modify knowledge, skills, strategies, beliefs, and behaviors. Since antiquity, the phenomenon of learning has occupied philosophers and researchers who have tried to interpret its process. The complexity of how people learn is depicted by Plato in his dialogue of Meno (70a–71d), where Meno asked Socrates whether virtue can be taught. *Is virtue the result of teaching and learning or practice or does it come to humans by nature or in some other way?* (as cited in Anderson & Osborn, 2009, p. 209). From a philosophical point of view, learning refers to the origin, nature, limits, and methods of acquiring knowledge (Schunk, 2012).

In his historical review of the perspectives expressed on human learning, Jensen (2005) concluded that the learning model is simple and based on both endogenous-hereditary and extrinsic-environmental factors. If somebody wants to learn something, he/she should either have to figure it out on his/her own or turn to another person who could show him/her how to learn it. Thus, two positions emerged that refer to the origin of knowledge, and its relation to the environment: empiricism, and rationality. The learning theories are based, mainly, on these two axes, environment, and heredity, with a significant impact on educational practice.

The first axis which is based on empiricism, where environment and experience are the only sources of knowledge, includes the so-called *behavioral theories*. For behaviorism, learning is the process of creating connections between stimuli and responses, aiming to change the behavior (De Houwer, Barnes-Holmes, & Moors, 2013). As it is cited in Bransford, Brown, and Cocking (1999), mainstream representatives including John B. Watson, Edward L. Thorndike, and Burrhus F. Skinner considered that it is enough to find the right external stimuli and use of rewards in alternation with penalties to achieve the desired behavior. Motives for learning are the physiological drives, such as hunger, and thirst, and external influences such as rewards and penalties (Skinner, 1938). As Sundberg argued (2013) Skinner avoided using terms such as drive or motivation, and he preferred using terms as deprivation, satiation (i.e. fullness), stimulation, and reinforcement, a response to a stimulus is more likely to happen or not in the future depending on the consequences of the previous response. Skinner (1950) stated that if we want to predict, and potentially control the probability of a particular response, the science of behavior must assess this probability and explore the conditions that determine it. Positive reinforcement makes the response more likely to happen again, while punishment makes it less likely.

The second axis emerged from the stream of rationalists. As cited in Schunk (2012), Jean Piaget, Lev Vygotsky, and Jerome Seymour Bruner are considered to be the representatives of *cognitive theories*, such as constructivism, sociocultural theory, discovery learning, etc. Cognitive theories of learning assume that reality is objective through symbolic mental constructs (Dede, 2008), emphasizing the acquisition of knowledge and skills, the formation of mental structures, the processing information, the beliefs, and the role of motives. So, from a cognitive point of view, learning is an internal mental phenomenon. Knowledge derives from the mind, and although people acquire information through senses, and interacting with the outside world, ideas are the product of the function of the mind. The central theme is the processing of information: their construction, acquisition, organization, coding, testing, memory, and recovery or oblivion. For cognitivists, the definition of learning includes a mechanistic approach to behavior, which aims to revealing the mental mechanisms that change this behavior (De Houwer et al., 2013). Humans are viewed as goal-directed agents who actively seek information with previous knowledge, skills, beliefs, and concepts. The way in which they observe, organize, and interpret their environment affects their ability to remember, reason, solve problems, and construct new knowledge (Bransford et al., 1999).

Behaviorism and cognitivism often appear to be competitive because of different positions and different views of things (Kaimara, Deliyannis, Oikonomou, Papadopoulou, & Fokides, 2018). However, with the emergence of new behaviorists such as Hull (1943) who paid a lot of attention to the motives, we see the human factor to interfere between the classical stimulus and response model. As cited in Fields (1996) Gagne's was one of the theorists who bridged the gap between the behaviorists of the 1950s, and 1960s, and the cognitivists of the 1970s, and 1980s. Gagne, Briggs, and Wager (1992) theories and research in instruction and learning recognized learning as a more complex process not only simple stimulus-response connections but also interactions of concepts, rules, principles, attitudes, intellectual skills, cognitive strategies, and metacognition. Thus, the principles of behaviorism and cognitivism are complementarities, and allow us to recognize their positive elements, and apply them in the field of learning.

In 1948, a group of researchers from various universities developed a classification system for educational objectives as the lack of a standardized vocabulary, and conceptual framework was found. They agreed that the classification scheme or taxonomy should reflect distinctions teachers make about student behaviors and that this taxonomy would be educationally meaningful. So they came to the conclusion that there are three classification systems, each in a different domain of behavior: cognitive, affective, and psychomotor, known as Bloom's taxonomy (Kropp & Stoker, 1966). The cognitive taxonomy has received much attention because of its applicability in education. Cognitive taxonomy is aimed for organizing educational objectives which describe cognitive behaviors and consists of six major levels: knowledge, comprehension, application, analysis, synthesis, and evaluation. Each of these major levels consists of sublevels, for example, cognitive processes described by comprehension constitute cognitive operators which are equally applicable to many content. Affective domain refers to the way that individuals deal with things emotionally (feelings, values, appreciations, motivations, and attitudes). Psychomotor domain is the area of physical movement, coordination, and use of motor skills. Halawi, McCarthy, and Pires (2009) argued that the perspective of Bloom's taxonomy provides an empirical measurement to account for differences between e-learning and traditional classroom-based instruction.

As cited in Ertmer and Newby (2013), Jonassen agreed that introductory knowledge acquisition is better supported by more objectivistic approaches (behavioral and/or cognitive) but suggested that constructivistic approaches as learners acquire more knowledge which provides them with the conceptual power needed to deal with complex and ill-structured problems.

For decades, researchers attempting to interpret the phenomenon of learning somehow conclude that the brain itself is the key to answer the questions that arise. Of course, the role of the brain in learning and behavior is not a new area, but its special role and importance recently proved (Schunk, 2012). Today, on the one hand, the explosion of technology, and neuroscience, which has highlighted the brain's functions while performing the learning, and memory cognitive functions, and on the other hand the weakness of theories individually to give convincing answers, led in new approaches to eliminate the limitations of traditional learning and improve the quality of teaching. Learning is a human activity that manifests itself differently from person to person, also taking into account individual differences. According to Dede (2008), the historical controversy between pedagogy and technology outlines the necessity of a universal method of teaching and learning that is the best for all types of content, students, and instructional objectives, based on the composition of the different principles of learning theories.

In educational programs, evaluation should not only focus on learning outcomes but also on educational processes and activities as well as on other variables such as knowledge structures, learning strategies, and motives (Pintrich, 1988). Students of all ages are more motivated when they can see the usefulness of what they are learning, when they can use this information to do something that has a positive impact on others, when they believe they can succeed in a particular project, and when they understand and value the outcome of their work (Bransford et al., 1999; Brophy, 2004). Educators can boost motivation in a variety of ways, such as making learning interesting by associating the material with students' interests, making it easier for students to set goals and monitor progress in meeting these goals by providing feedback and underlining the value learning (Schunk, 2012). As cited in Bransford et al. (1999), Piaget argued that one of the challenges faced by schools is to rely on the motivation of children, to explore it, to understand, and to use it in the service of learning. The motivation to think requires schools that value and foster reflection and mental constructions (Demetriou, Spanoudis, & Mouyi, 2011).

3 Motivation in Modern Learning Environments

A motivational model that finds a particular impact on the educational community and relates to the Self-determination Theory, (Ryan & Deci, 2000) volition, and self-regulation is the Keller's ARCS model which is an acronym for Attention, Relevance, Confidence, and Satisfaction (1987, 2008a). Keller in his interview to Simsek (2014) mentioned that he developed his model based on the idea that there are four key prerequisites/conditions in the learning process that can encourage and maintain motivation of the students. Each condition is analyzed into sub-elements. Keller (2008b) revised his first model by adding a fifth dimension "volition." Volition along with self-regulation supplemented the motivation theory, interpreting attitudes and behaviors that help a person overcome obstacles and insist on achieving its goals (ARCS-V). This review is the result of research that has shown that motivations are insufficient to explain human behavior if their relationship with volition and action is ignored. The volition depends on self-regulatory processes, processes that related to metacognitive regulation processes (Kostaridou-Efklides, 1999). A key assumption of the ARCS-V model is that the fundamental principles of learning, teaching, and motivation are the same in every context. It had come to the conclusion that there are five key principles associated with motivation (Keller, 2010):

1. The *curiosity* of the students is represented by the first condition of the model, the *Attention*. In order to ensure the students' attention, it is advisable to cultivate their surprise, curiosity, doubt, and/or distrust when a gap in their current knowledge is discovered, with techniques such as active participation, humor, conflict,

variety media, and examples from the real world. The educational material needs to contain interesting graphics, and animation, to extinguish the students' interest.

2. The *relevance* of knowledge is related to student goals and represents the second condition of the model. Relevance includes concepts and strategies that create links between the learning environment (content, teaching strategies) and social organization, student goals, learning style, and experiences. The strongest motivation for learning is achieved when the learner identifies himself/herself, and participates in actions that interest him/her, and has chosen them. Other concepts that can explain the relevance and at the same time are motivated are the need for achievement, affiliation, and power, competence, and flow.
3. *Confidence*, which is the third condition, relates to the students' belief that they can succeed and do their home lesson. It integrates variables related to students' feelings, personal control, and expectation for success. The expectation of success is cultivated through the creation of positive experiences that lead students to experience success and to see it as a result of their own skills and efforts rather than luck or easy task. The key principle confidence is included to the most popular theories of motivation that mentioned: self-efficacy, attribution theory, self-determination theory, and goal orientation theory.
4. *Satisfaction* of students, the fourth condition, refers to their expectations of the outcome of their efforts. Students should have positive feelings about their experiences and continue to be motivated. This means that external motivation/extrinsic reinforcement, such as positive rewards and recognition, should be used in accordance with established principles of behavior management and the amount of work and should not have harmful effects on internal motivation.
5. *Self-regulation* is the fifth condition and refers to the desire of students to use self-regulatory strategies. Sometimes students have a problem in staying focused on their goals and often happen in self-teaching environments supported by technology. Students often encounter obstacles that disorient them from their goal and cause distraction. Students who overcome these obstacles, have goal-oriented behaviors, and maintain to their intentions usually work volitionally and use self-regulatory strategies.

It is clear that the review of the literature shows motivation as a key factor in influencing the learning process and student performance. Intrinsic motivation as challenge, curiosity, control, and fantasy can be present in any learning environment (Malone & Lepper, 1987). The motivation as a student's cognitive state activates and maintains his/her attempt to understand the lesson by participating in appropriate cognitive processing (Mayer & Estrella, 2014). If a student has an incentive, he/she will approach even the most difficult lessons, he/she will persist, and he/she will enjoy the challenges. Research has been geared toward providing students with a flexible and adaptable learning environment that can motivate each student individually (Liu, Toprac, & Yuen, 2011). Such a learning environment could be supported by technology. According to Mayer's Cognitive Theory of Multimedia Learning (Mayer & Moreno, 2003; Park, Plass, &

Brünken, 2014), the spoken words enter the human cognitive system via the audio path (narration) and the written words and images through the visual path (on-screen text, illustrations, graphs, charts, photos, or map) or dynamic via both audio and visual path (animation, video, or interactive illustrations). Learning is a multimodal process where students are actively involved in reconstructing the information and messages that teachers communicate within the classroom using different channels such as speech, writing, images, gestures (Jewitt, Kress, Ogborn, & Tsatsarelis, 2001), combining images, colors, and words (Vincent, 2006). As Deliyannis (2007) argued, the combination of animation, video, audio, text, and virtual reality from a system with a supportive strategy and a specific interaction scenario can lead to increase of students' understanding of content. Multimedia learning effects require the consideration of the interplay of cognitive and motivational factors and the motivational role of seductive details and decorative illustrations (Park et al., 2014).

Mayer's theory, combined with the Orton-Gillingham Multisensory Method as cited in Rose and Zirkel (2007), which is based on neuroscientific findings, prove that during the learning process, the brain acquires information through all sensory organs and simultaneously activates multiple senses – visual, audio, tactile, and kinesthetic – providing the theoretical framework to support the integration of ICT into classrooms. Furthermore, digital learning environments are safe and controlled (Kalyvioti & Mikropoulos, 2014), motivate users in interface, support immediate feedback, and improve visual and memory skills. In addition, digital learning environments are flexible as they can be diversified, personalize, and be adaptable to the needs of the user, and therefore there are useful for students with special educational needs (SEN). Surveys have also shown the dynamic relationship between Universal Design and ICT as a powerful means toward inclusive education. "Design for All" provides the framework for accessibility, i.e., the ability of an interactive system to be used by everyone, including users with SEN or special learning difficulties, as dyslexia (Kaimara et al., 2018). Universal Design refers to the guidelines which are taking into account the diversity of users (due to different age, culture, or disability at the physical or cognitive level) and is aiming to design products which could be used by as many users as possible and in any technological platform (Dix, Finlay, Abowd, & Beale, 2004). Universal Design for Learning is based on multimedia, and multisensory learning theories, and draws on the following principles: (a) multiple ways of representation as there does not exist a single way for everyone to understand and interpret information, (b) multiple ways of expression as students react to learning stimuli differently, and (c) multiple ways of involvement as students are motivated or involved in learning in different ways. Additionally, technology supports communication, social networking, and collaboration and develops materials in alternative and multimodal modes (Gkyrtis, Gelastopoulou, & Kourbetis, 2018). Thanks to these qualities, digital learning environments are enable to increase student participation, and motivation in different ways, creating interest for children who for various reasons do not participate in the traditional educational.

4 Smart Education and Learning

Give the child a computer and the child will learn all alone. (Papert, 1984)

In recent years, "smart education", a concept that describes education in the digital era, underlines the importance of technological design to improve learning (Gros, 2016). "Smart educational environments", which are enriched with appropriate digital content in the context of real-world problems, are adaptable, effective, efficient, enjoyable, and engage learners and trainers. Smart education very much based on a model of three instructional strategies-guidelines known as e^3 for designing learning environments: "smart learning environment" is *effective*, *efficient*, and *engaging*. The first principles of instruction include the activation, demonstration, application integration, and task-centered (Merrill, 2007, 2008, 2009). Korean's Ministry of Education, Science, and Technology defined "smart" learning as S.M.A.R.T. from the initials of the words that describe it (Self-directed, Motivated, Adaptive, Resource-enriched, and Technology-embedded) (Kim, Cho, & Lee, 2013).

One might wonder why this education is smart. The rational question that arises is whether the previous ways of teaching were not smart? What is it that differentiates it? In the context of the traditional teaching method, students follow a curriculum (syllabus) aimed at a fantastic medium representative student without taking into account the different learning styles (Kolb & Kolb, 2005), individual interests, and their different educational needs. This leads to boredom, low performance, and discipline problems. In recent years, particular attention has been paid to the educational process of the heterogeneous student population and to the theory of differentiated instruction (Tomlinson et al., 2003). Differentiated instruction is based on the principles of social constructivism and includes all of our knowledge derived from cognitive learning theories, learning style, and brain development on the factors that influence learning readiness, interests, preferences, students' motivations, engagement, and academic development within schools (Algozzine & Anderson, 2007; Subban, 2006). The adoption of the modern perception of cognitive psychology and the recognition of individual differences, whether these stem from special educational needs of pupils with mental disabilities or special learning difficulties, or from different cultural backgrounds, have led to new approaches (Kaimara, Deliyannis, Oikonomou, & Aggelakos, 2018).

Zhu and his colleagues (2016) consider that the objective of smart learning environments is the experience they offer to students, which is rich, personalized, and unobstructed. Student is always seen as the heart of the "smart" learning environment, the goal of which is to provide self-teaching services and enhancing internal motivation. The student can attend courses at his/her own pace and have access to personalized learning content according to individual differences. Thus, for the student, "smart" refers to wisdom and intelligence; for the educational environment, the "smart" refers to engagement, intelligence, and development and for educational technology to achieve its purpose actively and effectively.

The definition of intelligence has been concern many researchers (Legg & Hutter, 2007). Many definitions of intelligence refer to the concept of adaptation. Smart is the one who has *the ability to adapt effectively to the environment, either by making a change in oneself or by changing the environment*, and this definition fits exactly to our purpose.

There are many different types of technology used to support and enhance "smart" learning, which refer to both "smart" hardware and "smart" technologies and software. Devices and technologies are inextricably linked (Gros, 2016). For the hardware, "smart" refers to the device, which is small, portable, and affordable (e.g., smartphones/tablets, laptop, Google glasses etc.) and support students anytime and anywhere. Other "smart devices" are interactive whiteboards, smart table, electronic bag (e-bag), wearable devices, sensors, cloud computing, and so on (Zhu et al., 2016). For software, "smart" refers to adaptability and flexibility.

Due to the rapid technological evolution, various communication environments and textual objects are overwhelming for the everyday life of the students. Technology offers the possibility to create innovative ways of teaching, and learning supports multimodality and redefines the experience of the classroom (Kaimara, Renessi, Papadoloulos, Deliyannis, & Dimitra, 2018). Multimodal learning environments permit the display of the educational content to more than one type of the sensory system, such as visual, audio, and written (Sankey, Birch¸& Gardiner, 2010). Young people use emerging technologies in their personal lives, even though many teachers have not yet found ways to integrate them into the classroom (Robin, 2008). Modern education should integrate technology in order to meet the demands of digital reality. According to Spector (2014), the "smart" learning environment supports design and innovative alternatives for learners and educators. The ten key features of smart learning environments (Zhu et al., 2016):

1. *Location-Aware: Sense learner's location in real time*
2. *Context-Aware: Explore different scenarios and information of activity.*
3. *Socially Aware: Sense social relationship.*
4. *Interoperability: Set standard between different resource, service and platform.*
5. *Seamless connection: Provide continuous service when any device connects.*
6. *Adaptability: Push learning resource according to learning access, preference and demand.*
7. *Ubiquitous: Predict learner's demand until express clearly, provide visual and transparent way to access learning resource and service to learner.*
8. *Whole record: Record learning path data to mine and analyze deeply, then give reasonable assessment, suggestion and push on-demand service.*
9. *Natural interaction: Transfer the senses of multimodal interaction including position and facial expression recognition.*
10. *High engagement: Immersing in multidirectional interaction learning experience in technology-riched environment.*

Beyond these features, smart learning environment facilitates collaboration even by the most competitive students and is associated with increased intrinsic motives (Spector, 2014).

5 Smart Learning Environments: Digital Games

Spector (2014) pointed out that a learning environment is smart when it is designed to include innovative features and capabilities, as smart hardware and software, which improve understanding and performance, to promote engagement, effectiveness, and efficiency and to support the collaboration, the struggling learners, and the motivations. Collaboration refers to people's desire to advise and guide others. In a smart learning environment, educators and peers can help students who are struggling but trying to do it. In the context of smart education, teachers are trying to gain the attention of students, show the relevance of learning content, and enhance students' self-confidence and satisfaction. It can be seen that smart education includes all of the features that are the basic principles of Keller's theory for motivation (ARCS-V) (Keller, 2010).

One example of "smart" software is digital games that use visualization, virtual and augmented reality technologies, robotics, and often support social networking, etc. So, a game made with software and played on digital technology platforms is called "digital game". According to Jimoyiannis (2010), a large number of surveys have shown that the use of ICT as an educational tool can lead to significant educational and pedagogical outcomes in schools and bring benefits to both students and teachers. Digital games, as "smart" software, promote learning based on two powerful factors, motivation and educational methodology (Prensky, 2009). The motivation refers to the reasons why a student will engage in a digital game, and the educational methodology is based on the theoretical framework Technological Pedagogical and Content Knowledge (TPACK), which refers to the dynamic association of the three categories of knowledge: (a) content, (b) pedagogy, and (c) technology (Mishra & Koehler, 2006). The necessity of this model arose from Mishra's and Koehler's findings that there is a lack of a theoretical basis on which a new pedagogy can be created which will serve the integration of educational technology by teachers. Integration of educational technology requires the professional development and training of teachers. Training aims both fostering positive attitudes toward technology integration and promoting good practice in the learning process.

Interactive multimedia and digital games as learning tools can be designed in such a way that could transform learning into an active process. Students can visualize relationships with time, interact dynamically, and immediately evaluate their knowledge (Nincarean, Alia, Halim, & Rahman, 2013). Technology can facilitate learning by delivering content through the real world and encourage social interaction. Students could even learn programming in a game-like activity, so that the whole process becomes an enjoyable experience (Fokides, 2018). Students are engaged in solving complex problems and in learning activities by creating links between what they already know and what they are called upon to learn, "connecting the uknown with the known" (Piaget, 2005, p. 99) and thus make meaning through their experiences, key aspect of constructivism, and Papert's constructionism (Papert & Harel, 1991). For both these cognitive approaches, it is important to demonstrate *how people learn through their experience as long as they are totally immersed in it*, constructing new knowledge by connecting a new experience to a prior experience (Ackermann, 2001; Annetta, 2010). Vygotsky's sociocultural theory (1978) focused on the social foundations of individual higher mental functioning. He researched the relationship between learning and development and among others, he proposed the Zone of Proximal Development (ZPD), concept in which the distance between a child's actual developmental level as determined by independent problem-solving and the higher level revealed in potential development as determined through problem-solving under adult guidance or in collaboration with more able peers. So, the issue for teachers is to find out the child's developmental point and thereby to help it build the new knowledge. This process is called "scaffolding". Nowadays, it is possible for students to communicate with other students who may be in another country and thus to have feedback, reflection, and review, according to connectivism theory (Kop & Hill, 2008; Mechlova & Malcik, 2012; Siemens, 2008). Driscoll (2002) suggested four basic principles that provide the integration of technology, and therefore the digital games, into learning process in the framework for the design of the learning scenarios by teachers. So, as technology emerges in a supportive educational process, learning (a) occurs in context, (b) is active, (c) is social, and (d) is reflective. In addition, games energize the students' creativity, and through their need to discover the mechanisms of game-play, students are encouraged to analyze and construct (Fokides, 2017). Games have the potential to enhance the motivation for learning because they stimulate students' curiosity, and interest through activities that make sense to them, and also allow them to have the control (Vos, Van Der Meijden, & Denessen, 2011). Papert underlined the importance of students participating in the process of creating their own products extending the constructivist learning theory by suggesting that children build their own understandings more effectively when they actively construct artifacts that have personal and cultural meaning for them (Fokides, 2017; Mackrell & Pratt, 2017). Jonassen (1994) argued that students work as designers using technology as a tool for analyzing the world, accessing information, interpreting, organizing their personal knowledge, and representing it to others. Creating a game is the best way to increase motivation and leads to more effective learning than playing an existing game, as the process gives pleasure, motivates, and raises interest. This important role of games in children's life creates a new and a promising area in the study of games (Kafai, 2006). To learn how to play and to make games is part of a larger "ecology" of games in which the traditional roles of "player" and "maker" are no longer treated as distinct entities (Kafai & Burke, 2015). Based on these new approaches, digital games support learning, thanks to their ability to interact, and create environments within students, and teachers are learning by doing (Roussou, 2004) and learning by design (Kalantzis, Cope, & Arvanitis, 2011; Kolodner, Crismond, Gray, Holbrook, &, Puntambekar, 1998; Kolodner, Hmelo, & Narayanan, 1996).

6 Gamification and Game-Based Learning

Within the broader context of educational technology, digital games are a powerful learning tool for “digital natives”. One of the most interesting features of digital technology is that it offers direct, interactive feedback (Salen & Zimmerman, 2004). The question that reasonably arises is what makes a digital game to be educational. A digital game can be described as educational, if it is an organized activity in a form of a game, which, through the combination of entertainment, and learning, aims at achieving learning objectives. Educational digital games could be applications using the characteristics of video, and computer games to create engaging, and immersive learning experiences for delivering specified learning goals, outcomes, and experiences (De Freitas, 2006). Gunter, Kenny, and Vick (2006) pointed out that putting educational content on games with the expectation of motivating children is not enough to call a digital game as an educational one. They define educational games as *serious games* which are supported by entertainment. They believe that the design of a serious game must be well-established in theories such as Gagne’s, Bloom’s, and Keller’s, and good educational practices must be formally incorporated into all serious games. For Michael and Chen (De Freitas, 2006), a serious game is a game in which education is the primary goal, rather than entertainment.

According to Balducci and Grana (2017), the best method to carry out a task is to turn it into a playful activity and through it to gain experience for future goals. This method is the basis of the *gamification* and serious gaming theories which are trying to introduce playful aspects in all the daily interactive tasks. Yu-kai Chou, who is called by Huang and Soman (2013, p. 6) as gamification guru, defined gamification as *the craft of deriving all the fun and addicting elements found in games and applying them to real-world or productive activities*, while Ray Wang described it as a *series of design principles, processes and systems used to influence, engage and motivate individuals, groups and communities to drive behaviors and effect desired outcomes*. So, gamification refers to the use of game design elements and describes a series of design principles, processes, and systems to motivate, engage, and increase user activity and retention (Deterding, Dixon, Khaled, & Nacke, 2011; Varela-Candamio, Enríquez-Díaz, & Rouco-Couzo, 2018). Gamification relates to games, not to play. This distinction leads us back to Caillois’ (2001) concept of *paidia,* and *ludus*, where paidia is “playing” and ludus is “gaming”. It is the use of game-based mechanics, aesthetics, and game thinking in order to engage people and through game-like activities to promote learning and problem-solving in non-games contexts. Pivec, Dziabenkon, and Schinnerl (2003), in their literature review about *game-based learning*, summarize the features that a game should have interactivity, rules, goals, challenge, risk, fantasy, curiosity, and control. As mentioned, Malone and Lepper (1987) defined intrinsic motivation as challenge, curiosity, control, and fantasy, and so we can note, therefore, that games and motives are directly related. Gamification should be better understood as a process, a process of making activities more game-like. A benefit of this approach is that it connects gamification to persuasive design (Werbach, 2014). Motivational systems such as persuasive technologies and gamification build on the assumption that human behavior and attitudes may be influenced through technology (Hamari, Koivisto, & Sarsa, 2014). Fogg's behavior model (FBM) for persuasive design situates systems within a continuous space defined by motivation (making engaging activities) and ability (promoting learning, achievement, and feelings of confidence) (Werbach, 2014). Fogg (2009) argued that in order to have a targeted behavior, a person must have sufficient motivation, sufficient ability, and effective trigger.

The design of game experience is an important feature of the process, and for this, various approaches have been developed that build on different game elements. Csikszentmihalyi (2014) introduced the concept of flow which gives a holistic sense of presence when we are fully involved in activity. This type of feeling is related to fun and enjoyment. He emphasized that in order to characterize an experience as a *flow experience*, it must be in proportion to the abilities of the person's experience. Thus, a correspondence of Csikszentmihalyi's flow theory to the Fogg's persuasive theory is found. The concept of flow is related to the concept of *immersion*. As it is cited in Lygkiaris and Deliyannis (2017), Björk and Holopainen identified four types of immersion: sensory-motoric, cognitive, emotional, and spatial, where spatial is the form of immersion used to describe the effectiveness of a Virtual Reality Application and is usually described with the term *presence*. Additionally, as it is cited in Lygkiaris and Deliyannis (2017), Brown and Cairns acknowledged three levels in the immersion process: engagement, absorption, and total immersion. The right situation to get emotionally immersed is based on two psychological processes, *suspension of disbelief* and *identification with the player character*. Deterding et al. (2011) suggested that the term "elements" allow us to distinguish gamification from serious games, and although Werbach (2014) agreed that not everything that includes game elements is gamification, he concluded that gamelike experiences can promote motivation and ability.

Motivation and engagement are components of player's satisfaction. Satisfaction is a multidimensional construct that involves different dimensions, such as flow, immersion, fun, aesthetics, compelling experiences, presence, pleasure, and enjoyment (Federoff, 2002; Phan, Keebler, & Chaparro, 2016; Schoenau-Fog, 2011). A number of researchers have explored the role of motives and engagement associated with games in order to record good designing practices. Przybylski, Rigby, and Ryan (2010) studied how engagement with video games shapes psychological processes and well-being effects based on self-determination theory. They suggested that effects of video games are based on their potential to satisfy basic psychological needs for competence, autonomy, freedom of choice according to personal interests, and relatedness. Through their research questionnaire entitled "The Development and Validation of the Game User Experience Satisfaction Scale-(GUESS)", Phan et al. (2016) concluded that the satisfaction that users receive when playing games is composed of nine factors: usability/playability, narratives, play engrossment, enjoyment, creative freedom, audio aesthetics, personal gratification, social connectivity, and visual aesthetics. However, when we refer to games with learning content, learning experience, and learning goals, further investigation is needed. Student's satisfaction is a multifactorial process, which depends on both its internal motives and the digital game itself.

Fokides and his colleagues (2018), in order to develop a scale for measuring the factors that affect, and ultimately shape the learning experience when playing serious games, conducted a comprehensive literature review, which revealed a substantial number of well-organized and interesting studies on educational games. On the other hand, fewer studies examined the users' learning experience when playing serious games. The most commonly used factors in the aforementioned studies were used for the development of a questionnaire. The questionnaire was tested for its validity and reliability in a pilot study in which higher education students (studying at the Department of Audio and Visual Arts, Corfu, Greece, and at the Department of Primary Education, Rhodes, Greece) played a number of serious games. The results indicated that 16 factors can holistically assess serious games: perceived realism, perceived ease of use, perceived usability, perceived sound effects' adequacy, perceived visual effects' adequacy, perceived narratives' adequacy, perceived feedback's adequacy, perceived goal's clarity, perceived adequacy of the learning material, immersion, enjoyment, perceived competence, motivation, perceived relevance to personal interests, perceived usefulness, and perceived knowledge improvement.

As the game industry matures, and games become more and more complex, there is an increasing need to develop scientific methodologies to analyze and measure the player's experience in order to gain a better understanding of the relationship and interactions between players and games (Nacke et al., 2009). Games have the ability to use their mechanisms and interaction to communicate a story. Game designers, in addition to using basic development and interactive design models, incorporate narrative techniques that combine the general context with individual scenarios, stories, and mixed media, creating a multifaceted and unique experience for the player (Lygkiaris & Deliyannis, 2017).

The design of digital educational games is a decisive boosting factor that facilitates player-student's involvement. Internationally, key components of design are usability and playability related to player's satisfaction. *Usability* is the extent to which a product can be used by specific users to achieve specific goals with effectiveness, efficiency, and satisfaction in a specific context of use. For software, usability/ease of use refers to its ability to be understood, to be learned, to be used, and to be attractive to the user under defined conditions (Bevan, 2001, 2006). *Playability* is defined as a set of attributes describing the player's experience. These qualities are satisfaction, learning, efficiency, immersion, motivation, emotion, and socialization (Sánchez, Zea, & Gutiérrez, 2009). Digital media serve the interaction with a two-way relationship, as opposed to the one-way form provided by a classic schoolbook. They are flexible, they work on the basis of the multisensory approach, and they can adapt to the cognitive limitations of each student, covering also specific educational needs (Kaimara et al., 2018). According to Prensky (2009), digital game-based learning will be considered as a system fully embedded in how people will be taught and learn for three main reasons:

1. The digital game responds to the needs and learning style of learners of today's and future generation.
2. The digital game, as a funny activity, offers motivation to the trainee.
3. The digital game is flexible; can be adapted to almost any object, information, or skill'; and is effective.

In education, technology can alter the experience of the user-student, and – depending on his/her learning profile – he/she will be able to adjust the means of access to the content. This possibility is offered successfully through the modern environments of virtual learning (Deliyannis & Papadopoulou, 2016) and the augmented reality technology, both in formal and informal education, such as in museums and archeological sites (Deliyannis & Honorato, 2016; Deliyannis & Papaioannou, 2017).

7 Effects of Digital Games

The effects of digital games have been explored in a general context. It seems, therefore, that effects are positive, bringing cognitive, emotional, motivational, and social benefits, but sometimes are negative related to contribution to obesity, addiction, cardio-metabolic deficiencies, etc. (Palaus, Marron, Viejo-Sobera, & Redolar-Ripoll, 2017). These evidences, which came after of systematic review based on neuroimaging techniques or references to structural or functional brain changes, examine long-term exposure to video games. Susi, Johannesson, and Backlund (2007) also reported as possible negative impacts health issues as headaches, fatigue, mood swings, repetitive strain injuries, etc.; psychosocial issues as depression, social isolation, less positive behavior toward society in general, increased gambling, substitute for social relationships, etc.; and the effects of violent computer games as aggressive behavior, negative personality development, etc. On the other hand, adolescents who play games had more favorable outcomes with respect to family closeness, school engagement, involvement in other leisure activities, positive mental health, substance use, self-concept, friendship network, and obedience to parents (Boyle, Connolly, Hainey, & Boyle, 2012). Without neglecting the impact of video games on players, and the concept of "problematic gaming behavior" (Männikkö, 2017), the researches recognize the lack of standardization in the different aspects of video game such as the participants' characteristics, the features of each video game genre, and the diverse study goals (Palaus et al., 2017).

The clarification that has been made in this chapter and the difference between digital games in general or video game as a leisure time activity, and digital educational games, and serious games allow us to investigate the effects of games in both formal and informal education. What is primarily concerned, to see whether digital educational games affect positively and/or negatively the learning. According to Van Eck (2006), the first step has been made: *we have largely overcome the stigma that games are play and thus the opposite of work*.

Benefits of digital educational games are self-monitoring, recognition, and problem-solving; critical thinking; decision-making; improvement of short- and long-term memory; cultivation of social skills such as collaboration, communication, and negotiation; and shared decision-making (Susi et al., 2007). Digital educational games allow teachers and students to connect real-world scenarios with school content, thus responding to the old question "Why do I need to know this?" (Annetta, 2010; Driscoll, 2002). The pedagogical exploitation of digital games as modern learning environments is based on the motivation of students. Digital educational games encourage learning fun, children's actions are meaningful, and knowledge is built effortlessly through active participation (Fokides, 2017). There are many reasons why digital games are applied in education. The most important, it turned out to be their high educational value as effective learning tools. As pupils come to school with an increasing knowledge of digital technology, digital game applications can be considered as ways of utilizing pupils' experience (Valasiadis, Katsadoros¸ Kakampoura, & Fokides, 2017). In the case of digital games, students take action in a pleasant, entertaining, collaborative environment. In motivation for learning, interest is no longer focused on whether a pupil can learn but to what drives the pupil to want to learn (Fokides & Tsolakidis, 2013).

But the danger is undermining, if we continue, based only on the good features of the games, such as their effectiveness, running the risk of creating the impression that all games are good for all learners, and for all learning outcomes. The research must (1) prove why digital game-based learning is engaging, and effective, and give (2) practical guidance for how (when, with whom, and under what conditions) games can be integrated into the learning process to maximize their learning potential (Van Eck, 2006).

8 Conclusions

Prensky (2003) emphasized that in digital games, at first glance, players seem to learn to fly planes, drive cars quickly, be in a theme park, be warriors, create culture or be veterinarians, etc. If, however, we deepen more, we are likely to find that players learn infinitely more. They receive information from many sources, make decisions quickly, accept the rules of a game, design strategies to tackle obstacles, and understand complicated systems through experimentation. And, increasingly, they learn to collaborate. Despite enormous potential of digital game-based learning, it is still difficult to integrate serious games into curriculum of formal education, although they are gaining acceptance and are positively accepted among children and teenagers (Susi et al., 2007; Zin, Jaafar, & Yue, 2009). The research pointed out that the adoption and the effectiveness of game-based learning depend largely on the acceptance by classroom teachers. Teachers need case studies of good practice in order to identify to digital games a new alternative effective methodological approach because of their potential to improve the quality of learning experiences and to facilitate knowledge acquisition and content understanding (Bourgonjon et al., 2013; Covaci, Ghinea, Lin, Huang, & Shih, 2018). It is evidence that many schools have computers that are too old for new games, and there is a lack of technical support, and also lack of time for teachers to familiarize themselves with the games and to identify their relevance to statutory curricula. There is also a difficulty in persuading school stakeholders to the potential benefits of computer games (Susi et al., 2007).

There is also evidence that children, the generation of Internet and computers, the "digital natives", use digital media constantly in their lives. Ignoring the existence of digital media, and preventing them from learning process, inside, and outside the classroom, all we can do is to make the education of students ineffective and boring. By careful examining all aspects of designing digital games, and having all the evidence that human learns through all senses, we can utilize the technology for the benefit of both teachers and students. Considering the effects of gamification, further research is needed to answer the question of how gamification motivates, as we still do not have sufficient confirmation (Sailer, Hense, Mayr, & Mandl, 2017).

Smart education that is supported by smart hardware and software which are portable, affordable, flexible, adaptable, effective, efficient, and enjoyable has the possibility to engage learners and teachers. Smart education through digital educational games and serious games gives alternative and complementary educational tools. Games clearly motivate users in ways that conventional instruction does not. For Annetta (2010) serious games are not a panacea; they are simply an instructional tool. As technology has inserted in most of the world's schools, as a separate subject and/or as a facilitator of the educational process, standard practice and experts' debates demonstrate that further pedagogical research into the development of smart pedagogy is needed. The new pedagogy could help teachers to conceive the importance of using digital educational materials, such as learning platforms, educational games, and teaching aids. Thus, it will be understood that digital educational materials are not just entertainment, but through fun and playful activities, they reinforce certain skills, as creativity, critical thinking, and ability to develop new and innovative solutions, and they contribute to cognitive development and knowledge building (Daniela, Rubene, & Goba, 2018). And as Skinner (1984) argued, the fascination of video games is adequate proof.

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Disrupting Education Using Smart Mobile Pedagogies

Matthew Kearney, Kevin Burden, and Sandy Schuck

Abstract As mobile technologies become more multifaceted and ubiquitous in society, educational researchers are investigating the use of these technologies in education. A growing body of evidence shows that traditional pedagogies still dominate the educational field and are misaligned with the diverse learning opportunities offered by the use of mobile technologies. There is an imperative to question those traditional notions of education, including how, where and when teaching and learning are enacted, and to explore the possible mediating roles of new mobile technologies. New smart pedagogies, which embrace the affordances offered by mobile technologies, have the potential to disrupt notions of schooling.
In this chapter, we examine the nature of smart pedagogies and their intersection with mobile pedagogies. We unpack notions of innovation and disruption. We then discuss smart mobile learning activities for school students identified from a Systematic Literature Review, together with the pedagogical principles underpinning them. We argue to encourage smart pedagogies, teacher educators should support teachers to implement 'feasible disruptions'. Consequently, implications for teacher education are explored.

Keywords Mobile learning · Smart pedagogies · Innovation · Disruption · Systematic Literature Review · Learning principles · School education · Teacher education

M. Kearney (✉) · S. Schuck
STEM Education Futures Research Centre, University of Technology Sydney, Ultimo, NSW, Australia
e-mail: matthew.kearney@uts.edu.au

K. Burden
University of Hull, Hull, UK

L. Daniela (ed.), *Didactics of Smart Pedagogy*,
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1 Disrupting Education Using Smart Mobile Pedagogies

This chapter deconstructs the notion of smart mobile pedagogies. We consider the construct of smart learning and investigate what pedagogies are aligned with smart learning. The chapter examines what these pedagogies may look like and provides examples of smart mobile pedagogies articulated in a Systematic Literature Review (SLR) recently completed by the authors. We discuss what makes a smart mobile pedagogy disruptive, unpack notions of innovation and disruption and examine what principles underpin smart and innovative mobile pedagogies. We investigate the value of disruption in new pedagogies and suggest a 'feasible disruption' model as being most likely to succeed in implementing innovation with smart mobile pedagogies. The chapter comprises three main foci: the first considers and discusses the notion of smart learning and smart pedagogies (Sect. 2), the second analyses ideas of innovation and disruption (Sect. 3) and the third considers a Systematic Literature Review conducted by the authors and identifies the principles that contribute to effective mobile learning (m-learning) or to underpinning smart mobile pedagogies (Sect. 4). We then draw on themes from these three foci to consider implications for teacher education in Sect. 5.

2 What Are Smart Learning and Smart Pedagogies?

Within the education literature, the word 'smart' is often used interchangeably to describe the spaces within which learning occurs (i.e. smart learning environments), the teaching strategies and approaches adopted by educators (i.e. smart pedagogies) and the outcomes and processes experienced by students (i.e. smart learning). Smart learning emphasises the autonomy and independence of the learner in an environment that is responsive and adaptive to their individual learning needs (Kim, Cho, & Lee, 2013; Lee, Zo, & Lee, 2014; Middleton, 2015). Smart learning is a student-centric perspective on learning which does not align easily with traditional didactic models of instruction in which the teacher sits at the heart of the educative process and the student is granted little opportunity to exercise any agency. Therefore, the primary focus of this section is what constitutes smart learning and allied to this, smart pedagogies, which are defined as those activities and teaching strategies that are conducive to, and enabling of, smart learning.

Whilst interpretations of what constitutes smart learning vary, with some focusing more on the technological drivers behind it (Hwang, 2014; Kim, Song, & Yoon, 2011; Lee et al., 2014; Lias & Elias, 2011; Scott & Benlamri, 2010) and others emphasising its more learner-centric and holistic characteristics (Gwak, 2010; Kim et al., 2013; Middleton, 2015), the essential elements are broadly agreed and can be summarised as learning that is:

1. Highly situated and authentic (Lias & Elias, 2011).
2. Adaptive and responsive to changing learning habits and behaviours (Hwang, 2014; Zhu, Yu, & Riezebos, 2016).

3. Learner-centric, self-directed and empowering (Kim et al., 2013; Middleton, 2015).
4. Highly personalised and customised to the individual (Hwang, 2014).
5. Interactive and dynamic (Huang, Yang, & Hu, 2012).
6. Seamless and highly contextual (Hwang, 2014; Scott & Benlamri, 2010).
7. Collaborative, interdependent and highly social (Kim et al., 2013).

These smart learning characteristics are not entirely new, and many of them such as collaboration, personalisation and learner centeredness have been actively promoted by some educators for many years in order to make learning more engaging, purposeful and meaningful (Kearney, Schuck, Burden, & Aubusson, 2012). However, the conditions and technologies are now aligning in ways that make these learning approaches more feasible and achievable than was previously the case. New developments include a combination of technical developments, such as ubiquitous personal devices, rich digital media, cloud computing and learning analytics, allied to the power of social networking and social media in bringing together what Middleton refers to as a 'perfect storm' of smart learning (2015, p. 15).

2.1 Technological Drivers

As the first generation of mobile phones has matured, they have developed into complex, multifaceted personal devices that provide access to a bewildering range of applications, tools and services, customised around the individual owner. This second generation of mobile phones, known as smart devices, combines advanced technical features, networked services, context awareness, geolocation, augmented reality, Big Data, learning analytics, wearable technologies, artificial intelligence (AI) and the Internet of Things (IoT) (Kim et al., 2011; Lee et al., 2014). It is the combination of all of these emerging technologies and services, rather than any single one, which has brought about the requisite conditions for smart learning to flourish at this point in time (Middleton, 2015).

Allied to these technical developments are infrastructure developments such as the exponential increase in bandwidth and connectivity available through services such as 4G/5G, ubiquitous Wi-Fi and unlimited data plans which mean students can access learning anywhere, anytime without worrying about the cost or robustness of the connection. The characteristics of smart learning described above have become possible as a result of a combination of various vectors which typically include growing connectivity (e.g. from wired Internet to wireless Internet to broadband Wi-Fi) and device sophistication (e.g. from desktop to mobile phone to smart device). This has facilitated a paradigmatic shift from e-Learning or first-generation use of computers in education to mobile learning (m-learning) and now 'smart learning' where access to pervasive broadband connectivity on smart, personal devices is blurring many of the barriers or boundaries that have previously kept formal and informal learning apart (see Lee et al., 2014).

2.2 Paradigm Shifts: From E–Learning to Smart Learning

e-Learning developed with the emergence of desktop technologies and web browsers in the 1990s, but it was highly 'tethered' and static in nature (Traxler, 2007), constrained by the physical infrastructures of the era (e.g. hard-wired ethernet and electrical cables). These technologies were usually purchased institutionally, leading to a corporate mindset towards learning in which the individual student had limited agency or control over how they used and interacted with the technology. Consequently e-Learning has tended to resemble traditional, formal learning in its structures, practices and underlying pedagogical approaches (Zhang, 2010). It has supplemented and extended the reach of traditional learning making it available at times and in spaces that were previously inaccessible for learners (e.g. learning at a distance), but the fundamental nature of learning itself has not altered.

In contrast, the emergence and application of mobile technologies have seen a paradigmatic shift in approaches to learning, a shift which is highly variable across different settings and contexts. Initially the introduction of mobile technologies in learning was also 'tethered' like e-Learning because of limited wireless phone connectivity (initially 2G and then 3G) and unreliable Wi-Fi connectivity. Unlike the e-Learning paradigm, which was browser focused, the m-learning paradigm relies upon agile, mobile devices which belong to the individual. In this respect the mobile learning paradigm represents a shift away from corporate technologies, owned and therefore controlled by the institution, to more personal and pervasive devices that are inherently individual and more customised. But in practice the predicted benefits of this shift to m-learning have not been fully realised, and many instantiations of mobile technology resemble the e-Learning paradigm where practice is largely restricted to formal teaching spaces and students are granted limited opportunities to exercise independence and choice. Indeed, our own research over a number of different studies that include schools, teacher education and universities (Burden & Kearney, 2016; Kearney, Burden, & Rai, 2015) suggests educators are exploiting a relatively limited range of m-learning affordances, and it is not common to find mobile technologies used to customise the learning experience of students or to make learning more authentic and realistic.

The promise of smart learning is that it returns control of learning to the student regardless of the context they are learning in. It increases their independence and enables them to feel more empowered which has not been evident in any of the previous technology paradigms:

> Smart learning assumes that the learner is at the heart of their learning: teachers, peers, technologies and the learning environment are, in effect, support actors and props to that purpose. (Middleton, 2015, p. 15)

The implications of this statement for teachers and educators are profound since it is not simply a matter of tinkering with current teaching models which might be compared to rearranging the deck chairs on the Titanic. With adaptive technologies, learning analytics and other cloud-based services, smart learning may be feasible without smart pedagogies, but the reverse is not true. Smart pedagogies are redundant without smart learning. It is imperative therefore that educators take the growth of smart learning seriously and understand its mechanisms and implication in order that they can design and align sympathetic and complementary smart pedagogies.

Once we recognise the significance and meaning of this shift to a more learning-centric paradigm of education, the implications that stem from it also make greater sense. In the smart learning paradigm, learners are empowered to exercise much greater agency, identifying their own learning pathways, outcomes and assessment opportunities. These freedoms challenge many of the restrictions that have traditionally bounded learning to particular places and times. Formal and informal learning becomes an artificial binary since learners are free to select the spaces and times when they prefer to learn. There are greater opportunities to work and learn collaboratively, supported by the power of crowdsourced learning and social media networks. Consequently, learning can be individualised and customised whilst still retaining the values and importance attached to social learning with peers. Learning is not restricted to face-to-face contexts, overcoming a hurdle that neither e-Learning nor m-learning has managed to completely address.

2.3 Smart Mobile Pedagogies Aligned to Smart Learning

We define smart pedagogies as the teaching strategies, activities and teacher-initiated approaches that support and enable smart learning to flourish. They are not conventional teaching approaches since these would be misaligned with the smart learning principles outlined in this section, particularly those that emphasise the autonomy and agency of the learner. Table 1 below summarises a selection of possible smart pedagogies alongside the smart learning characteristics they are intended to support. It should be noted that all of these pedagogies are ones afforded by smart devices and ubiquitous connectivity; hence, we use the term ‘smart mobile pedagogies’. For the purposes of conciseness, the smart learning characteristics mentioned above have been grouped according to their attributes.

The alignment of smart pedagogies and smart learning characteristics provides a clearer idea of what smart mobile pedagogies can encompass. Potentially these pedagogies are inherently innovative and possibly disruptive. The next section deconstructs notions of innovation in education, with a particular focus on smart mobile pedagogies.

3 Innovation and Disruption

This section examines notions of innovation in education, particularly in relation to digital pedagogies. The word ‘innovation’ is used liberally across education literature, policies and reports (Moyle, 2010) to describe new ideas, products, approaches

Table 1 Smart mobile pedagogies aligned to smart learning characteristics

Characteristics of smart learning that is		Corresponding smart mobile pedagogies
Situated and authentic		**Seamless pedagogies** that recognise the seamless nature of learning, enabling learners to extend their learning across several contexts Examples might include: · pedagogy utilises all spaces as valid learning contexts · pedagogy rooted in authentic, real-world contexts, using authentic tasks and tools · pedagogies rooted in the interests and experiences of learners
Adaptive and responsive to changing learning habits and behaviours	Personalised and adaptive learning	**Customised pedagogies** Examples might include: · teaching approaches that promote self-regulated and self-motivated learning strategies · self-paced pedagogies · differentiated learning pathways **Context-aware pedagogies:** · teaching strategies that offer instant and adaptive support to learners based on contextual factors
Learner-centric, self-directed and empowering		
Personalised and customised to the individual		
Interactive and dynamic		**Creative and multimodal pedagogies:** · That encourage learners to engage and be active rather than passive.
Seamless and contextual		**Context-aware pedagogies:** · Teaching strategies that offer instant and adaptive support to learners based on contextual factors.
Collaborative, interdependent and social		**Collaborative pedagogies that support and encourage learners to construct and participate in networks** Examples might include: · pedagogies supporting social networking · global and intercultural pedagogies

or processes (Fenwick, 2016). Innovations can be small or large-scale but need to go beyond superficial change to introduce new ideas or practices that are impactful and valuable to individuals or communities (Denning, 2004; Fenwick, 2016; Linfors & Hilmola, 2016). In an education context, for example, innovation could mean new curriculum, pedagogy or assessment solutions to improve student outcomes (Danaher, Gururajan, & Hafeez-Baig, 2009).

Interpretations of 'innovation', or the extent to which an idea or process is new or impactful, will ultimately depend on one's perception and context (Caldwell, 2018). Subsequently, some writers emphasise a 'frame of reference' (Moyle, 2010, p. 11) as critical to discussion of innovation. Tornatzky and Fleischer (1990) suggest that innovation needs to be impactful at least to the people or organisation carrying out the innovation, whilst Potgieter (2004) suggests that innovation in education needs to be 'an idea, practice, object or combination of these that is perceived as new by staff' (p. 271).

There are two ends of the innovation 'spectrum'. At the more conservative end are 'sustaining innovations', described as an adaption of existing approaches (Christensen, Horn, & Johnson, 2008; Fenwick, 2016) and a trade-off with established practices and paradigms (Christensen, 1997). Alternatively, at the radical end of the spectrum, 'disruptive' innovation is extremely different to the status quo and can initiate a paradigm shift (Christensen, 1997), transforming existing, dominant practices. In education, disruptive innovations create new practices, purposes and processes (e.g. of learning), new relationships between students and teachers and potentially a change in the nature of school and its relationship with the community: '…the innovation as a whole can be considered a 'disruption' to prevalent practices' (Law, 2008, p. 428). These new practices may demand reimaging of schooling, for example, allowing students 'to personalise education to fit their needs' (Christensen et al., 2008, p. 243). In the case of innovative pedagogies supported by technology (or digital pedagogies), sustaining innovation would support existing, prevalent technology-enhanced practices to achieve existing curriculum goals, whilst disruptive innovative digital pedagogies would promote new technology-mediated practices to achieve new goals and replace traditional approaches (Hedberg, 2006; Law, 2008). Or as Selwyn (2017, p. 32) explains, disruptive innovation 'is not about using technology to do the same things differently, but using technology to do fundamentally different things'.

Most of the education literature tends to discuss sustained innovation designed to simply improve the quality of established practices rather than supplant them. However, there is debate over which end of the spectrum is ideal for school contexts. Sustaining innovations set out to adapt existing approaches (critics label such changes as mere 'renovations') but ensure enhanced quality of existing practices (Fenwick, 2016). In contrast, disruptive innovations are radically different to the status quo, and their implementation can initially be less successful than the traditional practices they are attempting to replace. Another issue is the pace and scope of implementation of innovations. A gradual, incremental approach is often advocated in schools – institutions that are well-known for their conservatism and resistance to change (Law, 2003; Zhao, Pugh, Sheldon, & Byers, 2002). For instance, Zhao et al. (2002) studied a number of innovations in schools and found that an 'evolutionary rather than revolutionary' approach to innovations was more likely to succeed: 'Innovations that were the most distant from the teachers' existing practices and school culture were less likely to succeed…' (p. 512).

Innovation in schools is typically discussed with a focus on pedagogical innovation. There is general consensus that pedagogical innovations in schools attempt to change 'traditional teaching' that is assumed to be isolated, knowledge-focused and teacher-centred (Hedberg, 2006; Law, 2008). For example, in their discussion of innovative teaching, Zhu, Wang and Engels (2013) argue for less traditional approaches, drawing on social constructivist learning theory to emphasise active participation, collaboration in real learning situations and authentic learning tasks.

There is an increasingly well-accepted argument for schools to supplement or replace traditional pedagogical approaches with more innovative approaches to help students develop the diverse knowledge, skills and attitudes needed for living and working in the twenty-first century (OECD, 2018; Voogt, Erstad, Dede, & Mishra, 2013; Zhu et al., 2013) and to prepare them for careers that may not yet exist (Dede, 2011). Voogt et al. (2013) argue specifically for curriculum change, including an emphasis on new literacies, linking learning between formal and informal settings and new assessment frameworks, whilst Law (2008) makes similar arguments for pedagogical renewal: '…pedagogical innovation is becoming increasingly important in the 21C when the focus in education shifts toward lifelong learning and knowledge creation, demanding changes in educational goals, as well as curriculum and pedagogical processes' (p. 427). Zhu et al. (2013) explain the need for innovative teaching: 'It seems that innovative teaching is necessary for the present and future of education to help students reach their potential' (p. 9).

Innovative digital pedagogical approaches, or what Law (2008) calls 'ICT-using pedagogical innovations', typically explore the use of learning technologies to support new strategies that might change or replace traditional teaching approaches. Hedberg (2006) advocates the use of innovative digital pedagogies that facilitate a shift towards constructivist pedagogical approaches adopting student-centred learning strategies. He argues that these approaches give students control over choice of learning topics and sequences and typically encompass emphasis on their creation, evaluation and synthesis processes. Social interaction and social construction of knowledge are also emphasised, as well as a shift in focus 'from assessment of the end product to assessment of the learning journey' (p. 179). He also suggests that *disruptive* digital pedagogies need learning spaces that support a shift from the learner as 'a passive participant toward an active engaged constructor of their own experience' (p. 181). For example, when discussing 'online learning', Hedberg suggests a revolutionary move away from simply replicating traditional (classroom-based) teaching practices in an online environment. In a similar way, in their discussion of innovative mobile digital pedagogies, Schuck, Kearney and Burden (2017) discuss 'Third Space learning' as a disruption to existing practices: 'The ways that portable, multi-functional mobile devices can untether the learner from formal institutional learning give scope for learning to be conceptualised in an expanded variety of places, times and ways' (p. 121).

In Law's earlier (2003) study of innovative classroom practices, she used six dimensions of innovation/change in the context of digital pedagogies: intended learning objectives/curriculum goals, pedagogical roles of teacher, roles of learners, nature and sophistication of technology used, connectedness of classroom (i.e. collaboration with people outside of the school) and learning outcomes exhibited by the learner. These dimensions were used by Law (2003) to explore the innovations from each case in her study and to gauge the extent of change. She also highlighted the overall extent of innovations using categories ranging from 'Traditional' to 'Some new elements' to 'Emergent' to 'Innovative' to 'Most innovative' (p. 174).

More recently, a team at The Open University in the UK has issued an annual report since 2012 on 'new forms of teaching, learning and assessment for an interactive world' (Ferguson et al., 2017), focusing on 'novel or changing theories and practices of teaching, learning and assessment for the modern technology-enabled world' (p. 6). The group defines digital pedagogical innovation as 'new pedagogies making use of technologies to go further, to open up new possibilities' (p. 8). For example, they discuss 'crowd learning' pedagogy as allowing learners to 'update and revise knowledge, offering a more personal and local perspective than centrally published media' (p. 8); and they describe 'citizen inquiry' approaches as learners use technology to 'explore new areas of knowledge and to investigate together' (p. 8).

However, Ferguson et al. (2017) deliberately avoid technocentric discussion in their focus on new pedagogies: 'By examining innovative pedagogies, we aim to ride the roller coaster of technology adoption, highlighting ways of teaching, learning and assessing that can be successful both now and in the future' (p. 9). Law (2008) also warns that innovative digital pedagogies do not depend on the technology but rather on the intended use of the technology and the educational context. She argues that technology per se is not a catalyst but a 'lever' for changed practices. 'Technology is leveraged by teachers as a disruptive force (or resource) in realising pedagogical innovations' (p. 428).

3.1 Innovation with Smart Mobile Technologies

The discussion above has alluded in several cases to the potential disruption that smart learning, allied with smart pedagogies, poses for traditional educational structures and practices. These cases parallel the disruptive forces that Middleton recognises at the heart of his smart learning model (2015). Smart learning is predicated on the personal ownership of agile, mobile smart devices, and this challenges and disrupts the traditional model of technology ownership which is corporate and designed to control how learners access and use technology within, but not beyond, an institution. Given their growing ubiquity and pervasiveness, smart devices also challenge existing models of classroom organisation, even raising fundamental questions around the future utility and necessity of traditional classrooms, and therefore of schools themselves (Schuck et al., 2017). If learners are capable of accessing learning resources and the allied services that make deep learning a reality independently and without direct intervention and control from teachers, smart learning also begins to challenge the notion of ‘delivering’ learning which underpins most formal models of learning in schools. A fundamental challenge to the orthodox model of learning is social media and social networking which, Middleton claims, disrupts the one-to-many model of learning in which the teacher ‘delivers’ learning to the many. Social networks structure learning in an entirely different manner where multiple nodes and the network itself are all capable of supporting distributed but connected learning in a process Siemens terms ‘connectivism’ (Siemens, 2005). And finally, smart learning disrupts the content and transmission model of learning which situates learners as passive consumers of pre-packaged learning content – predominantly of a text-based nature – that is consumed but not created. Smart learning promises to realise many of the aspirations behind knowledge construction and co-authorship (Bereiter & Scardamalia, 2014) as user-generated content is accessed and repurposed rather than simply consumed.

In these multiple but related instances, smart learning and smart pedagogies have the potential to be hugely disruptive trends that challenge many of the norms and mores that education traditionally holds in high esteem.

4 Smart Mobile Pedagogical Innovation and Disruption

This section details the process and findings of a recent Systematic Literature Review (SLR) conducted by the authors, exploring innovative mobile digital pedagogies in school education. An SLR comprises more than an ad hoc search of literature. It uses a set of criteria and a well-defined procedure to scan various databases for articles that fit the criteria. As noted in previous studies, ‘It is a methodical and meticulous process of collecting and collating the published empirical studies of acceptable quality with systematic criteria for selection to reduce researcher bias and provide transparency to the process’ (Bano, Zowghi, Kearney, Schuck, & Aubusson, 2018, p. 33). We initiated a Systematic Literature Review with a focus on the following research question: *How does the use of mobile technologies support innovative teaching and learning practices for school-aged learners?* Three major search terms were derived: ‘mobile learning’, ‘innovation’ and ‘school-aged learners’. From these major search terms, synonyms and alternative terms were identified. For example, informed by the literature on digital pedagogical innovation (see previous section), the ‘innovation’ component of the search string included words such as ‘disrupt’, ‘renew’ and ‘redefine’, as well as phrases such as ‘new practice’, ‘new teaching approach’ and ‘emerging learning strategy’. The search string was applied on a range of databases to ensure that relevant studies were not missed.

This initial search and selection process yielded 208 papers. A further selection process was then carried out by the team of three researchers and a research assistant. Pairs of researchers applied the following selection criteria to all 208 papers included in the search results: the paper was published in English between 2010 and

2017; the SCImago journal ranking (SJR) of the paper was in the top two quartiles; the study targeted school-aged learners (5–18 years); the study adopted a rigorous methodology and compelling evidence was presented; the paper focused on innovative mobile pedagogies (as defined in the previous section); and strategies and approaches were identified (e.g. as interventions). If these criteria were not met, the paper was excluded. Issues related to the possible exclusion of papers were resolved through inter-researcher discussion at team meetings, and any remaining questions were resolved by reading the full text of papers. Different team members randomly checked among the results to reduce selection bias. At the conclusion of this process, there were 72 papers selected as being suitable for inclusion in this SLR.

As a final step, the research team scrutinised the final selection of 72 papers to identify studies that investigated or described practices that contained elements of disruptive innovation, again informed by the literature on digital pedagogical innovation (see previous section). Only nine papers were identified as containing medium to high levels of disruptive innovation practices in the context of m-learning, with the remaining 63 papers focusing on sustaining digital pedagogical innovations. Four of these nine papers were from Singaporean projects with primary/elementary school-aged learners, three focusing on science learning (Looi, Sun, & Xie, 2015; Toh, So, Seow, & Chen, 2017; Zhang et al., 2010) and one on language learning (Wong, Chai, Zhang, & King, 2015). The remaining five papers were from projects in South Korea (Ahn & Lee, 2016), focusing on language learning of middle school students; Israel (Barak & Ziv, 2013), focusing on middle school environmental education; the Netherlands (Schmitz, Klemke, Walhout, & Specht, 2015), focusing on the context of health education; Australia (Bower, Howe, McCredie, Robinson, & Grover, 2014), focusing on secondary school visual arts; and the USA (Akom, Shah, Nakai, & Cruz, 2016), focusing on community learning. Of these nine papers, only two papers (Akom et al., 2016; Toh et al., 2017) focused on practices that were perceived by the research team as demonstrating high levels of mobile pedagogical innovation, containing pedagogical elements that could potentially disrupt traditional practices (see Fig. 1 below). In Sect. 4.2 we expand on how these last two papers were innovative and disruptive.

4.1 Principles Underlying Smart Pedagogies

As indicated above, our SLR identified a set of 72 papers that discussed innovative or disruptive use of mobile pedagogies. One of the tasks that the authors did subsequent to identifying innovative and disruptive pedagogies in this review was to identify a set of pedagogical principles that were apparent in the selected papers. These pedagogical principles are now embedded in a survey that investigates their relative importance in the design of effective mobile pedagogical activities. At time of writing, a Delphi panel and an international group of school teachers who are engaged in m-learning are being surveyed to discover their perceptions of the relative rankings of the principles. In this sub-section of the chapter, we will outline the set of

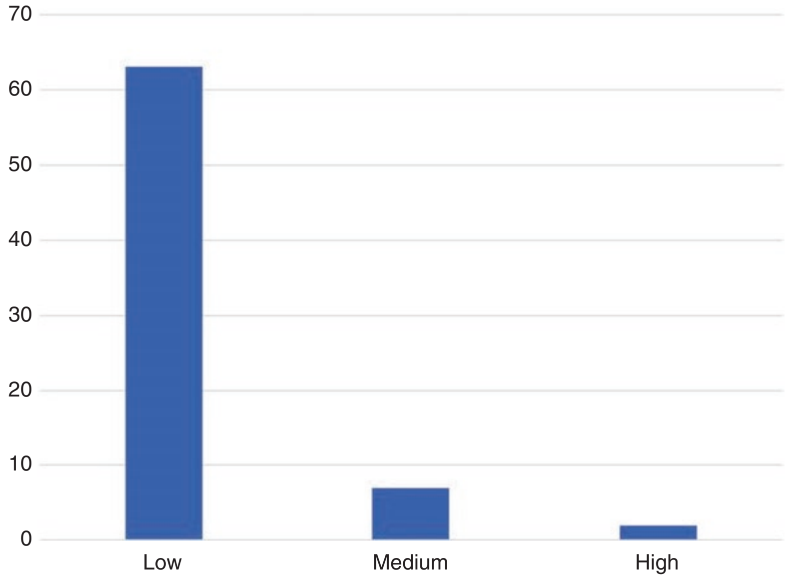

Fig. 1 Level of disruptive practices discussed in the final set of 72 papers

principles identified and consider their alignment with the seven characteristics of smart learning identified above (see Table 1) and the corresponding smart mobile pedagogies. We consider how much disruption is feasible, desirable and able to be implemented within the constraints of a teacher's role. We will also discuss implications for other stakeholders involved in disruptive mobile learning. Implications for teacher education are examined.

The set of principles identified from the SLR originally comprised a group of 42 distinct principles. By grouping like principles together, the list was narrowed down to a group of 21 principles. See Table 2 for details of these principles and the descriptions.

We are arguing that these 21 principles, or variations of these, underpin the innovative and effective activities that are discussed in the m-learning literature. When referencing these principles, it can be seen that they are closely aligned to the smart pedagogies indicated in Table 1.

Given the lag in take-up of disruptive pedagogies by school teachers, the following recommendation is suggested: that the type of innovation we should be encouraging in education of school-aged students incorporates change that is not merely involving small increments in innovation or what we have called sustaining innovations but ones that have some elements of disruption in them. Indeed, we should not expect all teachers to embrace radical innovation as this expectation is likely to lead to a low take-up of innovation of any kind, given that it will be too challenging for most to adopt such disruptive practices. Rather we suggest that we encourage innovation somewhere between conservative and radical and view disruption as being on a continuum. An important aspect of disruption, we argue, is

Table 2 Principles underpinning innovative smart mobile pedagogies emerging from SLR

Seamless learning: Activity occurs across a variety of physical and/or virtual settings
Digital play: Activity involves explorations without an explicit curriculum goal
Student agency: Students have the choice of how to do the activity
Student autonomy: Students determine the activity
Gamification: Applies elements of games such as competitions, random events, scoring
Customisation: Learning pathways are adapted to individual input
Authentic environment: Activity occurs in situ (i.e. it occurs in its original or natural location)
Simulation: Conducting realistic virtual task, e.g. Google expedition
Context-awareness: Activity adapts to environmental stimuli, for example, new vocabulary is determined by external items
Data sharing: Learners share digital artefacts with peers
Artefact construction: Learners make digital object, e.g. video, music, game
Co-construction: Learners use collaborative authoring tools, e.g. Google docs
Reflection: Learners reflect in multimodal ways, e.g. with vlogs, colours, sound
Real-world processes: Learners engage in activities similar to those done by practitioners, e.g. testing aerodynamics of object with app
Real-world tools: Activity uses app as tool, e.g. to compose music or paint a picture
Role-play: Learners assemble tools and methods and enact roles, e.g. citizen journalist
Peer review: Learners review each other's contributions, e.g. via blogs
Codesign for mobile learning: Students and teachers 'mobilise activities', i.e. transform them into ones with mobile features
Intergenerational learning: Learners across different generations work together, e.g. capturing an oral history
Bridging: Learners work across formal and informal contexts
Community-based: Learners conduct a community activity or project, e.g. monitoring litter

that it is feasible. Our next step with our Delphi panel in the research under discussion will be to ask them to identify the most feasible of several disruptive scenarios, so that these can be used as examples to assist teachers in developing their own feasible but disruptive pedagogies for mobile learning.

4.2 Illustrative Examples of Potential Disruption

To make this discussion more concrete, we revisit the aforementioned two papers from our SLR (Akom et al., 2016; Toh et al., 2017) that were the only ones found to focus on practices that contained pedagogical elements that could potentially disrupt traditional practices. We will then use these two examples to discuss the benefits and constraints of implementing such disruptive activities, with respect to the principles for effective m-learning identified above and with respect to their feasibility for implementation by most teachers engaged in mobile learning. These two illustrations show the smart pedagogies we suggest can disrupt traditional ways of learning.

The first illustration comes from an article by Akom et al. (2016). These authors describe how they utilised a digital platform called Streetwyse, as part of an activity which allowed young people to codevelop and participate in a community health promotion. They found that participation in this activity promoted the young people's self-esteem and supported the development of their leadership skills, environmental awareness and academic engagement. The authors worked with 90 young people, in a particular community, and focused on food availability. They mapped locations and information of retail food/drink stores in the urban area in which they lived. They found the majority of products sold were either liquor or foods with high salt and sugar content such as chips, soda drinks and confectionaries. They used available data to make recommendations about healthy food that should be stocked in the stores.

If the article is analysed for the pedagogical principles that are present, from the list above, it can be seen that there are a number of such pedagogical principles built into the scenario: seamless learning occurred as the students moved throughout the community and educational institution, student agency and autonomy were clearly present, the activity took place in an authentic environment, data sharing occurred between the young people and they used real-world processes to analyse and map the locality and codesigned the Streetwyse app they worked with. The activity is also quite disruptive as it called for a different way of working with young people, one that promoted their activism and authority.

The second illustration discusses practices emerging from the Toh et al. (2017) study from our SLR. Their paper describes how children (aged 9–10 years old) in their study used mobile devices across a range of informal and formal learning contexts to support their science learning through their daily lives via two case studies. Both cases described activities that were underpinned by an inquiry-based learning approach where the children's devices were promoted by their teachers as a 'cultural tool and learning hub' (p. 305), helping them to exploit their mobility across 'time and space'. The first case study described a child who was learning about marine studies drawing upon his real-life experiences in a range of family fishing and wildlife field trips. The child used his device to link up with family members, peers and teachers as social resources in his learning, for example, asking questions for additional help, as needed. His mother was a significant figure in his learning, helping him to value the process of finding solutions to questions independently. He also captured, created and archived numerous multimodal resources 'on the fly' (e.g. accessing real-time information and capturing photos and videos) and framed questions for inquiry using these resources. The second case study explained a variety of mainly self-initiated m-learning activities enacted by another child. This study participant used his device to blog for self-expression, to create resources such as imaginary worlds for role-playing and to create animations to extend his knowledge on science topics.

A number of our pedagogical principles from Table 2 were evident in this illustration. For example, *seamless learning* was clearly present in the first case study as the child's science activities spanned a range of informal and formal learning spaces. Elements of authentic learning (*authentic environment* and *real-world tools*) were also present, with the activities situated in real-life contexts (such as fishing) and use of tools such as the camera to enhance observation. There was also a strong sense of *student agency* as the child's inquiry-based learning was self-directed, and the traditional 'controlling' role of the teacher was diminished. In the second case study, the principle of *role-play* was apparent in the activities, as was *peer review* (use of blogs), *artefact construction* (learner-generated animation) and, to a lesser degree, *data sharing*. *Student autonomy* was also a feature, with the researchers expressing amazement at some of the self-initiated, digitised materials created by the participant in the second case (p. 310). In this way, this illustration described smart mobile pedagogical practices that contained numerous elements of disruptive innovation.

5 Implications for Teacher Education

The discussion above indicates the principles that have been identified as central to innovative and effective mobile learning activities. The pedagogies underpinning these activities are ones that we identify as smart pedagogies. We noted that their deployment may disrupt current practice, and we argue for 'feasible disruption' as the most desirable of innovative digital pedagogies. We now turn to the implications of promoting such pedagogies for teacher education.

Teacher education faces a number of challenges in the preparation of student teachers. Teacher educators need to keep abreast of emerging technologies and ensure that the pedagogies they suggest are current and in alignment with the needs and practices of contemporary schools and societies (Royle, Stager, & Traxler, 2014). They have the dual challenge of both keeping themselves current and also inspiring their students to be competent and confident users of new technologies and new pedagogies, with the aim of improving student outcomes (Burke & Foulger, 2014). Sadly, teacher education appears to lag behind in these endeavours (McClanahan, 2017). Indeed, education in general does not seem to have kept up with the innovations in technology use that industry and society in general are enjoying (McClanahan, 2017; Papert, 2004). Often the reason given for this state of affairs is that the teachers and teacher educators (Burden & Kearney, 2017) have not received sufficient preparation in using mobile pedagogies and other emerging digital pedagogies during their teacher education courses. Whilst this reason is debatable, the fact remains that teacher educators in general do not seem to employ innovative or disruptive pedagogies in their preparation of pre-service teachers.

The question that then becomes critical is how do teacher education institutions encourage their teaching staff to embrace innovations and support their students to do likewise. Given that the pre-service teachers are likely to be teaching school students long into the future (possibly for as long as 35 years into the future), what skills and competencies do teacher educators need to support them to develop (Schuck, Aubusson, Burden, & Brindley, 2018)? It is likely that the principles identified above should underpin any pedagogies. Further it seems that there are several factors that support innovation and smart pedagogies occurring in teacher education institutions. These include support at an institutional level, the expectation that all faculty members participate in the innovation (Burke & Foulger, 2014), addressing the values and beliefs of staff (Law, 2008) and importantly that there is some driver that leads to long-term implementation of the innovation (Bereiter, 2002).

Our recommendations therefore are that teacher educators consider the principles underpinning smart pedagogies and that their institutions offer them time and opportunity to develop their own skills in implementing these pedagogies. It is anticipated that once the teacher educators are comfortable with the role of innovator, they are more likely to be able to inspire their student teachers in this regard. Mindful of the research on innovation, there needs to be some driver that will encourage sustained implementation. This driver might be policy from government or accreditation bodies or demand from student teachers (Schuck et al., 2018). It is likely that all will become critical forces for change in the future.

6 Conclusion

Mobile pedagogies have been predicted as a 'game changer' for some time now, potentially engendering disruptive innovation and bringing school education into an 'Age of Mobilism' (Norris & Soloway, 2011). Despite these predictions, the use of mobile devices in schools has so far not been disruptive, with adopted mobile pedagogies predominantly replicating traditional transmissionist approaches (Kearney et al., 2015). This phenomenon follows a familiar historical pattern over the past four decades, whereby teachers tend to use increasingly sophisticated educational technologies in culturally familiar ways (Zhang, 2010), adopting traditional digital pedagogies that often align with existing school structures and practices that were originally designed for the industrial age, similar to 'attaching a jet engine to a stage coach' (Papert, 2004). This chapter offers a 'way forward' for breaking out of this cycle and optimising the impact of smart technology use on learning by children and teenagers. In particular, it offers evidence-based principles underpinning innovative smart mobile pedagogies that have emerged from a rigorous SLR study. We argue these principles should be applied to new smart mobile practices that go beyond sustained innovation but at the same time are 'feasibly disruptive' for teachers and teacher educators to implement, within the realities of conservative and often bureaucratic institutions that are resistant to change.

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Art Didactics and Creative Technologies: No Borders to Reform and Transform Education

Agnes Papadopoulou

Abstract The dynamic field *art and technology* as a field of synthesis, convergence, interaction, critical evaluation and practical application harmonizes perfectly with the structure of the curricula, aims, objectives, teaching principles and functional features of a modern educational system. The development of dynamic, technologically enriched learning environments has at its heart the use and creation of digital material, with students being directly involved in the creative process, the action, the challenge, the public exposure and the criticism. This chapter attempts to analyse how art didactics and creative technologies define a framework of active critical tasks, triggering students' thought and artistic creation. To the objections, mainly technological, about violation of boundaries and capabilities of a mediated world, we opt for the emblematic, representational role of art. Artworks undermine reality-perception codes by exploring variants and transformations, and students examine why artists used certain techniques, within processes of free experimentation. Particular emphasis is placed on the process which is not theory but mostly activity. They reflect, compensate, avoid prescriptions and become hardened against the aims of predetermined agendas. Aesthetic education shapes technique. Students, with the help of software programmes, create and are cut off from chain reactions that are in line with dominant cultural standards.

Keywords Art didactics · Art · Technology · Creative technologies · Smart learning environments

A. Papadopoulou (✉)
Department of Audio & Visual Arts, Ionian University, Corfu, Greece
e-mail: a.papadop@ionio.gr

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1 Introduction

Pedagogy investigates the role and function of school, formulates statements and views and suggests solutions. It is characterized to a relatively large degree by a regulatory manner of thinking and often finds itself facing failure, since instruction and teaching do not mean they will bring about a reliable effect, despite the optimism inherent in general in educational theories regarding the overall impact of education. On the one hand, in the choice of educational programmes, the form of construction, the teaching principles and the aims as well as the functional characteristics of education, one can detect a complexity (Perkins, 2014), and on the other hand – a frequent and long-standing problem almost inherent in the educational system – one can also detect a failure of practical application. As early as Freud himself (Freud, 1937), the problem has been noticed and placed in its proper place by claiming that instruction belongs to those "weak/soft" professions in which one can be certain beforehand of "insufficient success", precisely because, while after a related training children are informed on a given issue, they cannot make use of this knowledge and act on subjects they have received training on like primitive people.

In art, behind any form and its qualities, there is always a spiritual depth, an idea, an intention and a goal that will be translated through it. It is something similar to geometry that helps us understand the abstract concepts of mathematics. The usage of paradoxical simulations, strange metaphors, unusual descriptions and strange representations (Foucault, 2017) – and this is the most interesting – creates clearer meanings. What is at stake is that a non-standardized representation manner will not lead to a gradual incomprehension (Hall, 2012) but, without the use of standard conventions, will become perceived.

A modern pedagogical framework (Sharples et al., 2016) should provide more potential, in order to construct a fertile cognitive foundation necessary for the acquisition of new knowledge. The coveted aim of active learning means applying learning through activities using multimedia for the enrichment of the emerging knowledge, a flexible environment for cooperative learning, in which easy access is ensured, the use of multiple resources and multiple tools (Pacansky-Brock, 2017), the possibility of interaction and increased motivation (Read, 2017), dealing with today's issues and authentic tasks (situated learning).

The specific manner of how new technologies (social media, new literacies, e-books, smartphones, tablets) are integrated into educational practice is ultimately aimed at optimizing learning (Clarke & Svanaes, 2014). The technologically enriched learning environment is shaped, broadened and transformed into a source of information, a learning stimuli and a field of activities and communication with the individuals and groups living within and outside the school space (Sheehy, Ferguson, & Clough, 2014). It functions as a teaching field with significant effects on the process of cognitive and cultural development, since it offers new possibilities in the search, exploitation and management of information/cultural material (e.g. diffusion with interactive 360° video presentation). Students understand that digital creative tools are re-examined constantly in an ever-evolving and progressive technological field. The process of research is continuous and exciting. Therefore, the goal for students is not only to learn to use digital tools but also to visualize changes and ways of improvement, even if their proposals appear completely unlikely to bear fruit. It is a start.

Alternative digital worlds take on in the field of education the role of an interactive, adaptable communication medium, creating a dynamic field of synthetic possibilities. Students have to realize that alternative digital worlds are endowed with all those elements traditionally and customarily attributed to what we mean as a physical-real world (organization, structural complexity, autonomy, control). And thus, they have to acquire methodological thinking, perseverance and practice in reflective observation and research. The cognitive and affective engagement of students with the alternative digital worlds partly requires similar skills with their involvement in the physical-real world (Sax, 2016).

Art as a human creation, expression of culture, object of reflection, element of emotional engagement and special language directly related to technique and technology changes the landscape in education, departing from the traditional reading-learning model. In this chapter, emphasis is placed on the semantic/conceptual background of the activities through creative technology, that is, placing more emphasis on the process than in the final outcome through the technologies. A fertile ground is created for investigating the artistic act and how it influences artistic literacy. The critical process is not cast away. Aesthetic education acts as a bridge for the before and the after.

The objective of developing audiovisual literacy skills requires the creation of an appropriate learning environment, taking into account children's potential for aesthetic explorations. The personal work of each student with the help of software engages students in research and helps feedback. They involve themselves wholeheartedly in activities using digital tools and are driven to what they want to learn/apply. This is so, because they are given the opportunity to think through the whole process fuelling the self-regulated learning loop (Cleary, 2018). Additionally, solving individual problems of a synthetic process is required to "graft" existing technical practices and promotes self-confidence.

Art and the relation of art to technological development have a key role in the formation of the learning environment (material and social). It cannot be disputed that there are intense discussions as to whether art and technology are two terms that are joined by a combining term or "and" functions as a contrastive term, since technology is a technique that is constantly in progress and under conditions and that cannot stand up to any art due to constant change (software upgrades, compatibility issues).

Our position in favour of the combination of art and technology is based at the stake of interdisciplinarity, the subsequent enrichment of the sciences and the cooperation. First of all, it is occasioned by the indisputable fact that there has been a change and update in general of the ways how people communicate (Crockett & Churches, 2017) and the mechanisms of meaning investment, as well as a change in the means of production of a project. These are not merely organizational issues but strengthen the very combination of art and technology. The way of perception, conceptualization and experience has changed.

The complex art and technology binary creates a framework that enables the ability to receive knowledge, skills and attitudes during the learning process. We have learning taking place with an emphasis on multiple intelligences, challenging the inflexibility of previous programmes and educational material. It also functions as a complex circuit. It emphasizes the processes of concentrating on the management of information, the human-machine interface, data structures and the possibility of creating algorithms and with learning analytics (Vuorikari & Muñoz, 2016). We ensure not only space for experimentations and communication between students, by virtue of the creative processes, but also an understanding of the difficulties or the weaker link in the succession of synapses and results output. Students take ownership of the new knowledge in the best possible way and become participants in the evolution and development in economic, social and cultural sectors. This means they do not become accustomed at being solely consumers or to consume only as a substitute for action. The goal is to develop a prosumer culture. Students, as prosumers, can share, reuse, remix content and humanize their environments. Ritzer states that while prosumers have a greater ability than consumers to humanize their environments, there are a great number of difficulties which discourage con−/prosumer even on the Internet (Ritzer, 2016).

Students have the experience of dealing with many sites or Internet-based phenomena (such as Linux, Firefox, Wikipedia) that are totally constructed by prosumers. These experiences are likely to motivate to become prosumers. Additionally, the mission of art didactics is to install visual thinking, cultivate digital skills and help students to create. The digital image gains an executive function. The modifying combination, which is created by the convergence of versatile instruments, renders meaningless distinctions such as visual art or text. An indeterminate process from the beginning means that no interpretation is anticipated by the viewer. This undefined nature of the interactions also affects the process. Citing the contemporary video artist Bill Viola, Agamben focuses on the modern connection between time and moving image's ability to bring things to life (Agamben, 2013). Time advocates, as it defines what precedes and what follows, act as a parameter of hierarchization of events and situations and are inherent parameters in the aesthetics of digital virtual environments. Students explore and observe works of artists who have deployed cinematic techniques to stretch rather than structure time (Saltzman, 2015).

Students explore the content of the digital image/artwork (subject, objects, figures and other elements present). The digitalization of images transforms the visual arts into performing arts. Students study cultural, stylistic choices. The creation of digital objects aims at the acquisition by students of graphical skills (Yavgildina, Mishina, & Mishina, 2017). Perhaps there are interventions on modifying technological parameters (change of colour, scale, soundtrack or any intervention/variation is possible and proposed). Turning points are detected or a scaling that can be classified as zero, i.e. a clear and unified structure from which the classification in primary and secondary elements is absent. Students persist in non-stereotypical representation narratives (in what manner and by what medium). The use of empirical research (reading or decoding images almost instantly, giving little thought to any process of decoding), more in-depth research, producers' intended meanings (Schmidt & Cohen, 2014), reading images as ideological analyses, giving value of images (social, political, even monetary), encoding and decoding, appropriation and oppositional readings, reappropriations and counter-bricolage (Sturken & Cartwright, 2001), all contribute and are used to develop the scientific, visual thinking of students (Peachey, 2016) about concepts that are related to their educational, social, cultural and material environment.

Today, the successful structure of educational programmes lies on the adoption of a new way of viewing the world by adopting in advance the cause of wider changes and initiatives, as well as ways of effective intervention and action (Crockett & Churches, 2016). The biggest challenge is to put an end to the reproduction of perceptions, attitudes, expected ways of perception and understanding and the reception of things with a new look.

The contribution of art and technology to the construction of an educational system, aimed at the active, cooperative and meaning-invested application of knowledge, lies in the fact that it offers the potential to find a possible solution to any dysfunctions that might exist. This is because:

- New paths are proposed and enriched, and new associations are created (wide range of action and easier associations based on attributes and characteristics).
- Ideas are drawn from a wide range of themes. One feeds the other; there is interdisciplinarity, and the application of cross-curricular ideas, without specific fields being credited with main ideas and concepts.
- Students practise with a fresh look rather than in standardized ways of perception, involving concepts of applying meaning, identity shaping and learning strategies. These, will take place by applying the methodologies of constructivism, problem-solving, learning by doing, the interactive learning through feedback loops, quality data (esoteric knowledge) and quantitative data. In this way, it is possible to use the knowledge and skills of the students and most importantly,
- This contributes to all sides involved in learning process to understand how the needs (needs are not recorded by specific institutions/authorities) will be defined and in such a way they lead to a new set of circumstances. It has to be a process of democratization with a multiplication of contact points through the means provided by technology.

2 Reculturing Danger or Awakening?

Before the twentieth century, the term "participatory culture" did not exist, as it would be considered a tautology. The essence of modernism lies in the construction of a cultural and philosophical space that is simultaneously human and rational (Firat & Venkatesh, 1995).

Above all there was the human presence, the participation in the observance of traditions and a circularity of events repeated; this circularity extended to the community. People participated in local gatherings, events and performances, and a large part of culture was participatory.

Today we are in a constant search for the future social and cultural model. The echo of the older cultural model appears with the help of technology, and the concern about the next stage of development of technological advances is part of everyday life. The transformative power of technology brings philosophical, aesthetic and epistemological consequences in the field of the arts and culture (Falk & Dierking, 2013). Different ways of capturing new experiences, learners' experiences holistically across the many technologies, for example AR, new learning experiences (EduGlasses.com), and also in cultural heritage subjects learning process through creative technology is given as a new experience as well as an artistic choice (Crawford & Kane, 2018).

Culture in its various forms (Renfrew, 2009) cannot be isolated from everyday educational practice, but must be part of the learning process, as the reflective mood is strengthened (Mega, 2011) and personality develops holistically. The attitude towards teaching issues of culture (Peachey, 2015) and searching for the future social and cultural model with the transformative power of technology shows common elements to those that characterize a learning-beneficial behaviour, i.e. freedom of movement and expression, and also appropriately organized activity that aligns and involves smoothly the members of the team in their quests, and this fermentation brings about a strengthening of the team, and interaction with different options offers different levels of information according to one's interest, suggestions, correlations (Burawoy, 2010), possible changes and new avenues.

Exposure to computational, cooperative and virtual environments which are mediated by computational technology is an integral part of the learning experience of the twenty-first century (Means, Toyama, Murphy, Bakia, & Jones, 2010; Peachey, 2017). However, at the same time, it raises a series of questions about how to integrate this exposure effectively into the educational process and the learning benefit it brings.

The fact that the increasing diffusion of technology has not changed the field of education as might have been expected, and although on the one hand technology is being treated as a valuable educational tool and yet learning outcomes are not encouraging, triggered at the beginning of the twenty-first-century studies (Salomon, 2002; Collins & Halverson, 2009). These decoding, appropriation and oppositional of expectations and that ultimately the belief that computational technology in education unconditionally benefits the learning process is unfounded.

The behavioural intent of art teachers using technology influences the improvement of learning outcomes. The openness in the experience on the part of the educators – as a strong predictive factor of their effectiveness in school and with many powerful benefits in their future professional path – also drives students by influencing their learning and their performance.

The openness of art teachers is due to the nature of their work and to the study of artists/artworks – art is like a "cut", and it shakes us out of our habitual modes of being and puts other conditions into play (O' Sullivan, 2006, p. 125) – and derives from the act of viewing (one can briefly mention JMW Turner: his emblematic oil painting, *Rain*, *Steam and Speed – The Great Western Railway*, 1844, raised the subject of compression of time and space). On this subject, Edgar Allan Poe (1848/2010) in *Eureka* states that "Space and Duration are one" (Poe, 2010, p. 118). Thus, art teachers learn new perceptual behaviours, signifying that the act of viewing is an act of thinking (Berger, 2017).

Art can induce changes in visual or perceptual experience. Art teachers involve students in educational activities which exploit possible transformations and, by undermining perception and experience codes, strengthen the critical character of the participants. All this is in line with the basic pedagogical principles of artistic education courses and the particular "marriage" that applies to art educators. They function as both pedagogues and artists, i.e. scholars which participate in the social process – omnipresent art (Rosen, 2011) in a worldwide consensus over fundamental principles and rights – and are concerned about the foreseeable future and contribute to this future that is changing. On the one hand, their studies with all the views of researchers attempt to posit universal rules for reactions and link with biological or neurological connections (the first attempts were made by Vitz (1988), Zeki (2000) and more recently by Huston, Nadal, Mora, Agnati, and Cela-Conde (2015) and Starr (2013)) and on the other hand, through artworks and their contact with the "augmented" information, the complex interconnection of events and the emotional and psychological reactions, art teachers welcome new ways and don't use nor they are enthusiasitc over possibilities of technology, but live with technology. They understand the importance of using new technologies in teaching and creation and look ahead to avoid problems such as the lack of digital skills.

Technology provides the possibility to organize educational resources. It modifies all the processes of how one acquires knowledge and how it is used. Technology changes the way knowledge is disseminated; it provides the ability to intervene, comment and broadcast experiences in relation to new knowledge, by way of applying metacognitive skills and strategies, for example, with wikis the user has the ability to add, modify and decline content. However, this advantage constitutes at the same time a major obstacle if the framework and the aims of the activity within the school have not been adequately set, with corresponding preparation and appropriate recasting of the pedagogical framework (Boyd & Cutcher, 2015), and are not effectively communicated to the participants.

Technology is not just the material means (computers, laptops, tablets/iPads, smartphones, interactive whiteboards and similar devices) but also the systematic approach whose aim is to improve human learning. The terms "technology", "educational technology", "new technologies" and "new media" are interrelated. More specifically, the term ICT refers to blogs, wikis, podcasts, vlogs and other Internet tools that facilitate cooperation and convert the classroom into a space mainly for questions, and concerns can be placed. In the same vein, it is recommended that one uses social networking tools (Facebook, Twitter, LinkedIn), cooperative tools (Google Docs, Padlet, Linoit, Canvanizer, Wikis), content-sharing tools (YouTube, Slideshare, Instagram, Viber, blogs), learning management systems (the Moodle platform, Edmodo and similar ones operating on locally developed platforms and used in specific countries) and social search tools (Delicious and

Digg are the first that come to mind, though of course there are many more) in the classroom. The tools mentioned are of course indicative only, since the existing range changes daily as new tools are launched, old ones close or are updated under new conditions (payment-only usually) and popularity rises or wanes. Reference to the new tools in education means, in essence, the correct use of the new tools. It primarily presupposes investigating factors that are related to the support of views and reasons for choosing to project-specific material and content on the platforms where this content is published and circulated and to the new reality that these convergence conditions are created. A risk can be identified that students are subject to a control regime proposing various supposedly primary issues (such as the economic benefit that indeed has a weight, but it is not true that it is a primary issue).

The way of incorporating these technologies into educational practice that maximizes learning benefits means:

- Focus on user environments (cyberspace is more real than everyday life, video games are more exciting and fascinating than everyday school activities and through a self-assessment and reflective process, objectives are being set and pursued. And the main objective being for students to realize that anyone who spends time and effort can have a richer entertainment experience)
- Multiple ways of approaching the process, which is open and cross-thematic approaches (the connections between different components contribute and expand the meaning, and also experiencing the other media forms, such as cinema, video games, comics, interactive graphic novels, etc., will improve the experience as a whole)
- Open and emerging processes (Avi Rosen argues: …*cyberspace can be comprehended as a container of Platonic ideas that symbolizes the Platonic triangles and tables that emerge from the mathematical algorithms, the data can be manipulated, altered and copied by the demiurge surfer*) (Rosen, 2011, p. 597)
- Multiple responses, coordination of actions (one knows whom to ask, students can contact the creators, and so they can understand their actions/works and thus produce a framework for their own actions/works), unconventional aspects and threaded discussions, suggestions or implications of other things

3 Vertigo or Selectivity?

The type of major issues with which education is confronted is also the real field of arts. It is the aim of tomorrow's citizens to have universal participation, primarily with a sense of responsibility; with a degree of autonomy, within a state governed by the rule of law; and with a common commitment.

The action and reaction that the contemporary individual attempts to articulate while addressing society's problematic nature are by necessity self-evident consequences of the formation of a consciousness within the institutional and personal conditions in the field of education and the formation of their thinking on issues touching upon the areas of culture and civilization. Political, economic and social changes are also important considerations in the specific circumstances at hand, but not necessarily with self-evident consequences.

The choice of a generalized, simplistic and in the worst case inhuman, violent and barbaric way of dealing with all sorts of reality means that the process of finding solutions, methods and means to deal with reality is full of manipulations and distortions, without a trace of creativity produced at the level of thought and awakening it. There can be no devaluation of the existing situation, while there has been no critical assessment and indication of the need for new proposals and new learning paths in relation to the problems identified or that are to come.

Therefore, having students learn how to find the right information from valid sources and the mere transfer of knowledge in a behaviouristic-based logic are not enough. The aim is to attach meaning to the presence of students at school, away from the "provable", the given fact/datum, that which completely coincides with the students' current repertoire of action, which has been in place for years. We have to pay close attention to their needs and their own truths.

Science and art both begin where knowledge ends (Kemp, 2006). New media have formed a digital environment for creating educational activities where users participate (in different ages, experiences, possibilities, creating an astonishing surplus of knowledge); take initiative; develop collaborative work applications on the Internet (cloud computing); utilize the World Wide Web to create collaborative, digital and artistic programmes; focus on the artistic work; develop artistic skills; and entertain themselves (adults usually use technology for information and communication, while young people have fun and meet people with common interests where they find a place of common reference). Users/students belong to specific communities (Glas, 2012) and express themselves freely through democratic processes and common goals. Consequently, unpredictable results (and this is what is interesting) are produced. Transfer of knowledge and skills in new contexts takes place and this is extremely interesting.

One does not overlook of course that a number of problems arise: the risk of the allure of surfing; the continuous information flow which minimizes the time for thought and reflection (Kemp, 2014); the wealth of messages and the heterogeneity which is either cognitive or aesthetic, thematic and methodological. It is not possible to create a coherent sight, since a useful structure for the acquisition of knowledge and understanding is not provided.

The role of education is to help students learn to use the new media without distortions (mistaken learning) and misunderstandings (resistance to learning due to a simplistic and dangerous finding that typing the question automatically leads to the response on the screen).

Additionally, a particular attention should be paid to the fact that digital networks strengthen and potentially weaken everyday expressive action. One cannot consider as freedom of action the continuous interconnectivity and the exchange of meaningless messages, that is to say, for it to be degraded or to be spent in wishes, wordplays, constant exposure and collapse of the boundaries between the private and public spaces, with the sole concern being attracting admirers/followers as proof of recognition and personal worth.

It is equally significant to point out that the uncritical involvement in and engagement with particular tendencies, with the sole criterion being to attract massive numbers of users, is interpreted as the adoption of herd behaviour.

The usage and transmission of multimedia content through systematic processing and collaborative learning involve students in the cognitive/learning function. Instrumental learning focuses on problem-solving and deals with emergent behaviours (Maurissens, 2017) and action. Communicative learning is based on dialogue, finding analogies and engaging in case studying but mainly on the meaning of the shared experience. Those were the two types of learning that will lead to the third form of learning, emancipatory learning (Biesta, 2017).

Freedom of action is inextricably linked with the ability to make decisions, taking personal responsibility for one's choices. Freedom of action is constantly struggling with necessity. The quintessence of teaching is that publicity, projection, should not be more important than the essence of content and the elimination of ambiguity in the projected data, whether on the Internet or in globalized paradigms and cultural centres.

The artist combines the new with the old and the traditional with the sophisticated, making use of the new media, even if what will come out is a strange merging of "real" and "ideal". They function through their work as a barrier, protecting the user from any "short circuit" and finding ways to change the course run and most importantly find values and create constants. Therefore, an artist has to choose the media interface that suits their aesthetic quests, transforming digital data into a state that will be perceived (aspects of vision can be uniquely powerful) and presented with a particular artistic manipulation; this is the attitude to the way things are taught which are encoded in a digital database. Selectivity becomes absolutely regulatory.

4 Paradigm Change in Education

4.1 Art and Education: General Principles

The process of approaching knowledge in the field of education should be of the same logic and structure as in the field of art, that is, without attempting to guide, heterogeneities and the value of use being replaced by the exchange value. The aim is to ensure pupils' participation in an education that defends a multitude of solid virtues, a world in constant movement (Malabou, 2008).

Teaching art means that we are moving away from any cumulative logic, avoiding conflicts – contrasts and bipolar combinations (e.g. realistic and nonrealistic, part and whole, ugliness and beauty).

Two different methods of study have been made for aesthetics: the philosophical approach and the empirical approach. From the dominant structures of culture, there are also some interesting suggestions, such as the intuitive approach on the part of hermeneutics and the experiential conception of meaning on the part of phenomenology.

In the field of art, the aesthetic – moral reservation against the closure of meaning – finds a fertile soil, contributing to the dispersion of experiences and interpretations. Meanings are polysemous. Efforts are being made to bring about changes in the pressures of various social systems. The aim is to redefine what to be human is over themes, views and perceptions and to comprehend if norms are supported and if issues of integration and repetition are being raised.

It is extremely interesting how something can be defined as unique and how it is currently associated with database management systems. The value of uniqueness is demonstrated in many forms of consolidation through the artistic modes of expression. The aim is to capture the basic components of a creation that whatever changes means it enforces its transformation into something different or weakens it. Decontamination processes from anything superfluous are encouraged (concurrent power).

The evolution of art has been marked by the concept of experimentation. Already at the beginning of the twentieth century, the efforts of Pablo Picasso and Georges Braque of the Cubism movement expanded the canvas beyond the painting, involving daily materials in their works, such as textiles and newspaper clippings. They contributed to the distortion of the conventional use of perspective in painting up to their time. Braque was thinking of a more "tangible" space, and the unification of this space with the visual one is apparent in the still nature of his works. Picasso turned his interest in the fourth dimension, that is, the simultaneous representation of objects from different facets. For artists, the combination of intellectual understanding and technological training is the desired goal.

In the early twentieth century, the creative thinking of artists, such as Klee, Picasso and Itten, and also scientists, such as Einstein, resolved artistic problems with technical proficiency and insight. Later artists with the unusual way of conceiving and creating their artistic work, photographic works by Bernd & Hilla Becher, Jeff Wall and other, artists capturing an image from a video source (video camera or replay device) using digitization software, contemporary works that modify existing-appropriated material (such as Andreas Gursky) and artists such as Richard Prince who reframed the images (Prince et al., 2003), all the above demonstrate that the visual mental representations of the artists are a cornerstone in the construction of multimedia new forms of Art.

Artists with their works advocate cognition and feeling and they create conditions in a manner that is discerning and extremely constructive. It is very interesting to study specific projects based on the mechanisms of attention by using modern applications of digital editing. Technological development not only determines the "eye", that is the intellectual involvement of the artist, but also affects the very ontological state of the artwork, opening up new horizons towards the "constructional" perspective of modern society.

Art with drastic interventions on events and their internal structures, without necessarily the linguistically mediating interaction, but sometimes the undermining of linguistic structures and even visual structures (especially the audiovisual expression of show business), calls into question well-established positions and principles, highlighting unstable, incompatible meanings. Works of art are not meant to explain but to think with them. This is accomplished by extracting elements from pre-existing frameworks (Johnson, 2015), incorporating them into a new set of things and triggering new positions and new perspectives. A practice is being launched that is capable of generating meanings that have not yet been expressed, or the renegotiation of hierarchies, meanings and positions is achieved.

The particular point of view through which art teaching in schools demonstrates artistic practices is by emphasizing the way that these practices are understood as socially (Papastergiadis, 2010) and politically significant and how art influences the manner of understanding issues of different scientific fields (visual culture, social and political studies, to name a few).

It is extremely interesting to compare the image of the future from Fritz Lang's Metropolis (1926) cinematographic work and the works of artists Cica Ghost and Eupalinos Ugajin as to how we can imagine the future. Artists seek to impart their works with similar conceptual qualities, managing pioneering, groundbreaking themes and bringing them to the public's consciousness in a new way. The function of art as a conceptual "intruder" gives the keys to unlock the treasure chest of information around themes that are primarily of interest to students.

By the same logic, by taking students out of a prolonged exposure to the same symbols and similar narratives, it may be suggested that they find out how these are used in cinema, video games and comics as symbols of technological avant-garde that are concerning either space or ultra-modern metropoles and study the corresponding design directions (signifiers –signified pairs, projection of individual components, complexity). Representations, such as complex modular space stations which can be associated with crane images underlining the perpetual modification and development of a megacity, large number of transparent surfaces, act as significant elements for the technological avant-garde that advocate the release from the structural static models. The adoption of a strange, unfamiliar shape, the capabiilities of the superweapons, the choice of materials, the analysis of the shell and material in pair, the merge of organic and mechanical elements, the use of curves and volumes as a repetitive pattern, like the meaning of the drop construction, lead to conclusions such as the use of individual repeated elements that refer to popular molecular models and demonstrate the lack of human scale sense.

Knowledge, understanding, application and consequently the transformation of knowledge presuppose interaction, active participation, selection, filtering, classification, evaluation, exchange, creation and re-creation. Truth is not realized individually but collectively (systems as structures) and holistically.

This means that openness and plurality are supported with multiple images and sounds at the same time using pedagogical practices that wish to change the world, to contribute by making the difference with e-portfolios, personal recording studios (GarageBand), drawing pad, computerized kilns and similar applications.

On the one hand, the technological knowledge of representational practices that highlight data (social networks, video-sharing sites, multimedia devices, smart phones) and the exciting techniques of imaging practices (MIT Scratch, Processing, Max/MSP, Unity3D, Unreal Engine or other) and, on the other hand, the comprehension of the data that composes the modern situation. Emphasis is given not only on the useful and applied objectives but also on the importance of the research of the unknown or even the unthinkable. In order to achieve the second goal, artistic expression, artistic creation is extremely useful and directly correlated with the field of education, i.e. arts and technology, art teaching and creative technologies in school.

The criteria of creative processing are studied: originality, appropriateness (or that something is not just correct but completed or satisfactory), a feeling of satisfaction, irritability (a change in the usual and conventional), density (difference between condensation and chaotic complexities), poeticity (a combination of elements of simplicity and complexity), sensitivity and flexibility.

5 Teaching of Art in the Digital Age: Reforming the Goals

Schools have to invest in the future, and especially lessons related to the history of art help to achieve this properly: students learn about the past by studying artworks over the years to live and create in the future. This engagement goes beyond the actual artistic developments of themselves and a functional classification in terms of movements. They deal with the peculiarities, the presentation of the major morphological innovations over the years. The availability of technology can help the study of the pastiche that relates to collages of past trends and the ironic, self-reported, paradoxical mix of existing codes such as architectural, artistic, cinematographic, literary, musical and others. The use of new technologies and the data of a digital culture helps to understand the integration either through the introduction of parody products (e.g. Parody Products iDrink Cell Phone Flask, 4.5 oz) or music bands such as the attribution of much of the work of the well-known heavy-metal band Metallica by four cellos from the Finnish band Apocalyptica.

The theory and analyses of cultural trends are in line with the ability for students to experiment with materials by implementing these that are supported and then taking a “step back” to see in their totality the needs of every era, the culture and artworks that correspond. Students should be able to read and understand the cultures of every day, even if they are to demonstrate their worthlessness.

In the attempt to form a historical retrospection, cultures could be studied according to technological changes (machine, photographs, videos, digital culture and other inventions). Old creation techniques are not abolished, but remain, and this co-existence forms a notable relationship. Today, every view with artworks based on the computer comes into a different relationship with time, since the computer gives birth to and extends artistic action.

The creation of websites by teachers providing short tutorials on concepts of art, techniques and works of various eras is particularly useful. Compared to traditional teaching methods, this approach is a differentiating factor for acquiring specific knowledge: this knowledge includes a visual alphabet and the use of new technologies as a means of developing children’s creative features (Maslyk, 2016), but the most interesting thing is that exactly because students carry smart devices and they can benefit from various relevant information (Zhu, Yu, & Riezebos, 2016), they will have also access to the teacher's website and accept more insightful information. Additionally, they can read the critique of their teacher, and they can upload their observations and their thoughts. This material can be used in the classroom.

Based on this material, the art teacher can extend the lesson and work with students' answers. Researchers believe that through the involvement with art, individuals can gather richer details about the participants (Leavy, 2015) in relation to interviews, or any questionnaires, exactly because there is not the fear of the wrong answer nor any pioneering perception about art will cause bitter comments. This unlocks students so they don't get bogged down by in analyses, they think innovatively.

Art can communicate an idea to a larger audience and more easily in contrast to the written code. With regard to the ability to arrange and organize in the younger age, emphasis should be placed on how to teach motifs – the patterning – in relation to the following variables: dimension, orientation, number of items skipped and position of the missing item (Gadzichowski, 2012). The organized succession of events in the various forms of art – the interdisciplinary approach of motifs – with the help of software (Scratch, Snap) contributes to the multifaceted understanding and more generally to the abstract cognitive ability.

For older students who are convinced of the need for communication (Van Dijck, 2013) and use networks (like Facebook, WhatsApp, Skype, Viber, Messenger, Twitter, YouTube, Instagram, Wikis, to name a few), understanding is also facilitated (since a friendly tone is prevalent, due to the use of their own code and not the use of the "official" language of the school) and mutual co-operation. These conditions favour the social dimension of creativity, according to which creative ideas are not the products of a single individual, but products of collaborative creativity.

The knowledge and understanding that arise through the conception of the ways of connecting things and connecting with our inner world, the focus on other individuals, the understanding and conception of their reality and, finally the focus on the outside world and the understanding of the interdependence of systems in the wider environment (Goleman & Senge, 2014) are processes that are extremely interesting for young people, because nothing can be exhaustively predicted. The systemic approach involves no didacticism intention. The act of learning is a natural process, and the contribution of art is the answer to the dilemma of a free or more structured educational methodology.

The goal is to exploit various modes of expression: the image, the body, the body posture, gestures, photography, persona, sound environments, sound effects, sound constructions and sequences. On a practical level, students familiarize themselves with audiovisual synchronization techniques.

Students must have the knowledge and skills to use basic vocabularies, materials, tools and techniques in every field of the arts. They should be able to communicate at a basic level in the various arts fields: visual arts, music, dance and theatre. Dialogues between works of art, which are indicative of aesthetic "pluralism", create a fertile field of inspiration and creation.

Therefore, students are not only prepared to communicate with the work of art but also as creators, with imagination, confronting challenges and assumptions, changing factors and variables, continuously asking, what if?, and acting in the space of school they are involved in:

- Collective visual practices (creating a site in opposition to high traffic sites, which often recycle identical image compositions, that is, an assembly of similar presentations that create a multiplying effect serving specific purposes)
- Interactive installations (students' participation and the public thus addressed can receive instant feedback – ranging from emoji to detailed critique – and get fast reviews/comments/responses for the outcome of their own research work)
- Technical/organizational issues of realizing the ideas, exploiting different skills and talents, respecting different learning styles, emphasizing the relationship between time and achieving a goal

6 Art and Creative Technologies: Transform Education

Peppler, discussing the role of Artistic education in the digital age, notes that it includes active participation, a personal link to work that will inspire learning and the development of an art that benefits the community (Peppler, 2010).

A number of methods are suggested and presented for art didactics to explore. These are the behavioural approach (exercise and practice), the cognitive approach (exploratory learning), discovery methods, constructivism (experiential learning), cooperative learning, working in small groups, differentiated pedagogy, learning by doing, emphasis on self-action and autonomy and cross-thematic approaches to knowledge and projects, always with the valuable use of ICT in the educational process.

Collections of images, photographs, quizzes, puzzles, crosswords, timelines, conceptual maps, interactive images, websites, virtual tours, event-based presentations, awareness and practice exercises, online games, open activities, editing and production of audiovisual and textual cultural material and simulation games are treated as research, playful processes, to which students pay attention, discover, remember and act with dexterity and precision. They are also clearly involved in processes that have less measurable indicators, such as a sense of pleasure, bliss, tranquillity, balance, fullness and confront the unpleasant feeilings such as unfamiliarity, discomfort, denial and rejection.

The goal is also a self-directed activity. When studying works of art, students follow a schematic separation based on material criteria and based on styles and combination of forms, landscapes, colours and designs. Artists know that their good fortune, both in materials and skills, must be shared. With the use of various visual arts (Gombrich, to make painting more uncertain used a frosted glass (Kemp, 2014)), there are now various image manipulation programmes (Photoshop, matte painting). These focus on the interpretation of light, tonic gradients and games of light and shadow, in the study of the line, geometricity, symmetry and rhythm. Students develop artistic skills through the study of compositions and elements in relation to the actual paintings. Using photo techniques, morphing software, they smoothly transform one image into another, add motion effects and ask what exactly this metamorphosis seeks and what does it aims at. Modern artists such as Richard Pettibone are studied: they are attempting to reproduce a small scale of famous works of modern art, and it is a matter of exploration if it means something new is being done or a reconstruction of the old one is being attempted.

Students with digital photos and video cameras edit the material using a three-dimensional design software and communicate in an audiovisual way images and stories, invoking emotion. This invocation will probably lead (and we would hope that this is the case) to personalization and end in seduction. Students identify/understand ways and choices (mainly advertising options), which require the elimination of meaning and the separation of the appearance from thought. It is beneficial for them to learn also through the body: the audiovisual experience supplemented by the kinaesthetic perception; practise the "muscular senses" in the orientation within space. Through VR/AR, semi-immersive/projected virtual reality or fully immersive virtual reality, where only the virtual environment exists and all the moves take place within it and the user draws audiovisual stimuli from it, they acquire a different relation with the environment, a very individual one. These types of environments are extremely attractive for students, but at a high economical cost for the average school.

Technology is understood as an experience (*constructive processes are the glue of experience*, Ali-Azzawi, 2013, p. 25). It comprises four interrelated threads of the user experience (compositional, emotional, sensual, spatiotemporal) and six sense-interpreting processes (interpreting, reflecting, appropriating, recounting, anticipating, connecting). In addition, engagement is considered, whether all of our five senses are taken advantage of, aesthetic judgement and presence. One evaluates the user's experience goals and then how these are fulfilled and satisfied during interaction.

It is noted that the art and technology sectors, especially the social interactive design (Treske, 2013, 2015), influence and complement each other. Technology works by going from object to meta-object, interface and ultimately towards the integration of the audience with the situation. Emphasis is placed on the actions, and this can mean that the viewer participates either by typing or by using special devices, e.g. headphones or ambient approaches such as cameras, touch sensors, floor pads and infrared rays.

In interactive artistic depictions, students draw conclusions, such as if the depictions are abstract, aniconic, if a bridge between the natural and virtual worlds is created. They understand that the relationship of the environment in which an installation is placed with the ways in which the user/viewer actively "connects" the features of the installation with the action within the environment is interrelated. The dimensions of the space, any movement and connection of the movement to the space (taking into account the direction, speed, time variables) and the change in temperature, sound and light, are the changes brought in the work of art. Students understand the importance of the circumstances and the power of environmental factors. Understanding the relationship that a user develops in an interactive setting is completely different from the experience of traditional painting or sculpture (this also answers many adolescents' complaints that you cannot have fun while visiting a gallery or museum; indicatively we mention the Hacktile Interactive Animation Installation (2015) by Tess Martin and The Treachery of Sanctuary (2012) by Chris Milk).

The multiplicity of choices within a technologically enriched learning environment increases the student's ability to function according to the environment in which they are located. Space, time and subject cease to be exclusive factors of perception.

The n-dimensional space (already from Los Angeles' ACM Siggraph (2009), where three-dimensional models of Roman monuments were displayed on the floor via super-portable computers) shows that we are now talking about an extended artistic field.

7 Conclusions

The future outline of the role of education is indissolubly linked to digital technology. The new culture emerging from the development of digital technology diffuses throughout the landscape of social life. It affects the ways of attributing meaning to reality, as well as the ways of transmitting information, the ideas of creativity, uniqueness and expressiveness.

Modern man is experiencing a cultural dilemma: while fearing technology, we rush to digitize monuments and cultural works in general. It is precisely because the monument is a spiritual and material creation that enshrines the testimony of the existence of individual and collective activity of humanity. The monument is transformed into a space of collective memory signifier and signified, where the material body and its state of preservation are signifiers, while its complex cultural, scientific, artistic, symbolic, ideological and experiential content is the signified. The monument is an estate common to humanity, but it is always the creation of a particular society, culture, religion and historical period that is proof of their cultural authenticity. Anthropologist William Mazzarella observed that a cynicism about the social functions of media is accompanied by a romantic search for authenticity (Mazzarella, 2004). However, mediation is the most basic cultural process.

For these reasons schools feel the need to have their CDs or DVDs in the library with cultural monuments, works of art, but it is now considered an outdated way of presentation. Teachers can create a bookmark archive of sites for regular use in the classroom (museums, galleries, artists' sites) and tours (Google Earth, Google Street view, Google Panoramas) in archaeological sites and cultural monuments. Students can create stories that link different points, buildings, monuments to cities and archaeological sites using augmented reality applications. Besides, the interest is always focused on the stories, and the participation of the students is decisive. In any learning function, documentation is best structured with play and fun.

Art didactics and creative technologies do not set unrealistic goals, taking into account the necessary correlations, pupils' needs, and at the same time, they succeed in surprising and provoking, but finally supporting students by ensuring:

- The interaction of students with the environment
- Their preparation for constant and unpredictable changes focus on the problems solving procedures (problem capture capacity, information/data collection, problem analysis) and
- The ability to express themselves, incubate, develop, communicate and implement ideas.

The analysis of modes of aesthetics, conceptual processing and synthesis in a single polymorphic set aims at assessing the modes of expression and inspiring students to act. There are no unchanging principles in art and there is no stopping in technological development. So, the need for a radical transformation of the manner of education is a fact.

Art and technology means space with imagination, time with imagination, imagination with reality and creation, play of memories, play of associations and imagination with the senses, with the body, for the sake of an ever-higher aesthetic effect.

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Toward a Smart Pedagogy: Devising a Methodology for Innovation

Alvino Moser and Luciano F. de Medeiros

Abstract A plethora of practical suggestions could be considered to make pedagogy smarter, more active, and attractive to students while simultaneously being efficient and obtaining results. Creative suggestions are not always innovative. In order to achieve innovation, an interesting method is proposed by Jean-Charles Cailliez and described here, consisting of four main steps: (i) following the path indicated by Boethius and Thomas Aquinas in the Middle Ages to acquire a *mens ingeniosa*, a kind of creative imagination resulting in *inspiration*, properly obtained from a few conditions and possibilities, restricted by appropriate observations, and underpinned by correct prospections; (ii) insight and enlightenment for the *ideation* of creativity will be greatly facilitated by co-design within a team; (iii) after the ideation, generated by inspiration, then comes the time for *implementation*, that is, creating prototypes of projects in an interactive manner and generating pedagogical actions capable of being tested by experimentation; and (iv) *innovation*, when the idea materializes itself and may be carried out and be useful. Nevertheless, innovation requires steps of its own, such as incubation, creation of a pilot project, testing, acquiring value, and devising possible uses. For any hypothetical use of an idea, creativity indicates when, how, and in which contexts we should use it. Next, we must design an experiment in order to know how efficient of a pedagogical strategy it is and, eventually, have such resource available for specific, didactic goals. Pedagogy should not be centered only on unique and exclusive resources, but ensure an articulated relationship with other resources. A final discussion is proposed considering whether a smart pedagogy will require smart technologies, with some indications about the importance of the role of advanced technologies, such as artificial intelligence, in such innovation scenarios.

Keywords Philosophy of education · Innovative methodologies · Smart pedagogy · Flipped classroom · DIY workers

A. Moser · L. F. de Medeiros (✉)
Program of Master in Education and New Technologies,
UNINTER International Universitary Center, Paraná, Brasil
e-mail: alvino.m@uninter.com; luciano.me@uninter.com

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1 Introduction

Faced with a series of profound changes at the turn of the millennium, particularly regarding technology and its advances, the twenty-first-century teacher is already aware of the necessity to develop a different look at how students learn. Today, there is a kind of renaissance, a phenomenon of openness in relation to the ways of thinking education, based on the premise of an active student, aware of his abilities and limitations and responsible for his learning process. Such Copernican revolution in education displaces the center of gravity from the teacher, who takes on a role of guiding the student's journey toward knowledge.

In educational settings, whether in a brick-and-mortar school or in a virtual environment, the teacher plays an important role, in which he not only teaches but offers the students a series of resources that provide the opportunity to learn according to their own style and on their own time. In this scenario, interactions are potentiated and are also "potentiators" of a more effective process. Distances are shortened so that both teacher and student, as well as student and student, interact in the social construction of meaningful and useful knowledge in the new century.

Within the group of different practices developed from the perspective of active student participation, with the use of different resources and the new role of the teacher, a path opens to devise methodologies that can distill the essence present in such experiments and serve as a beacon for proposals where the exploration of creativity, interaction, and innovation has a relevant place in the planning of educational actions. These may include a range of methodologies and technologies, from inverted classrooms to MOOCs, adaptive learning, virtual and augmented reality, environments enriched with artificial intelligence (AI), and other methodologies classified as active.

The methodology explored here (Cailliez, 2017) contemplates four phases for a smart pedagogy: inspiration, ideation, implementation, and innovation. The article will detail the discussion of each of the phases, without losing the systemic perspective regarding its interfaces, in a spectrum that will include from philosophical aspects to experimentations and results, along with considerations regarding technology.

2 *Mens Ingeniosa*: The Inspiration

Is it possible to conceive, in a smart pedagogy method, something as fluid as inspiration? In Ancient Greece, Platonic philosophy attributed the inspiration of men, in the eloquence of their speeches, to the influence of the Muses. In Plato's "Phaedrus," Socrates explains that the Muses were able to lead men to a kind of delirium, which would transport them to a new world, where they would produce odes and poems capable of elevating the human soul and bringing it closer to perfection (Plato, 2011).

This statement concerning delusion is interesting, as it can be interpreted as a different way of thinking, which frees man from intellectualism and rationalization and launches the mental exploration of new possibilities, opening the way for insights into the genesis of new ideas. Thus inspiration, both to ancient philosophers and those who believe in sacred books, was a gift from the gods. The Muses, in Greek mythology, were the entities to which inspiration was attributed in artistic and scientific creation.

In Greek ancient times, people watched leaves and branches float on water, but it was Archimedes who, with his celebrated "Eureka," discovered the principle of buoyancy that allowed the construction of more sophisticated boats than those based on primitive canoes and rafts. Before that, inspiration came from wondering why bodies did not sink in water. In other words, inspiration came from looking at phenomena under different perspectives. Therefore, the principle of buoyancy of bodies based on the concept of thrust inspires, in the late eighteenth and early nineteenth centuries, the "discovery" of the propeller plane.

The word "discover" comes from the Latin *dis cooperire*, meaning "to see what is under the veil, hidden, that which requires new observations from different angles." The same is true of literary works, such as poetry. Although *poeisis* is a creation in Greek, it is nonetheless "discovery," "invention." The Newtonian principle of action and reaction already allowed the construction of jet aircrafts, but that was only possible with the articulation of further discoveries, just as the steam boiler was invented when James Watt had the "insight," the inspiration to observe what happens when water boils in the kettle when making tea or cooking. However, in order to be used as the locomotive or steam engine, other discoveries were necessary.

With regard to inspiration, the *mens ingeniosa* in pedagogy, teaching has been carried out since times immemorial, because sacred rites and sects in general need initiation rites. Without going back much in time, let us turn to the Egyptians. They needed builders for houses, temples, and palaces, so those who knew how to learn from their predecessors through practice in a situated cognition became "masters" of the most varied arts (construction, carpentry, painting, pipes, etc.) and taught their disciples. Teaching was oral and practical: it covered everything from basic skills to advanced knowledge, whether in architecture or painting or crafts or teaching methods such as drawing and calculating. Surely these masters needed to be inventive. Manacorda (2006) describes masters and pedagogues who called for physical punishment to maintain discipline and order so that students would strive for their studies. And such punishments were the rule for centuries until not too long ago.

The Pharaohs, in addition to priests who knew how to read and write, needed scribes and collectors for administrative tasks. Then the need arose for teachers of mathematics and astronomy, well developed in Chalcedon and also among the Sumerians, as well as other knowledge needed for weather forecasting, agriculture, cooking, and other needs. This called for the invention of writing.

From that moment, the "teachers" or "masters," the "pedagogues," began to use text to support their teaching. And so came other inventions: chalkboards, albums, maps, mimeographs, slide projectors, epidiascopes, and multimedia projectors. Pedagogy, however, only in rare cases has reinvented itself: the same thing was done with different technologies. The means were changed or adapted, but the methodology was practically the same.

This does not mean that there was no inspiration or *mens ingeniosa*, the creative mind, according to Boethius and Thomas Aquinas as it is cited in (Siqueira, 1943). According to Maffesoli (2009), the faculty of our time is an imagination that provides creativity: "But, of course, one must not mistake one's time, one must be in tune with the imaginary that constitutes this epoch. Where the need to recognize the values that characterize, it is no longer necessary to fear this expression, nascent postmodernity."

History tells there have been pedagogical inventions. However, what was practiced was more of the same. The five steps of John Herbart's method (review, exposure, demonstration, exercises, and evaluation), and even the methodologies developed by Rousseau, John Dewey, Maria Montessori, Édouard Claparède, Celestin Freinet, Johann Heinrich Pestalozzi, and others, can be noted. Recently, flipped classrooms are recommended, but the teaching is still based on didactic material, whether by means of books or videos. In line with the lack of inspiration, in general what prevails is routine. As Maffesoli (2009) corroborates, there is a founding tautology or repetition remaining the center of the picture, a redundancy that characterizes the everyday hedonism. A showing of the first thing that appears, full of common sense, particularly strange to the demonstrating that designates these so-called theory patches for what they are: "servant 'pawns' always ready to lecture others."

Inspiration is not always a spark, or a sudden insight, but may come from various attempts at changing perspectives, as was the case of Alfred Lothar Wegener's continental drift in accordance with (Romano & Cifelli, 2015). At other times, it happens by chance, as was the discovery of Kekulé's benzene nucleus according with (Rothenberg, 1995). We can also cite the example of Fermi and Pontecorvo's discovery of the reduced acceleration of the neutrinos in nuclear fission as it is cited in (de Carvalho, 2015), which occurred by pure chance when using an unprepared piece of paraffin.

3 Modeling and Ideation

Intuition paved the way for the later advent of models. Models are products of the reflective activity of the mind, in which the course of various ideas is taking shape and enabling the materialization of emergent conceptions of a *mens ingeniosa*. The brain is a simulator of reality. According to Dennett (1997), the development of a structure such as the brain allowed the emergence of creatures that could retain in their internal environment the different situations which could be faced in the external environment. Increasingly in time, simulating reality is a task in which the mind merges with technologies. It is not configured just in a reactive but also a proactive way, with the modification of the external environment itself (Medeiros, Moser, & Santos, 2014).

The mathematician Jacques Hadamard explored the role that discovery plays in mathematics, identifying it as a process of invention originated from introspective or subjective methods. The thinker, in observing his inner self, works with information on both conscious and unconscious levels. Poincaré admitted as indisputable the role of the unconscious in mathematics, which produces sudden illuminations as the result of long and laborious work, according with (Hadamard, 2009).

Scientific ideas, in the elaboration of physical and mathematical theories, are "free constructions of thought." Poincaré and Einstein understood that they are not induced in a logical and univocal, necessary, and compulsory way from the data obtained from experiments. Moreover, they are not inscribed in an innate or a priori structure of thought. It is in this space of freedom that the idea of creation enters into the scientific work that leads to discovery. Clearly, Poincaré and Einstein persevered in this aspect which was, for them, the most important characteristic of the activity of knowledge and which was effectively at the center of their epistemologies as it is cited in Paty (2001).

In Husserl's approach to the problem of ideation, in the scope of his phenomenology, the activity of a reflexive consciousness (*noesis*) gives a transcendent meaning to intentional experiences. In the structure of the intentional act, there is a variety of existing data as pure intuition (*noema*). For Husserl, the *noema* is the pure sense or meaning, the constructed essence, and acts of consciousness are subject to variations of form, eidetic (*eidos*), as variations of an essence which is in turn invariant as it is cited in (Depraz, 2011, pp. 21–22).

Carreira (2009) presents the concept of "virtual manipulatives" – such as Prensky's digital natives (2001), who deal with mathematical concepts in digital technologies – in three ways: manipulation/experimentation, visualization, and research. The activities of experimenting, manipulating, visualizing, and investigating are constitutive elements of mathematical thinking, as well as the natural habitat of digital natives and their ability to participate in this habitat. Borba and Villareal (2005) emphasize the experimental-with-technologies approach, where in an experimentation environment conjectures are produced, different representations are combined in great multiplicity, and processes are tested by trial and error.

Therefore, modeling/ideation approaches simulation as a research method, because a research method requires both rational and empirical approaches, rational because it involves the intellectual effort in the conceptual modeling of problems (based on the concrete object or products of thought experiments) and empirical to allow a debugging process of the problems addressed based on a trial-and-error method.

4 Time to Prototype: Implementation

How much can one learn when actively building a prototype? In the implementation phase, the emphasis is on creating prototypes of projects and pedagogical actions to be used in experimentation. The notion of prototype is linked to practical making of a viable model conceived in the previous phase. The higher the level of detail of the model, the greater the chance of success of the prototype under testing. This notion is widely explored in engineering and software development, but can be extended to pedagogy in the design of new projects and teaching and learning proposals, exploring the multiple combinations of resources available.

The key notion behind prototyping connects with the formation of concrete thinking in the Piagetian constructivist perspective of learning. The genetic epistemology of Piaget is often misinterpreted, and the formation of abstract thinking ends up acquiring greater importance than the previous phase, concrete thinking, which would play a key role in understanding the events of reality. As a result of this, Papert's constructionism aimed to rescue the importance of concrete thinking, which would be on equal terms with abstract thinking (Papert, 2008).

It is important to emphasize that concrete thinking is not a contemporary concept. The research of anthropologist Lévi-Strauss made it possible to identify that primitive societies produced their science based on observation and concrete thinking, different from the Western trajectory which prioritized abstraction (Lévi-Strauss, 2012). For example, an indigenous Brazilian fishing with a spear would know exactly how to reach a fish in shallow waters in a river, unconsciously taking into account the law of refraction of light. How can one compare this knowledge that provided him the fishing skill with that of a high school student who studied Snell's law, which governs the phenomena of refraction? While one learned from observation and concrete thinking, another learned from the abstraction of this phenomenon. The object of study learned was the same but from different learning perspectives. On what basis could it be said that the indigenous has no knowledge of optical physics?

Thus, Lévi-Strauss coined the term *bricolage*, which would be a dialogue between the matter of creation and the means of execution, bridging the technical and aesthetic characteristics of the prototypes that are created. The bricolage worker is an artist, and in his process of creation in the form of art, he identifies the confrontation between structure and accident and order and chaos and an incessant dialogue between model, matter, and the user who appreciates the work (Lévi-Strauss, 2012, p. 44). Therefore, in this conception, prototyping is the task of the bricolage worker, the one who sends the resources and efforts, using the process of trial and error for the emergent materialization of the model.

Another key element that emerges from the DIY (do it yourself) activity is subversion. Michel de Certeau (1990), in his *L'Invention du quotidien*, notes on the manipulation of products by practitioners who did not manufacture them. The common man escapes conformation with the uses conditioned by manufacturers, inventing the art of making, assembling DIY objects, manifesting techniques of resistance by means of subtle wiles, and thus regaining property of the object in his own way. Thus, along with the original intentionality embedded in the products, there is a secondary production "hidden" in the processes of its use (de Certeau, 1990).

From a micro to macro perspective, the bricolage or DIY worker moves toward maker culture, having in its substrate the proposal of predominantly constructive activities in the creation of prototypes. The convergence of various technologies such as prototyping through 3D printers, design software, electronic automation, and robotics, among others, has allowed the formation of a "perfect storm," and prototyping has become a "fire of Prometheus," illuminating the creative possibilities within the reach of schools and not only of some elected few.

The main message at this stage is boldness: by performing a prototypical action, failures and errors may occur. Now, mistakes should not be signs of stagnation, but warnings for reflection, to correct and engender something new and smarter. There are innovation experiences whose achievements are limited in time and space, and some only occur with few educators. An example is Joseph Jacotot, who from 1818 to 1837 taught by implementing his pandemic method of immersion as it is cited in (Rancière, 2002). Much has been written about this method, but who actually applies it? Even better known is Socratic maieutic, but who applies it? Another example is Carl Rogers' non-directivity (1961), the permissive school, Rogers' radicalization, as described by O'Neil (1960).

Therefore, research and experiments should be done by several teachers from different schools. We must expect the resistance of teachers (Maffesoli, 2009, p. 11) with no scientific spirit, who will not accept to be challenged or put to the test. In the face of the new, in general, they will try to do the same with different means. In other words, they are resistant to accommodation without leaving their comfort zone. Accommodating requires sometimes radical changes, but without relinquishing the security of scientific evidence. Because of the absence of this support, many "creative" practices did not last long.

5 The Idea in Practice: Innovation

In the path from creative ideas to pedagogical innovations, inspiration is not enough to innovate. How many very good, sometimes even great, ideas ended up in the "graveyard" because they were not tested or did not create any usable value? Innovation is "when an idea finds the hands of he who will use it," always defined according to who uses it. Pedagogy is similar. We must consider that the idea of "reversing class" is just a creative idea, and there is a long way to go before turning it into educational innovation. For this purpose, it is necessary to try prototyping to challenge the idea under real conditions of use. The course must be changed so that life can be given. And this is always done with the students (Cailliez, 2017, p. 133).

Carr et al. (2011) said that, in general, technologies have the power to influence the manner in which mankind deals with the world in a particular form, whether stimulating or instigating changes at many levels of the sociocultural system, having a strong displacement toward innovation.

Although the inverted classroom provides visible benefits to students such as skill development, teamwork, or new interactions with the teacher, no scientific study has yet been done to measure its real impact on their learning abilities. This is probably a research opportunity. The level of success in this field is very high, but it still does not allow to state whether a marginal increase in academic success is due to the method or not (Cailliez, 2017, p. 133).

A pedagogical innovation can be something that happens without necessarily being an innovative technology. Existing methods, techniques, and resources can be used in new contexts, such as the unusual computer design in the Sugata Mitra's hole in the wall (Mitra, 2008). However, the advent of new technologies, particularly smart technologies, can produce new and interesting combinations capable of innovating in the pedagogical environment.

Educational robotics has been a good example of innovation in the field of pedagogy. According to Komis, Romero, and Misirli (2017), though, such an undertaking requires the development of skills so that students can act in solving problems or challenges, developing projects in a co-creative way, stimulating critical and computational thinking.

However, innovation by itself is not a guarantee of success. Assessment of the effectiveness of innovation solutions will require a broad follow-up, starting with their insertion until reaching maturity. A good intent in such direction is that offered by the methodology of hype cycles fostered by Gartner in five steps: technology trigger, peak of inflated expectations, trough of disillusionment, slope of enlightenment, and plateau of productivity as it is described in Dedehayir and Steinert (2016).

6 Smart Pedagogy vs. Smart Technology

The advancement of technology, particularly regarding the adoption of artificial intelligence (AI) processes, has been the focus of this second decade of the twenty-first century. In what way can such an attitude influence pedagogical innovations? Can smart systems 1 day have primacy over the human brain in conception, modeling, prototyping, or even creating?

It is undeniable that educational systems have benefited from a range of smart technologies, such as the use of intelligent tutoring systems, the modeling of evasion scenarios, or the adoption of machine learning processes to advise learning routes in virtual environments. However, how can we limit the operation of machines acting *in lieu* of humans? Can a *mens ingeniosa* be simulated by AI? Will a smarter pedagogy foster the competition of smart tools?

Some directions on such use are being imagined or applied in order to demonstrate how AI can relate to education (Borge, 2016; Teachthought, 2014):

- ***AI can help basic activities in education, such as assessments:*** evaluating homework and applying tests to large classes can be quite tedious work. The AI can be used to automate the correction of objective and even discursive questions, taking advantage of intelligent text processing technologies developed in technologies such as the one used in IBM Watson.
- ***Educational software can be adapted to the needs of students with AI:*** with the emergence of adaptive learning, virtual environments have the potential to not be simple mass content delivery tools, allowing content customization according to the needs or preferences of the students. The intelligent management of learning objects in virtual courses allows the collection of statistical data about how students have used such objects and which have been effective in learning.
- ***AI can point to where courses need improvement:*** virtual environments can give feedback on questions that students are frequently missing, allowing gaps to be identified where content could be improved or new topics added for better understanding.
- ***Students can benefit from additional support or reinforcement from AI tutors:*** the same way virtual assistants are helping smartphone users, smart tutors, or educational assistants can be useful tools for students to understand the content, work on exercises, and better self-manage their learning. Such assistants communicate in natural language, and the more "automatic" part of teaching content based on concepts, examples, illustrations, or links is done by the assistant.
- ***AI-driven programs can give students and educators useful and relevant feedback:*** AI can assist educators and students in designing courses that are tailored to their needs, providing feedback on the success of the course as a whole. Online schools use AI systems that monitor students' progress and flag any problems with the student's performance to the teachers.
- ***AI changes the way people encounter and interact with information:*** in general, people do not realize how the various systems they use on a daily basis already have built-in AI that affect their interaction with information. Systems are no longer simple query interfaces; they engender more complex processes of combining information that make interaction to more human.
- ***AI changes the role of teachers:*** smarter teaching tools will require smarter participation from the teacher, as in guiding a more complex learning process rather than being just a source of knowledge. Even if we see an increase in assessment, content recommendation, performance analysis, and communicative interaction with educational artificial intelligence, certain activities not performed by the systems will require teacher counseling. Regarding the fallibility of machines, it is assumed that there is no adequate solution for the frame problem, which means that an intelligent system must decide on the information it has, but also take into account the information that it does not have.
- ***AI can make learning by trial and error less intimidating:*** smart tutor systems have been used over the years to allow for trial-and-error learning and simulation in direct interaction with students. These are tools that do not tire of explaining. In addition, they can be effective in cases where students have difficulties in dealing with people or manifesting shyness.

- ***The data science powered by AI can change the way schools find, teach, and support students:*** modern data science, widely used in mass data processing for more corporate purposes, has great potential to be applied in schools and educational companies. From prospecting high-performing students to learning support, the use of data mining techniques can help highlight hidden data patterns globally, enabling the better knowledge of the educational setting and the adoption of best practices for content management and academic and professional careers.
- ***AI can change the way students learn, who teaches what and how they acquire basic skills:*** as in Heisenberg's uncertainty principle, where the observation of a quantum object modifies the object's own behavior, the use of intelligent tools profoundly modifies the way students and teachers interact with technology. Interactions with smart technological devices are now given a greater degree of personalization rather than just the hand-keyboard-mouse-eye-monitor relationship. And the human being will adapt to the new communicative forms provided by intelligent systems that will listen and speak and make decisions and suggestions.

Thus, there is much to be mapped about the ways in which a smart pedagogy will be combined with smart technologies. The background for controversies between researchers on different perspectives persists: AIs that have animated "minds" on silicon substrates (strong AI) or AIs that can at best simulate human behavior (weak AI). Certain elements necessary for smart pedagogy, such as creativity and inspiration, may lie within the framework of human minds alone. In any case, the impact on education will be unstoppable, and people will have to find a way to adapt to existing and future scenarios.

7 Conclusion

Talking about innovation in education brings to mind the parable of Papert (2008) about the travelers of the past who are transported to the present time and come across various types of crafts, in addition to the school. It may already be possible to say that the changes brought about by the turn of the millennium, including the Internet, mobile technologies, and artificial intelligence, have substantially modified the educational landscape, significantly distancing it from the way the processes have been for centuries. However, the concentration of technologies in the more developed countries cannot be ignored, while others still lack the progress made by some. Thus, we must consider that public policies in different countries may be different, and we can see disparities in the use of technology in schools in different parts of the world.

However, the exposed in this article demonstrates that much of the innovation that can happen in an educational process is largely related to the subjects involved, be they students or teachers, who become learners at all stages of a methodology for innovation. It is not yet known whether a machine is capable of expressing thoughts as we know them. Up to the present, creativity is still the prerogative of the human being, and a creative inspiration has a high power of transformation.

In devising a methodology to innovate in education, the inspiration of a *mens ingeniosa* passes through modeling, which gives form to the ideas, and then, through implementation, these ideas are debugged and improved. The result is innovation that has the capacity to transform, modify, and allow the construction of new worlds and scenarios in order for education to take flight and unfurl new territories, allowing learners to follow paths that can magnify and emancipate humanity. Perhaps 1 day, in a context of high innovation in education, the parable of Papert will cease to make sense.

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Learning Platforms: How to Make the Right Choice

Linda Daniela and Arta Rūdolfa

Abstract Learning through online platform opportunities is one way of organizing a technology-enhanced learning process. This chapter provides an overview of the place and role of learning platforms in the pedagogical process, defines the differences between learning platforms and learning management systems and offers a toolkit for evaluating learning platforms. The toolkit includes 22 criteria divided into 43 sub-criteria, which can be evaluated at 3 levels. This tool can help teachers, school administrators and other stakeholders to make a pedagogically based choice when it comes to choosing which learning platform solutions to use to scaffold student learning in a transformed learning process that is affected by digitalization.

Keywords Learning platforms · Learning management systems · Evaluation criteria · Evaluation tool · Pedagogical competence

1 Introduction

Many technologies and technological solutions are not new in society as a whole or in the educational environment. There has been a discussion of their place and role since the beginning of industrialization, when it was argued that industrialization would deprive people of their work. Today, technology is becoming digital, which raises new challenges in all possible dimensions, including those of the educational environment. Historical experience with industrial processes has shown that people still work, but the skills and knowledge required in the labour market and the competencies needed to adapt to new challenges remain a question for many people.

With the development of information technology and the digitization of various processes, it is possible to use the latest technologies, digital tools, teaching software, mobile applications and many other innovative solutions in the educational environment to make the learning process more interesting, facilitate learner self-directed learning and scaffold the development of metacognitive processes.

L. Daniela (✉) · A. Rūdolfa
Faculty of Education, Psychology, and Art, University of Latvia, Riga, Latvia

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However, with the increase in the opportunities provided by technology, it is also necessary to make pedagogically reasonable choices in terms of which of the technological solutions should be used to promote learner progress, initially entailing mastery of the principles of using different technologies, but later learning how to use technologies as scaffolding tools that help achieve higher goals, acquire new knowledge and create new innovations. At the same time, using the opportunities provided by digitization can be done by purposefully promoting the development of metacognitive processes and is pedagogically justified, taking into account the peculiarities of the development of learners, the conditions for the development of information processing, attention persistence, motivation and other essential aspects of the pedagogical process.

The quality of education can be improved in a variety of ways: it is possible to change the content of learning, learning forms, learning methods and teaching aids by promoting the use of online teaching materials through the introduction of programming in learning content through digital learning materials, learning management systems (LMSs), learning platforms (LPs) and various other technological solutions in the learning process. These can essentially provide a shift in the learning paradigm towards technology-enhanced learning, in which the main goal is to promote learning outcomes (LOs). By using digital learning materials and digital solutions learners have the possibility to be active in constructing their knowledge and learning can be multidimensional in sense of possibilities provided by digital solutions, rather than being merely involved with typographically produced learning materials.

Global technology and the wireless marketplace are extremely dynamic (Hwang & Tsai, 2011). The field of research in this industry is incalculably broad, and pedagogical science should be able to progress with the times by getting rid of out-of-date information and integrating new knowledge and developing new competences (Jones & Shao, 2011). Teachers need to develop new competencies which have previously not been needed, developing critical thinking and becoming continuous learners and educators who use technological advancements. To a certain extent, this means developing the skills of circus artists, who are not only capable of juggling countless balls that characterize knowledge, attitudes, skills, motivation, etc. but also have the ability to balance the uncertain foundations when it comes to making pedagogically sound decisions about technology and solutions and predicting the outcomes of their use, which have not yet been verified. Taking into account the fact that technological opportunities ensure that learning takes place outside the boundaries of time and space, the teacher must also be able to lead learning processes in this pedagogically transformed environment, without certain time and space boundaries, so that the acquisition of knowledge is meaningful and geared towards development.

The levels and types of digitalization of study materials and technological solutions that can be used in the educational process are highly diverse, and each of them has their own specificity. Therefore, it is not possible to analyse the whole spectrum of digital resources, digital solutions, digital teaching materials, teaching aids and other possible technological solutions. One of the technological solutions used in the learning process, combining both information technology and online availability and digitized training material, is the learning platform (LP). Online LPs have been proven to be effective (Organisation for Economic Co-operation and Development [OECD], 2015) because they allow access to information at any time and anywhere, given connection to the Internet or an Intranet. In addition, there are studies that have concluded that learning and pupils' learning practices change as a result of the opportunities offered by such platforms (Boticki, Baksa, Seow, & Looi, 2015; Snodin, 2013). LPs give students the opportunity to revise and strengthen their knowledge by adapting to their individual abilities and perceptual peculiarities. In turn, the use of LPs can considerably save educators' time in preparing theoretical, practical and test work and receiving immediate feedback on the students' progress and results in a particular subject. It is important to understand here that we define LPs as different from LMSs and later these differences are defined in the text.

In this book, the competence of the teacher to operate in the technology-enhanced learning environment is defined as smart pedagogic competence, but here we aim to define one aspect of this competence – predicting the pedagogical outcomes of the LP as a particular digital solution and critically evaluating the proposed technological solutions from the point of view of their pedagogical potential. This chapter is devoted to the place and role of the LP in the learning process, defining its specific aspects and offering an assessment tool for evaluating the pedagogical potential of using the LP.

2 Online Learning Possibilities

The use of an LP in the learning process, combining the principles of digital learning implemented by students when connecting to the learning environment through the Internet (sometimes the Intranet), is a relatively new phenomenon. However, the history of the use of self-connecting principles to a particular automation system is relatively long since it is believed that the origins date back to 1924, when Sidney Pressey invented a first machine that resembled a typewriter and could be used to train memory processes and answer test questions, foreseeing the choice of a specific answer, which began to be used at the Ohio State University (Watters, 2015). The next major milestone was in 2002, when the world was introduced to the Moodle system, first used by universities (ProProfs, 2017). Previously, educators used online technologies as information presentation tools and information storage tools to support learning. However, researchers point to the great potential of online technology to improve people's learning in an interactive way. The use of online learning technologies should thus be transformed from presentation and storage tools to the next level, namely, tools to promote interactive learning by involving students actively in information processing, analysis and knowledge design and applying technology to support their decision making (Tu, 2006).

To describe related but conceptually different e-learning platforms, there are different terms and related acronyms (Pina, 2013). Terms such as LMSs, LPs, online learning, e-schools, school administration systems, web-based LPs and cloud-based school learning systems are very widely used in different sources.

A number of researchers use the term LMS (Ellis, 2009; Fındık-Coşkunçay, Alkış, & Özkan-Yıldırım, 2018) to describe learning through online platforms, which provides open opportunities for monitoring process changes at an educational establishment level, as well as planning, decision making and follow-up on future developments in educational policy and practice. LMS functions are systemic and offer the necessary functionality to support online or blended learning and manage learning processes (Wang & Wang, 2010). The role of the LMS varies according to the organization's goals, online learning strategies and desired outcomes. In some cases, LMSs can even have built-in e-learning authoring tools that allow one to create online learning materials without the need for additional third-party software – doing so online (Pappas, 2017).

The LMS is a concept that has not been precisely defined with regard to what can be considered an LMS and what cannot, although it is a term that is widely used (Watson & Watson, 2007). Despite Watson and Watson's attempt to clarify and define what an LMS is, the terminology used is still unclear, and the same term is employed to describe online learning with one meaning here and a different meaning there.

Among the published studies on online learning forms, Lytridis and Tsinakos (2017) describe Mobile LPs in which the main focus is on materials created by teachers (or other professionals) to which pupils can connect using mobile devices (in the context of the article, they are talking about smart devices that are able to connect using data transmission networks). These have various advantages:

- Ease of use: The students use these familiar devices every day and do not have to learn a new tool in the learning process, thus mitigating the cognitive load and increasing the speed at which learners work and perform tasks.
- Content available at any time: The students are not limited to scheduled training sessions, but instead freely opt for the time at which they access the training materials.
- Communication capabilities using a wireless network specific to the smart device, such as chat messages, SMS, voice calls, shared calendars, access to forums, etc., promote cooperation in the learning process.

However, analysis of the mLearn training platform aimed at providing educators with tools for organizing and conducting educational trips both outside (in cities, on websites, etc.) and in premises (e.g. in museums) (Lytridis & Tsinakos, 2017) has not been considered in terms of pedagogical work to promote learning outcomes. Organizing this kind of learning process is also one of the forms of online learning, but it does not cover the entire structure of the learning process; rather, it addresses only individual elements, so it cannot be described fully as a structured LP.

There are studies in which the term virtual LP (VLP) is used, defined by Britain and Liber as early as 2004. According to these authors, VLPs are characterized by parameters such as a message board, a course (list of subjects), various tasks, a repository of multimodal teaching materials, seeker opportunities, file upload and download capabilities, the necessary file selection options, conference organizing opportunities, evaluation options, a list of pupils and email addresses to which information can be sent, synchronous cooperation opportunities, a calendar, stats for the accumulation and analysis of statistics and page navigation (Andrew, Maslin-Prothero, & Ewens, 2015; Britain & Liber, 2004; Crook & Cluley, 2009; Gallagher, 2016; Johannesen, 2012). A group of researchers in 2014 (Gaines, Paul, & Rukobo, 2014) defined the VLP (used analogously to the term "platform") as giving students the opportunity to learn remotely, at any time and anywhere, providing access to learning materials that are appropriately developed to reach learning standards. The structure of the VLP is similar to that of a traditional school and provides the opportunity either to make full use of online learning opportunities or combine these with traditional learning (blended learning). Gaines et al. (2014) also developed criteria for evaluating VLPs by dividing them into several groups:

- Virtual learning implementation strategies
- Virtual learning materials in line with the latest research and best practices
- Content of study in accordance with the standard of education and the goals to be achieved
- Assessment of the capacity of the system from the perspective of students and from the financial aspect

The parameters characterizing the VLP defined by these authors indicate that the material stored is according to a specific curriculum, which means that all users of this platform are provided with the same teaching content, combined with traditional teaching methods.

One study in 2003 used the term web-based LP, defining it as an application that consists of various components used to acquire learning content through interactive exercises and multimedia materials (Pahl, 2003). Based on these components, teaching strategies determine how this content is displayed and software tools improve access to this content (Allen & Allen, 2002; Pahl, 2003).

3 Learning Management Systems Versus Learning Platforms

It can be concluded that the various forms of online LPs, regardless of the terms used in their descriptions, are characterized by the organization of the learning process offered, and these platforms can be divided into two groups with derivatives (see Fig. 1), in which one group has management system features, offering a structured learning process for LMS, while the second group comprises online LPs that offer structured learning content a teacher can use to provide students with online learning opportunities. Both of these have online connection capabilities and opportunities to use management systems, but the difference lies in whether learning content is provided by teachers or platform developers (see Fig. 2).

LMS is a term used to indicate a platform employed to collect information about students, enable them to access online teaching materials and provide support for various types of learning that can be used both in the classroom and online, as well

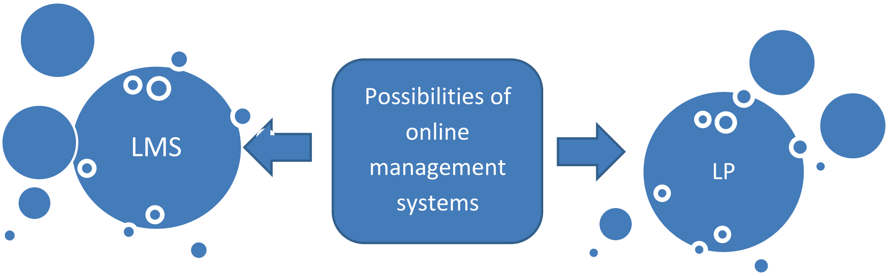

Fig. 1 Groups of online learning platforms

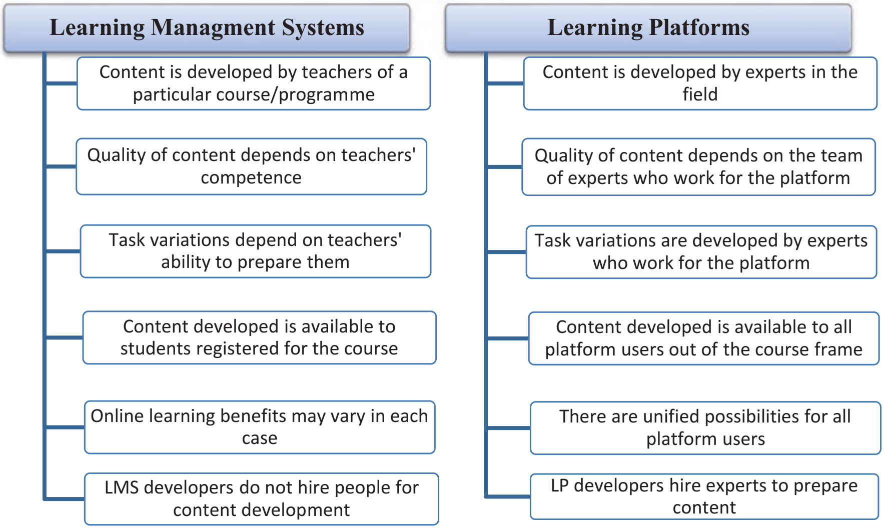

Fig. 2 Learning management systems vs. learning platforms

as through blended learning principles. According to ProProfs (2017), the features that characterize LMSs are as follows:

- It is possible to develop different courses.
- It is possible to follow students' progress.
- Data can be analysed in relation to different dimensions.
- It is possible to upload and download documents.
- Data protection and connection to the network are ensured.
- Access to materials is possible by logging into the system.
- Students have the opportunity to organize their own learning processes.
- Connection is possible any time and anywhere.
- Mutual peer learning is possible.
- Gamification principles are used.
- The system is social.

The world's most popular LMSs are now Blackboard and Moodle: they have become sites on which lecturers can communicate with their students and vice versa, and they can be used as active learning platforms. However, unfortunately there are also researches which show that they are commonly used only as an advanced mode for the exchange of materials – replacing typographic materials with digitally produced materials – and thus their potential is not being fully exploited (Cleveland & Block, 2017; Misseyanni, Daniela, Lytras, Papadopolou, & Marouli, 2017). This demonstrates that there are still hidden aspects in the use of LMSs for which solutions must be sought.

The main parameter that characterizes LMSs is that they are sites on which online learning can take place, statistics on learning outcomes can be accumulated, tests can be posted and student progress can be tracked; however, the main emphasis is on the fact that they provide *free content*, based on the idea that educators can create their own content, tailor-made for the learning needs of specific students, etc. On the one hand, this principle is very positive because it provides pedagogical freedom for teachers when deciding the types of material students are offered; on the other hand, there are many risks in using such forms of learning, as follows:

- The diverse digital competences of educators can lead to the potential of LMSs not being exploited fully, for example, because the materials are unstructured, not interactive, not arranged thematically, not easy to follow and of differing quality in diverse study courses. Therefore, all students are not provided with equal opportunities.
- There is the potential for overload of professional work, since academic staff must conduct lectures on the spot and be prepared to continue working online, which means that the principle *learning beyond the boundaries of time and space* has a negative impact on the boundaries of teachers' private space and time.
- There can be negative outcomes in terms of the development of students' learning competences because they assume that the information included in the LMS is absolute and they do not put much effort into searching for additional information.

LPs, in contrast, are characterized by the fact that their developers create learning content and offer teachers and students the opportunity to use it. There are again variations in the options available: The content of study is developed and available online, but it is not interactive; Students also have access only to the teaching materials that apply to their class and group subjects, but it is not possible to look at the information learned in previous steps, to repeat if something has been forgotten or to learn independently. However, if the LP is structured and appropriate content is provided, there are more benefits from the educational and pedagogical perspective than is the case with LMSs.

Currently, the *Khan Academy* LP, founded by S. Khan, is highly popular worldwide. Using this platform, it is possible to study mathematics, chemistry and physics from the kindergarten level to the highest levels, and it allows students to learn at an appropriate pace without being in a particular classroom (Khan Academy, 2016). There are also platforms dedicated to specific subject field, such as robotics for example (Tuluri et al., 2014). In Latvia, the LP *tasks.lv* (translation from Latvian uzdevumi.lv) is available, providing accessible study materials and training tasks for all subjects in grades 1–12. The teacher is not responsible for the development of the study materials but uses the opportunities offered by the platform, and the students can access the teaching materials at any level.

It can be concluded that the use of LPs brings the following positive benefits:

- Automatic progress assessment systems help teachers to tailor tasks to student groups.
- Adaptive learning systems automatically adapt the level of education and the path to each student.
- Software algorithms are able to recommend the next optimal learning experience for each student.
- Smart use of technology can increase student motivation by offering an exciting learning environment.
- Automatic feedback systems provide immediate support.
- More engaging tasks and more positive feedback motivate students and create greater motivation to engage in learning.
- Personal, regular, tailor-made training feedback should support the progress of learning.

To sum up, LMSs and LPs are essentially different in terms of the content provision. LMSs provide a place and opportunity for teachers to work on creating and delivering online teaching materials, develop tasks, communicate with students and use all of the other LMS capabilities, while LPs are sites for which expert teams develop unified learning content that will provide everyone with equal opportunities for its use. The LMS system provides students with the possibility to register for specific courses and thus access the content of teaching that teachers have set up or developed for a specific course of study, while LPs provide students with the opportunity to learn by accessing various materials. This facilitates the work of teachers since existing teaching materials can be used, thus saving teachers' time. This type of online teaching process has several advantages and is linked to the fact that the principles of the LMS can be used, but the training content is provided by a team of experts maintained by the platform, which ensures that all the content of the platform is pedagogically and sequentially structured and it does not depend on the level of digital competence of each individual teacher.

4 Learning Platform Evaluation Tool

Given that there are quite a few suggestions on how to organize online learning, teachers and school administrators need to understand what criteria can be used to choose an appropriate LP, so an original evaluation tool was developed. In developing this kind of assessment tool, it is necessary to take into account not only the technical parameters and possibilities but most importantly the pedagogical value. Analysing the information in databases of scientific article on study platforms and their evaluation, it can be concluded that very little information on the types of evaluation is available. More emphasis is placed on the evaluation of LPs from a technological point of view, but not much information can be found on their assessment from the pedagogical perspective (also taking into account the technological aspect) (Dabbagh, 2005; Dağ, 2016; Edmunds & Hartnett, 2014; Watson & Watson, 2007).

The evaluation tool developed (see Table 1) consists of 22 criteria and 43 subcriteria, and the evaluation is carried out on 3 levels. This tool is useful for assessing the pedagogic potential of LPs, provided that the evaluation is carried out by people who already have certain competencies in the assessment of pedagogical processes. To assess whether the platform used influences learning outcomes, other tools must be used for measurement from the perspective of knowledge growth.

The main objective of the development of the evaluation tool is to enable the use of meaningful, convenient and effective LPs in the modern teaching process. The learning outcomes of the learners are more important than the way in which they are acquired, and therefore it is essential to analyse not only the technical and visual parameters of the learning platforms but also their educational values and pedagogic potential.

The evaluation tool developed envisages assessing the visual perceptibility, accessibility and interactivity of LPs, whether there is the possibility for students to receive feedback, whether there is regular updating of content and whether the learners are afforded self-directed learning opportunities. It is also possible to evaluate the manageability of LPs and the opportunities to create new content. The majority of the criteria are scored using 0, 1 or 2 points, but some criteria are evaluated only in terms of whether the particular parameter is met (1 point) or not (0 points). The evaluation tool was developed on the basis of analysis of the theoretical literature and various training platforms and a synthesis of the authors' experiences. It was verified by evaluating the LPs used in Latvia.

When evaluating LPs and their quality, the main factors to consider are the following:

- Conformity of the content with the set curriculum
- Effective use of ICT – online availability (and most popular smart devices)
- Usability and accessibility of the digital learning tool
- The degree of interactivity of the digital learning tool (interactive engagement is desirable)
- Provision of feedback (answer/explanation, analysis of student's progress)
- Compatibility with other digital tools
- Provision of two-way communication on the platform
- Capability of teaching aids to be used for promoting self-directed learning (understandable and simple, not necessarily a need for adult presence)

When evaluating an LP, the criteria given in items 1–21 in Table 1 should be addressed; the higher the score the platform attains, the greater the pedagogic potential of the use of such a platform. The results for item 22 should be read vice versa (i.e. the item is reverse coded): a higher number of "clicks" indicate a more complicated design that is not user-friendly.

Table 1 Learning platform evaluation tool

Criteria	Sub-criteria	Levels	Evaluation
1. Visual perceptibility	The LP is easy to understand and the content is structured. The content matches the purpose, style and presentation. The text is easy to read, suitable for the students' age. The structuring of information on the platform is very important; its essence is to arrange the study content within a user-perceived system. The structured content of the LP facilitates its perception and learning, as well as facilitating targeted teaching		
	1. The learning subjects are grouped thematically and arranged in a structured way by subject	0 – The subjects are not thematically grouped and not structured	
		1 – The subjects are thematically grouped but not structured	
		2 – The subjects are thematically grouped and structured	
	2. The main sections have been identified and highlighted	0 – No major sections have been identified or highlighted	
		1 – The main sections have been identified but not highlighted	
		2 – The main sections have been identified and highlighted	
	3. Headings of chapters and subdivisions contain brief and specific information about the content of the topic	0 – There is no information on the content of the chapters	
		1 – Information on the content of the chapters is written in a long/ uncertain manner	
		2 – The heading contain brief and specific information on the content of the chapters	
	4. Precisely defined assignments, examples and facts that correspond with the content	0 – The terms of the assignments are not clear	
		1 – The terms of the assignments are precise, but there are no examples or facts given	
		2 – Rules of the assignments are precise and examples and facts are given	
	5. Key theoretical information is provided, enhanced with symbols and graphical presentations of information to highlight concepts and principles	0 – No theoretical background is given	
		1 – Symbols and graphical figures are used but are unstructured	
		2 – Symbols and graphical figures are used and are structured	
	6. The illustrative material is easy to perceive with understandable explanations (specific information sources are provided, for example, the periodic table for chemical elements, physical size tables, etc.)	0 – There is no illustrative material	
		1 – The illustrative material is provided, but it is not explained (incomprehensible) or not provided for all topics	
		2 – The illustrative material is easy to perceive and is explained	

	7. The graphic design format is good and easy to read, and the colours do not interfere with the content (too bright, too diverse), rather supporting easier perception of the content of the teaching	0 – The graphic design is difficult to perceive	
		1 – The graphic design, the font size and type and the use of colours for sites are difficult to perceive in some places	
		2 – Easy to perceive graphic design, font size and colour application	
	8. Conforms to grammatical aspects (clarity, no grammatical or linguistic style errors)*	0 – The text is unclear (sentences too long or too short and misleading wording)	
		1 – The text can be misunderstood	
		2 – The text is easy to understand and unobtrusive	
2. Definition of the objectives target, tasks and results to be achieved	The LP clearly defines the objectives, tasks and results to be achieved for each assignment. These are in line with the goals, objectives and outcomes set in the curriculum of the subject.* (An objective analysis of the content, objectives and results of the learning platform would require in-depth analysis by experts, entailing content analysis for each subject and topic)	0 – The objectives, tasks or results are not clearly defined	
		1 – The objectives, tasks, or the results are partly defined	
		2 – The objective, tasks and the results are clearly defined	
3. Accessibility	The accessibility of the LP can be simplified or rendered more complicated with additional requirements for access to learning content. Using HTML software provides access to the LP in an online environment without installing specific software on the device. A modern and easy-to-use LP must be built using HTML software and be available online from any device with an Internet connection	0 – The LP is built without HTML and requires the installation of specific software on the device (offers installing software for an extra fee)	
		1 – The LP is built without HTML and requires the installation of specific software on the device (offers free installation of software)	
		2 – The LP is created using HTML, providing access to the online environment	
4. Self-directed learning process	To use the LP for individualized, self-directed learning, it is important that the structure of use and the terms of reference are understandable without the teacher's instructions and presence	0 – Self-directed learning process is not possible	
		1 – Self-directed learning process is not possible in all situations (explanations are needed before starting work)	
		2 – Self-directed learning process is possible	
5. Interactivity	The LP provides interactivity, engages learners, fosters participation in the learning process and provides active and independent work	0 – The LP lacks interactivity or has poor interactivity	
		1 – The LP has a limited and low level of interactivity	
		2 – The LP has a high level of interactivity	

(continued)

Table 1 (continued)

Criteria	Sub-criteria	Levels	Evaluation
6. Feedback	One of the most important tasks of the LP is to provide feedback to the user. The LP's ability to generate feedback is basically accomplished in two ways: first of all, the "right/wrong answer" principle with or without explanation for solving a task (this applies more to the learning process itself) and second, after the submission of the tests, the user is informed about the number of points obtained and the assessment (in compliance with the basic principles of educational evaluation specified in the educational standards and curriculum)		
	Feedback by informing learner of the correct or incorrect answers/solutions to the task, with or without explanation	0 – Information on correct answers/solutions is not given	
		1 – Information on correct answers/solutions is given, but no explanation is provided	
		2 – Information on correct answers/solutions and explanation is given	
	Feedback during the test – submitting an assignment, informing the user about the points obtained or rating in the LP (according to the basic principles of educational evaluation defined in the educational standards and curriculum)	0 – It is not possible to receive any feedback	
		1 – It is possible to receive feedback or a score only	
		2 – It is possible to receive feedback – the number of points or a rating form and an explanation	
	Mutual communication (student-teacher-parent). In the LP, the learner, teacher and parents have the opportunity to communicate using comments, email or chat options. The LP facilitates communication (student-student, teacher-student, teacher-parent). At least one of the communication options is offered – a discussion forum, mutual exchange of information and commentary on assignments– as teacher feedback, email messages or other options	0 – No communication options are offered	
		1 – Possibility for a teacher to comment (one-way communication)	
		2 – Options are offered and two-way communication is provided	
	Student progress analysis and summary statistics provide an opportunity to assess the student's progress individually and provide a complete overview for the teacher, parent and school leadership on learning outcomes and critical issues	0 – No progress analysis is provided	
		1 – Results on progress analysis are only available to the teacher	
		2 – Progress analysis, data storage and availability (teacher, student, parent) are provided	

7. Regular content updates	The LP is a learning tool that can be updated and continuously developed in terms of the content of instruction and also provides the rationale for such a teaching tool since it permits the content to be updated at any time and prevents the learner from learning obsolete information or inaccurate data	0 – The content is not updated or renewed	
		1 – The content is updated and renewed at certain periods (e.g. once a year)	
		2 – The content is updated or renewed continuously	
8. Fee-based or free availability	The LP can be completely free of charge and chargeable or give partial access to content regardless of the fee paid	0 – All services and educational content are only chargeable	
		1 – Some of the services and training content are available in the free of charge version	
		2 – All services and educational content are available in the free of charge version	
9. LP handling/ usability/ navigability	Technical standards for LPs require the testing of knowledge and skills. One of the most significant differences between differentiated learning materials (DLMs) and other types of electronic materials is the greater user interactivity and collaboration in the workflows inherent in the learning platforms – the DLM must be designed in such a way that it is possible to perform a series of operations		
	Possibility of assigning a task	0 – Unable to send/connect to email (other way of communication)	
		1 – It is possible to use one of the options (sending by email or connecting), but not both	
		2 – It is possible to send via email and connect	
	Possibility of monitoring performance time and quality of work on assignment (correct and incorrect answers)	0 – Information on performance time and/or quality is not available	
		1 – Partial information on runtime or quality is available (it is possible to control the duration of the time spent on assignment)	
		2 – There is full information on runtime, quality and the ability to control the time spent on assignmnet	
	It is possible to evaluate using automatic and semi-automatic methods	0 – No evaluation options is provided	
		1 – Only automatic evaluation is possible	
		2 – Both automatic and semi-automatic evaluations are possible	

(continued)

Table 1 (continued)

Criteria	Sub-criteria	Levels	Evaluation
10. Create new content/ technical capabilities	Teachers can create new content (theory, exercises, lesson assignments)	0 – It is not possible to create new content	
		1 – It is possible to combine assignments and tests only from the existing offer	
		2 – It is possible to combine existing assignments and tests and own content created	
	Teachers can combine the content of the tests from existing tests on platform or create new tests	0 – It is not possible to create a test	
		1 – It is possible to combine the content of the tests only from the existing offer	
		2 – It is possible to combine existing content and create new tests	
11. Content usage possibilities	It is possible to apply the content offered in the LP in different ways – during the teaching process – not only assigning tasks and tests		
	Study content is structured according to the content of the textbook (e-book)*	0 – The LP does not provide topics relevant to the textbook	
		1 – The LP offers some topics according to the content of the textbook	
		2 – The LP offers all content according to the textbook	
	It is possible to print materials for work in lessons	0 – A "print version" of the material is not offered/cannot be printed	
		1 – It is possible to print only part of the material (it is not forbidden to print, but there is no printing option provided)	
		2 – It is possible to print any material	
12. Courses on use of LP	Lectures/courses are provided. Hands-on training, training using the LP, training in an educational institution and distance learning online	0 – No training is available (only user guide available)	
		1 – Courses are offered to educational institutions for ICT professionals, or training is offered at the premises of the LP office	
		2 – LP offers hands-on training at an educational institution (at a convenient time and place for teachers)	

13. LP usability	Usability as a functional or nonfunctional requirement is not directly measurable, but it is possible to quantify the indirect metrics (number of problem messages, user-generated automated reports). However, the LP will not produce the desired result if its usability is inherently unbearable and if the user has to make a particular effort to understand the platform's handling, structure, navigation and application, thus reducing the time and attention to learning content. The LP should, in essence, provide effective and efficient learning and more effective content than other modes of learning		
	Instructions for use: The LP contains a user manual and built-in support functions that contain instructions on the use and functionality of the particular LP. Contact information for advisory support, video/audio tutorials and user manuals are available. User instructions are easy to understand	0 – No user guide is provided	
		1 – A user guide is provided – readable manual (text, pictures)	
		2 – A user guide is provided: text, pictures, video tutorial and other support functions, such as advisory chat and phone consultation	
	Content is presented in a variety of complementary formats – textual, audible and visual – images and video	0 – Content is presented in a one-way format (e.g. read only)	
		1 – Content is presented in a couple of ways	
		2 – Content is presented in different ways (multidimensional)	
	The content is relevant to a specific target group (students), including certain age-related developmental features*	0 – Content is not relevant to the target group	
		1 – Content is only partially relevant to the target group (or the content is relevant, but the target group is not specified)	
		2 – Content is relevant to the target group	
	Mistakes: It is possible to return to the previous question and correct an answer previously submitted if the student has understood that he/she has responded incorrectly. After an error, the user can easily and quickly eradicate the erroneous operation. An error correction is provided by returning to previous tasks/steps	0 – It is not possible to correct the response submitted	
		1 – It is possible to correct the mistake only in the previous step of the task	
		2 – It is possible to return to the previous questions at any stage of the task and correct the answer previously given	
	It is possible to ask questions, clarify uncertainties and point to problems to developers of the LP	0 – It is not possible to find how to communicate with LP developers	
		1 – User complaints and suggestions are accepted and heard, but no communication is made, and it is not clear when an answer could be expected	
		2 – Communication options are easy to find and the response is received quickly and is appropriate (the response is given in up to 24 h)	

(continued)

Table 1 (continued)

Criteria	Sub-criteria	Levels	Evaluation
14. Connectivity with other learning management systems	Regardless of the LP's development technology, it must meet certain sustainability and connectivity standards. Connectivity with other training platforms, learning management systems, connecting to an existing social networking account or email and many other solutions. If the platform is "disconnected" from connectivity, it is virtually impossible to meet sustainability conditions	0 – It is not possible to connect with other systems	
		1 – It is possible to connect with only one particular system	
		2 – It is possible to connect with other learning management systems	
15. LP loading time	The load time for the LP is 8 Mbits = 1 MB = 1 s	0 – LP load time > 4.9 s	
		1 – LP load time = 4.9 s	
		2 – LP load time < 4.9 s	
16. Sign up to the platform	Sign up for a LP	0 – It is not possible to sign up	
		1 – Sign up is possible using one existing account or by creating a new user profile on the platform	
		2 – Sign up is possible from more than three existing accounts (e-class, Google, etc.) and also by creating a new user profile on the platform	
17. Screening tests	The training platform provides an opportunity for diagnostic tests	0 – The LP does not provide the opportunity to perform diagnostic tests online	
		1 – The LP can be tailored to organize diagnostic tests online	
		2 – The LP provides the opportunity for online diagnostic tests	
18. Adaptation for special needs	The LP can be adapted to users with special needs, such as zooming in, playing text on audio, increasing text size, etc.* (the objective assessment of the use of training platforms for special needs would require in-depth expert analysis)	0 – It is not possible to customize for a user with special needs	
		1 – It is possible to customize to a specific group of special needs (e.g. it is possible to enlarge the screen image, and it adapts to the screen)	
		2 – It is possible to customize for users with diverse special needs	
19. Respect for copyright	The developers of the LP follow the legislative regulation on the copyright issues. The law explains how the concept of "work" is interpreted in the copyright sense and how it is protected, but it is essential to understand that the content of the training platform is sometimes created by connecting several materials created by several authors. With that, it must be understood that not only is content protected but also design and software*		
20. The system of royalties	The developers of the LP, in accordance with the law, contract experts to provide the content of the platform*		

21. Effective use of ICT in the development of DLM	The LP should be suitable for operating on common operating systems in terms of the type of access in both online and offline modes. Its development requires the use of the most commonly used leading technologies, software, algorithms and devices*		
	The LP development architecture employs the most commonly used leading software and algorithms.* (For the objective assessment of the effective use of leading technologies, an in-depth, technical expert analysis is required)	HTML	
		PHP	
		SQL	
		ASP	
		CSS	
		CGI	
		Perl	
		OSGI	
		JavaScript	
		Other	
	The LP is developed using open source web servers, providing operations through the most popular operating systems. Server power is one of the basic rules for efficient use of the training platform*	Apache HTTP	
		Nginx	
		Microsoft IIS	
		Other	
	The developers of the LP offer options for storing data*	0 – It is possible to use only the server offered by the LP	
		1 – It is possible to select the server that stores the data	
		2 – It is possible to choose where to store data (state, municipality, educational institution servers, cloud-based solutions, etc.)	
	The devices the LP is designed for	Computer	
		Smartphone/tablet	
		Interactive whiteboard	
		Interactive screen	
		Projector	
		Other	
22. Clicks	How many "clicks" it takes to start the task right after registration	*Points attained here indicate that the system is complicated and these cannot be integrated with the other points attained previously. More clicks indicate more complexity*	

Criteria marked with * cannot be evaluated unambiguously without in-depth exploration and expert involvement

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Part II
Research on Technology-Enhanced Learning Process

In the following part of the book **Research on Technology-Enhanced Learning Process**, there are 13 chapters on research outcomes on technology-enhanced learning. Authors introduce a new method to assess the emergence and evolution of collective cognitive responsibility, give an insight in particular initiatives to change teacher education and to change learning process, and discuss what is the impact on kindergarten children's mathematical competence after the implementation of a software application. Some authors propose the combination of gamification with game technologies in order to produce smart learning environments or give insight on activity model designed to support the development of an innovative twenty-first-century learning environment. There are summarised ideas on virtual reality applications in education which highlight how a variety of digital pedagogical approaches can be used to support learning. Reader will find different ideas which can be implemented in the study process to support knowledge building in technology-enhanced learning.

Exploring Collective Cognitive Responsibility Through the Emergence and Flow of Forms of Engagement in a Knowledge Building Community

Calixto Gutiérrez-Braojos, Jesús Montejo-Gámez, Leanne Ma, Bodong Chen, Marta Muñoz de Escalona-Fernández, Marlene Scardamalia, and Carl Bereiter

Abstract Knowledge Building is a SMART pedagogy that encourages students to take collective responsibility for knowledge advancement; Knowledge Forum technology is designed to support them in this work. This study explores the application of a new method to assess the emergence and evolution of collective cognitive responsibility (CCR) based on peer valuation of impactful builders in an undergraduate course at the University of Granada. Scientometric and economic indices were adapted to analyze the equidistribution of impactful builders in the community and the flow of impact builders across various discussion threads and to identify features of students who were considered as impactful builders. Results point to the challenge of developing CCR in a university course where there is a lot of content to cover over a short period of time. While there are emergent impact builders and collaborators across the discussion topics, many students remained as less committed participants in the course. Students shared that impactful builders were those who shared new ideas and facilitated collective understanding. This study suggests that peer valuation of students' contributions could be one way to approximate students' engagement in CCR and potentially empower less committed participants to become impactful builders and collaborators. Further implications are discussed within the context of education for knowledge creation.

C. Gutiérrez-Braojos (✉) · J. Montejo-Gámez · M. Muñoz de Escalona-Fernández
Universidad de Granada, Granada, Spain
e-mail: calixtogb@ugr.es; jmontejo@ugr.es; mmef@correo.ugr.es

L. Ma · M. Scardamalia · C. Bereiter
University of Toronto, Toronto, ON, Canada
e-mail: leanne.ma@mail.utoronto.ca; marlene.scardamalia@utoronto.ca; carl.bereiter@utoronto.ca

B. Chen
University of Minnesota, Minneapolis, MN, USA
e-mail: chenbd@umn.edu

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1 Introduction

The prosperity of today's societies depends on the capacity of citizens to deal with change and increasing complexity across all aspects of modern life (Bereiter & Scardamalia, 2018; David & Foray, 2003; Homer-Dixon, 2000). Education plays a critical role in equipping students with the fundamental competencies to grapple with complex issues, such as climate change, economic inequalities, and political unrest. As Daniela and Lytras (2018) point out, "the education sector must adopt SMART pedagogies to adjust flexibly and to apply innovations for the development of the individuals' knowledge, skills, and competences." The essence of SMART education consists of putting pedagogy and technology together to create environments for developing capacity to take part in the advancement of a knowledge society (Gutiérrez-Braojos, Montejo-Gámez, Marín-Jiménez, & Martinez, 2018; Zhu, Yu, & Riezebos, 2016). Spector (2014) asserts that SMART learning environments should promote (i) conversation between learners, (ii) reflection to elicit self-assessment, (iii) innovation, and (iv) self-organization. In this sense, SMART pedagogies can be thought as approaches to teaching that empower learners to develop innovative talents that involve higher levels of thinking, creation, and collaboration augmented by technology – in essence, the capacity to create knowledge (Bereiter & Scardamalia, 2014).

Knowledge Building (KB) theory, pedagogy, and technology have been developed over the past several decades to enhance students' capacities to create new knowledge and to engage in sustained creative work with ideas (Bereiter & Scardamalia, 2003, 2010; Scardamalia & Bereiter, 1991; Scardamalia, Bereiter, McLean, Swallow, & Woodruff, 1989). KB is differentiated from traditional pedagogical approaches through its emphasis on community knowledge rather than individualistic goals and turning over high levels of agency to students. Grounded in a set of 12 principles (Scardamalia, 2002), KB promotes a sense of collective cognitive responsibility among students and epistemic agency toward the continual improvement of ideas. Students work together to identify shared problems of understanding, develop and test their theories, consult expert resources, and engage in discussions to create coherence among ideas and advance the community knowledge. The teacher empowers each student to be an active member of the community and to assume increasing levels of agency for setting goals, monitoring progress, and managing the creation of community knowledge. With the support of technology, KB can happen anywhere, anytime, and in any subject area (see Chen & Hong, 2016 for review). KB helps achieve goals underlying SMART pedagogy.

1.1 Knowledge Building Discourse

Knowledge Builders create knowledge of value to a community in order to advance individual and collective understanding (Scardamalia & Bereiter, 2003). This means that ideas need to be externalized as shared conceptual artifacts, so that students can connect these ideas and achieve coherence out of idea diversity. To achieve this, students share and build on each other's ideas through collaborative, constructive discourse (van Aalst, 2009). During Knowledge Building discourse, students define and analyze the problem(s), introduce new ideas, consider promising ideas, compare/contrast ideas, evaluate information sources, reflect on their discourse, and work toward building higher-level ideas (Scardamalia & Bereiter, 2016). Examples of productive discourse moves include formulating thought-provoking questions, theorizing, obtaining evidence, working with evidence, creating syntheses and analogies, and supporting discussion (Chuy, Resendes, & Scardamalia, 2010).

1.2 Knowledge Forum Technology

Knowledge Forum (KF) is a digital asynchronous communication platform optimized to support Knowledge Building. KF is designed to keep ideas at the center of online interactions so that students are in position to take collective responsibility for knowledge advancement and engage in sustained Knowledge Building discourse (Scardamalia, 2004). Ideas are contributed in the form of notes (i.e., multimedia objects) into a KF community space to be further elaborated by other members of the community. Students can build on each other's ideas by extending or critiquing existing ones or adding new ideas. Inside KF notes, there are a set of theory-building scaffolds ("my theory," "new information," "I need to understand," "this theory does not explain," "a better theory," "putting our knowledge together") which encourage idea improvement and idea coherence. These scaffolds are customizable. Additionally, students can use the promising ideas tool to highlight promising directions to make new advances (Chen, Scardamalia, & Bereiter, 2015) and the idea thread mapper tool to make connections across multiple discussion threads (Zhang et al., 2015). These tools support group monitoring and provide feedback as a natural part of Knowledge Building discourse, helping to sustain idea improvement.

1.3 Collective Responsibility for the Advancement of Knowledge

A key social dynamic in a Knowledge Building community is *collective cognitive responsibility* (CCR), which refers to the coordinated efforts of all members of the community to advance the state of the community knowledge. Scardamalia (2002) explains, “Collective responsibility […] refers to the condition in which responsibility for the success of a group effort is distributed across all the members […], students take responsibility for knowing what needs to be known and for ensuring that others know what needs to be known” (pp. 68–69). Traditionally, cognitive responsibility is left to teachers. In Knowledge Building students are encouraged to take ownership of their learning at the highest levels. Studies examining CCR in Knowledge Building communities reveal that students interact closely with one another (Philip, 2010) and rotate leadership (Ma, Matsuzawa, & Scardamalia, 2016) to facilitate the flow of ideas. Over time, the teacher becomes only one of many important contributors to the community knowledge (Zhang, Scardamalia, Reeve, & Messina, 2009).

In this chapter, we explore new measures to assess the emergence and evolution of CCR. Since a KB community self-organizes in the creation of knowledge, we propose that CCR can be estimated from the number of contributions a member has that are valued by the community by highlighting the importance of peer valuation. Furthermore, we propose that CCR, in its fullest form, occurs when the shared recognition of ideas is equidistributed by members along topics of discussion. Ideas are generally recognized by members of a community to be “impactful” because they are original and promising solutions to shared knowledge problems and/or instrumental to facilitating an equitable distribution of knowledge (Gutiérrez-Braojos, Chen, & Resendes, 2013). Gutiérrez-Braojos (2011) refers to “impactful builders” as students who provide impactful contributions which help others achieve an integrative understanding of the collective knowledge produced up to that moment. Thus, in order to operationalize impact builders, we adapt scientometrics used to measure researcher impact. In order to operationalize CCR, we adapt economic measures of inequality to analyze the equidistribution of impactful builders in a KB community, as well as the flow of impact builders across various discussion threads in time.

2 Objectives

The main purpose of the study is to develop a new method for analyzing CCR and examining how members in a KB community are involved in CCR:

O1: *Developing and comparing measures of impactful builders*
O2: *Exploring the equidistribution of impactful builders*
O3: *Defining member roles based on ranked measures of impactful builders*
O4: *Exploring the flow of impactful builders across topics of discussion*
O5: *Understanding the value of the impactful builders’ contributions for the community*

3 Methodology

3.1 Sample and Learning Environment

The participants in this study were 57 undergraduates (47 females, 10 males, 19 years old) enrolled in a course on educational research, as part of a 4-year degree program in Social Education at the University of Granada in Spain. Over the span of 16 weeks, students engaged in Knowledge Building discourse and worked toward advancing collective understanding around seven topics of interest concerning educational research (What is "good" social-educational research?; research paradigms; how to conduct information searches, how to write a research paper; mixed data-gathering procedures; qualitative and quantitative data analysis; how to present and disseminate research; and a synthesis of all course topics). The course was designed in blended mode, with Knowledge Forum serving as the online space to create, share, and improve ideas both in and out of class. Students met face-to-face twice a week to collaboratively solve a set knowledge problems on a discussion topic; they worked together as a whole community and in small groups. These small groups, generally consisting of five students, were instrumental to facilitating students' comprehension of the course content. As well, throughout the 16 weeks, students worked in their portfolios to reflect on their learning and how they contributed to advancing the community knowledge. Students were also encouraged to reflect on the most important ideas in the community, cite their peer's ideas, and justify their choices.

In this chapter, we used the students' portfolios to extract citation metrics and identify impact builders and the emergence of CCR during Knowledge Building across three of the seven course topics: (i) research paradigms (RP from now on), (ii) mixed data-gathering procedures (DG), and (iii) qualitative and quantitative data analysis (DA).

3.2 Development of Measures and Application of Analytic Strategies

This study adopts a pragmatic approach to research design. More specifically, we applied a sequential explicative mixed design (Creswell, 2003) in two phases. In the first phase, quantitative analyses were performed in order to tackle O1, O2, O3, and O4. For the quantitative analyses, Google Sheets was used to organize the data and calculate the student indexes, SPSS was used to run the statistical analyses (mean, standard deviation, etc.), and R was used to compute Gini coefficient and Lorenz curve (which are explained below). In the second phase, qualitative analyses were carried out to complete the analysis associated with O5.

3.2.1 Phase 1: Quantitative Analyses

O1: Developing and Comparing Measures of Impactful Builders

With the aim to calculate different indices of impact builders, students' portfolios were collected after finishing the course. Students' portfolios included mentions (i.e., citations) to all the contributions in the KB community that they valued as relevant, as well as their reasons for choosing those contributions: (a) it provides new ideas, (b) it facilitates understanding, or (c) other reasons (open comments). Next, data from each KF contribution (i.e., author/authors, KB scaffolds employed, note title and content, and the previous note that the impactful note built onto) was extracted and compiled into a spreadsheet that allowed us to quantify the impact of one's contributions regarding the addressed topics among peers. These indices, which constitute the variables of the study, are defined as follows:

Value of Impactful Builder (VIB)
Analogous to what happens in a scientific research community, the value that peers give to one's contribution is measured using the number of citations obtained per contribution provided. In other words, the relative value of an impact builder is

$$VIB = RMC / AC,$$

where RMC stands for the received mentions in the community and AC refers to the number of academic contributions (i.e., nonsocial contributions) made by the student. This index should be interpreted as the mean value that peers give *to each contribution* that this student built onto.

Community's Valuation of Contributions (CVC)
The second proposed index provides a measure of a student's performance that avoids the possible bias induced by VIB. Concretely, the community's valuation of contributions is

$$CVC = VIB^{*}RMC. \text{Therefore, } CVC = RMC^2 / AC,$$

which weighs the value of VIB by using the received mentions. Thus, CVC informs us about those builders who generate many impactful contributions. The square in the numerator promotes the overall importance of being recognized by peers as opposed to producing a few high-quality contributions.

Contribution to the Advancement of Ideas Valued by the Community (CAC)
The main drawback of VIB and CVC is that they are focused on peer recognition per contribution without providing a fixed range of values, thus making it difficult to compare across discussion topics when the total number of contributions, participants, and citations could vary greatly. In order to address this, we developed a third

index to take into account the ratio of mentions received by one individual with respect to the total amount of mentions in the whole community. Thus, the contribution to the advancement of ideas valued by the community is

$$\mathrm{CAC} = 100^{*}\left(\mathrm{RMC} / \mathbf{TRM}\right),$$

where **TRM** represents the total amount of mentions received in the community (i.e., the sum of the values of RMC along all the members of the community). The CAC value for one student should be interpreted as the percentage of the peer recognition provided in the community that was devoted to the student (Gutiérrez-Braojos, Chen, & Resendes, 2013). This index, with values ranging from 0 to 100, has two main advantages: CAC not only allows us to compare students from different contexts but also makes it possible to connect any empirical data with an ideal situation of equidistribution of impact, where values of the index per individual should be equal to (100/*N*), where *N* stands for the number of members in the community.

O2: Exploring the Equidistribution of the Builders' Impact

Once the value of indexes was quantified for any student, CCR was analyzed in terms of measures of inequality. In particular, this study takes advantage of Lorenz curves (Lorenz, 1905) for the distribution of wealth and the Gini coefficient (Gini, 1912, 1921) applied to VIB, CVC, and CAC. When applied to these measures of impactful builders in a KB community, the Lorenz curve displays the relationship between the percentage of impact accumulated by a group of members with respect to the total impact in the community (y-axis) and the percentage of the population that such a group accounts for (x-axis). This curve is usually compared to the ideal situation of CCR, where impact is equally distributed within the community.

Figure 1 displays an example of Lorenz curve for a generic measure of impact I. The gray line, which represents the measurements provided by index I, goes through point (20, 0). This means that the group of members that accounts for 20% of the community does not accumulate any impact or, in other words, there are several individuals that account for 20% of the community and whose values of I are 0. Likewise, the gray line also goes through point (80, 60); thus the group of individuals that accounts for 80% of the community accumulates 60% of the impact. In turn, in the ideal situation where impact is equally distributed (black line), all members share the same value of I. In this case, the group of individuals that accounts for 20% of the community accumulates 20% of the impact; also, the group of individuals that accounts for 80% of the community accumulates 80%, etc. This implies that the percentage of impact accumulated by a group of individuals is always equal to the percentage of the population that such a group accounts for. In other words, whenever the value of the index I is equidistributed, the Lorenz curve associated with I is a straight, diagonal line.

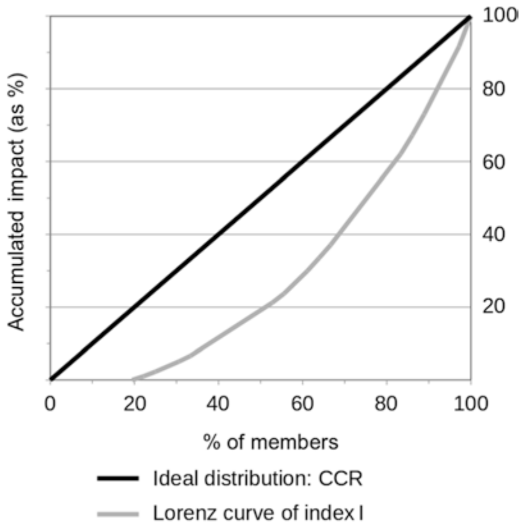

Fig. 1 Example of Lorenz curve

The cumulative nature of the Lorenz curves provides a visual tool to observe how much a community approaches the ideal situation of CCR: the closer the Lorenz curve is to the straight line, the closer is the community to the state of CCR. There are measures that quantify the difference between the curve and the straight line. One of them is the Gini coefficient (Gini, 1912, 1921), whose value is proportional to the area between the two lines and is usually used as a measure of inequality. In this scope, lower values of the Gini coeffient associated to the index I indicate more equality in the distribution of the impact according to I.

O3: Defining Member Roles Based on Ranked Measures of the Builders' Impact

Subsequently, to deal with O3, we proceeded to identify member roles based on their levels of commitment to CCR across each of the three topics of interest. Concretely, for each index and topic of discussion, the students were classified into three levels of commitment: impactful builders, collaborators, and less committed participants. The students were classified into these roles based on the position of their score along the y-axis of the Lorenz curve (i.e., their position with respect to three percentile ranges of the VIB, CVC, and CAC values). For example, students whose scores were above the value 66.66 on the y-axis of the Lorenz curve were ranked as "impactful builders." Students whose scores were less than the value 33.32 on the y-axis of the Lorenz curve were ranked as "less committed participants" in the community. Students whose scores were between 33.33 and 66.65 on the y-axis of the Lorenz curve were ranked as "collaborators." In this way, each index provides groups of individuals according to their engagement measured by the index. Although one individual can be ranked as different roles according to different indexes, it is expected that the most committed students remain as impactful for every index. These members of the community are called thematic impactful builders.

O4: Exploring the Flow of Impactful Builders Across Topics of Discussion

Since the study goes through different topics (and through time), it is interesting to look for impactful builders who keep their role along different topics or along wide lapses of time. To do this, notions of transience and continuance introduced by Price (1986) in the framework of Scientometry have been adapted to our scope. Price (1986) attended to understand dynamics of research papers' authorships along time. For this purpose, he considered continuant authors, who publish every single year in this topic, and transient authors, who publish just once or a few isolated times. These naive ideas were concreted to different roles of publishing authors according to their commitment with the research in the topic during a 5-year lapse of time. Taking advantage of the analogy between publicating in a research journal and being cited by a peer in a KB community allows to take Price's roles to describe commitment of students with the CCR. Concretely, for any fixed index, one-topic impactful builders are called just "impactful builder," whereas "continuant impactful builders" refer to those individuals who are impactful along two topics. Likewise, a "core impactful builder" is someone who remains as impactful in every topic of interest in the community. Price's terminology allows to analyze the flow of each member's roles within each topic of discussion, i.e., temporal fluctuations of the levels of commitment with CCR based on each index. This helped us identify whether there were students who had consistently high levels of commitment to CCR over time (i.e., those who remained stable as "impactful builders").

3.2.2 Phase 2: Qualitative Analyses

O5: Understanding the Value of the Impactful Builders' Contributions for the Community

We analyzed the reasons for which the impactful builders' contributions were selected. Recall that when students selected their peer's contributions, they indicated their value according to three options: (i) it advanced the community knowledge, (ii) it facilitated my own understanding, and (iii) other options, in which students had to further explain the value of their contribution selected. In order to understand additional reasons why a student may choose a contribution to be impactful, explanations in the "Other options" qualitative analysis were applied by two experts with 100% inter-rater agreement. Two new reasons were found: (iii) it added new tools or resources for the community, and (iv) it provided suggestions to improve the communication or written expression. These four reasons are then compared across the three indexes and the three topics.

4 Results

4.1 Phase 1: Quantitative Analyses

4.1.1 Analyses of Indexes and Distributions Across Topics (O1, O2)

Table 1 shows the relative value of impactful builder (VIB), community's valuation of contributions (CVC), and contribution to the advancement of ideas valued by the community (CAC) values across the three discussion topics of (i) research paradigms (RP), (ii) mixed data-gathering procedures (DG), and (iii) qualitative and quantitative data analysis (DA). It can be seen that different patterns emerge in the mean values of the indices along the topics of discussion. Given the min and max values, the means are relatively low (i.e., close to 0). However, a more consistent pattern is observed in the indices regarding the behavior of the median along the discussion topics. While in the discussion topics DG and DA, 50% of students have a median value of VIB index equal to zero; in the RP topic, the median is equal to 0.18 for VIB, 0.33 for CVC, and 1.08 for CAC (Table 1).

Likewise, in all three indices, the coefficient of positive asymmetry (g) indicates that the distribution is asymmetric to the right side, that is, low values are observed for most students, especially in the topics DG and DA, independent of the index (VIB, CVC, CAC). As well, the coefficient of variation for the three indexes is lower in the topic RP with respect to the rest of the topics of discussion (DG and DA). This indicates that the data are more concentrated in the mean in the first topic of discussion. Finally, the Gini coefficient for "PR" presents a lower concentration than in the rest of topics, especially in the VIB index (G = 0.56).

Table 1 Measurements associated with VIB, CVC, and CAC

	Indices of the builders' impact								
	VIB			CVC			CAC		
	RP	DG	DA	RP	DG	DA	RP	DG	DA
Mean	0.24	0.23	0.27	0.93	1.02	1.26	2.17	1.9	1.81
Me	0.18	0	0	0.33	0	0	1.08	0	0
Min	0	0	0	0	0	0	0	0	0
Max	1	3	4	10	18	25	11	15.68	24
Sd	0.25	0.56	0.79	1.74	2.97	4.36	2.61	3.67	5.38
CV	1.04	2.43	2.93	1.87	2.91	3.46	1.2	1.93	2.97
g1	1.21	3.47	3.12	3.38	4.18	4.1	1.75	2.02	3.18
G	0.56	0.85	0.9	0.73	0.89	0.92	0.59	0.81	0.91

Figure 2 shows the Lorenz curves associated with VIB, CVC, and CAC where each kind of line indicates a topic of discussion. The x-axis represents the accumulated percentage of members; the y-axis represents the accumulated percentage of impact according to the indices (VIB, CVC, CAC), and the diagonal shows the ideal scenario for CCR in which the number of impactful contributions and author is at a 1:1 ratio. The two horizontal lines of the graphs divide their area into three levels of commitment to CCR. The students who overcome the point 66.67 of the y-axis are impactful builders, and who stand between the 33.33 and 66.667 of the y-axis are collaborators, the rest are considered as less committed participants.

The following observations can be made from Fig. 2. Regarding RP, the Lorenz curve of VIB contains the point (70, 33.33), i.e., 70% of the population accumulates 33.33% of the impact per contribution in the discussions about the research paradigms. Likewise, in the topic DG, the Lorenz curve of VIB passes through (90, 33.33). This means that 90% of the community accumulates 33.33% of the impact weighted by the number of impactful contributions when community discussed about DA. Also, the curve of CAC in the topic DG goes through (90, 33.33), which represents that 90% of the community accumulates 33.33% of the percentage of citations received or, equivalently, 10% of the community accumulates two third parts of citations received concerning the topic DA. The Lorenz curves show that impactful contributions in the community are generally concentrated in a group of students. Whereas the number of impactful contributions is considerably more equidistributed in the topic of RP regardless of the indices (VIB, CVC, CAC), there is less equidistribution in the topics of DG and DA. To summarize, it can be seen that impactful builders and collaborators represent 10–30% of students, whereas less committed participants represent 70–90% of students.

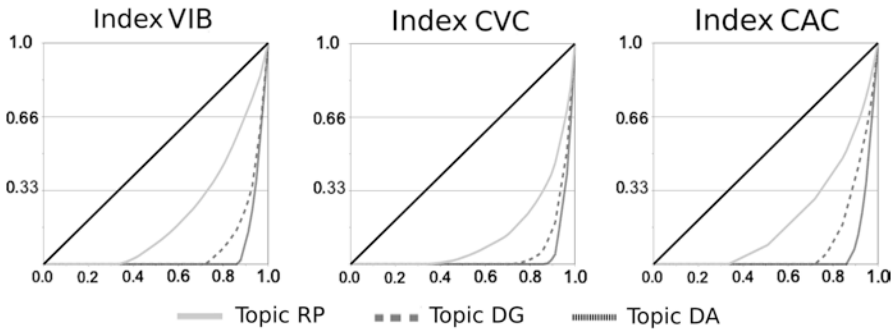

Fig. 2 Lorenz curves associated with VIB, CVC, and CAC

4.1.2 Roles Identification and Analysis of the Flow of Impact Builders (O3, O4)

Figure 3 shows the distributions of impact in the community according to the criteria previously described, as well as the transitions of roles through the topics of interest. Broadly speaking, impactful builders constituted at most 11% of the community, and less committed members represented the majority of the community (at

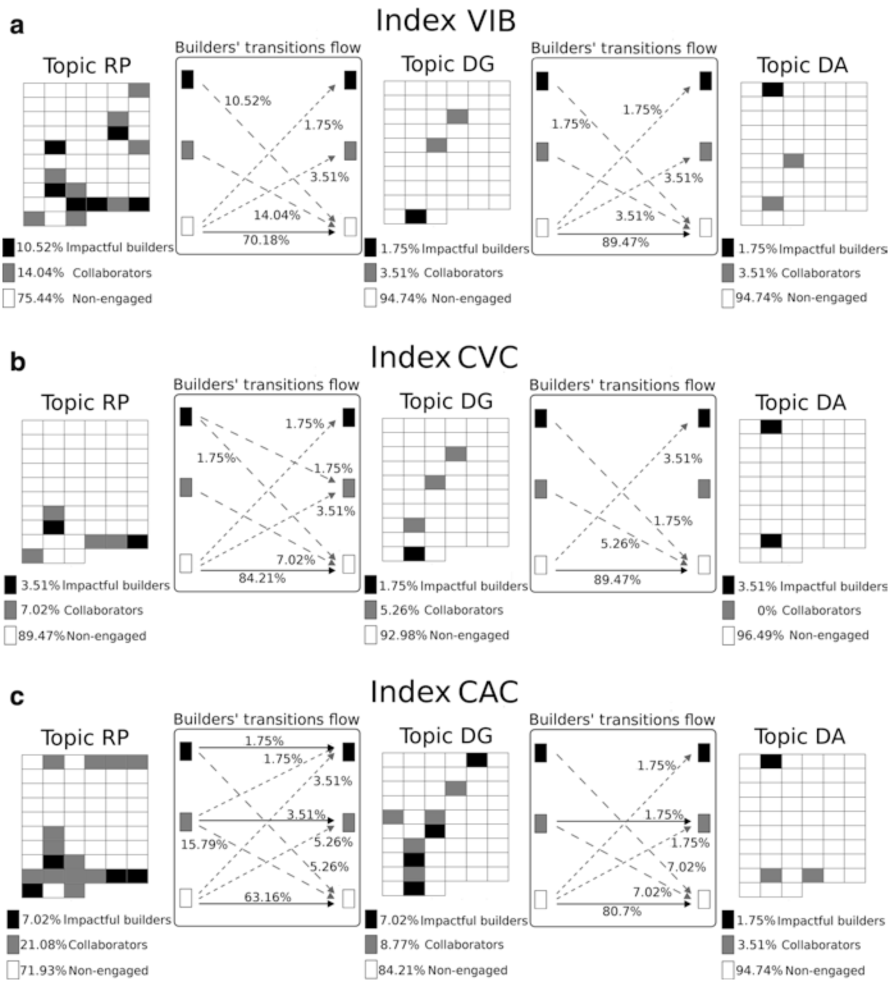

Fig. 3 Identification and flows of impact builders. *Note a):* Locations in the tables represent students; the same location in the table corresponds to the same student. These locations number students according to their location in the table (from left to right and top to bottom). The numbersare used below to refer the students. *Note b):* Identification of roles according to VIB, CVC, and CAC indexes and dynamics of impact along the topics. *Note c):* All the percentages are expressed with respect to the number of participants in the study

least 71% of students). The proportion of students who held consistently high levels of commitment to CCR over time (impactful builders and collaborators) was 4% in all the topic transitions.

In what concerns the impact per contribution in the community (VIB index), a more balanced recognition for peers' contributions in the community was found in topic RP (10.52% of impactful builders) than topics DG and DA (94.74% of less committed members in both cases). Also, the transitions between topics were strong, in such a way that neither consistent impactful builders nor collaborators were found over the three topics of discussion. As for the valuation of the contributions by the community, the CVC index provided a slightly more unbalanced situation for topic RP than the VIB index (less committed individuals amounted to 89.47% of the community). Nevertheless, for topics DA and DG, this index displays a similar situation than the previous, with a scarce level of impact and collaboration (in topic DA the recognition of the whole community was concentrated on two single students) and drastic transitions due to changes in topic. Finally, regarding the ratio of received mentions, the CAC index draws a slightly different scenario in two senses. On one hand, this measure led to a little more balanced depiction of roles for DG with 84.21% of less committed members, in contrast to the ratios of more than 92% that arose from the other indexes. On the other hand, CAC was the only index that allowed to detect a consistent core collaborator along all topics and a consistent impactful builders between RP and DG. In spite of this, a global outlook of results reveals lack of continuant impactful builders in the community.

As previously mentioned, none of the indexes revealed consistent or core impactful builders along the three topics of interest. What is more, the ratio of impactful builders is less than 11% for every index and topic of discussion. Nevertheless, for a given topic, results did expose thematic impactful builders, i.e., members in the community who are recognized as impactful builders according VIB, CVC, and CAC at the same time. Indeed, Fig. 3 shows that contributions made by students 44 and 54 (in the sequel S44 and S54, respectively) were positively valued when working on the topic RP. Likewise, student 56 (S56) was recognized by their peers concerning topic DG, and student 2 (S2) was identified as the thematic impactful builder for topic DA.

4.2 *Phase 2: Qualitative Analyses*

4.2.1 Analysis of the Value of Impactful Builders' Contributions (O5)

Figure 4 shows the reasons that led to the selection of impactful builders. The members of this community have selected most of the impactful builders based on four reasons: (i) contributions which improve ideas with new ideas or vertical improvement of knowledge, (ii) contributions which facilitate the understanding of others or horizontal improvement of knowledge, (iii) contributions which provide tools and resources, and (iv) contributions which offer feedback to improve aspects related

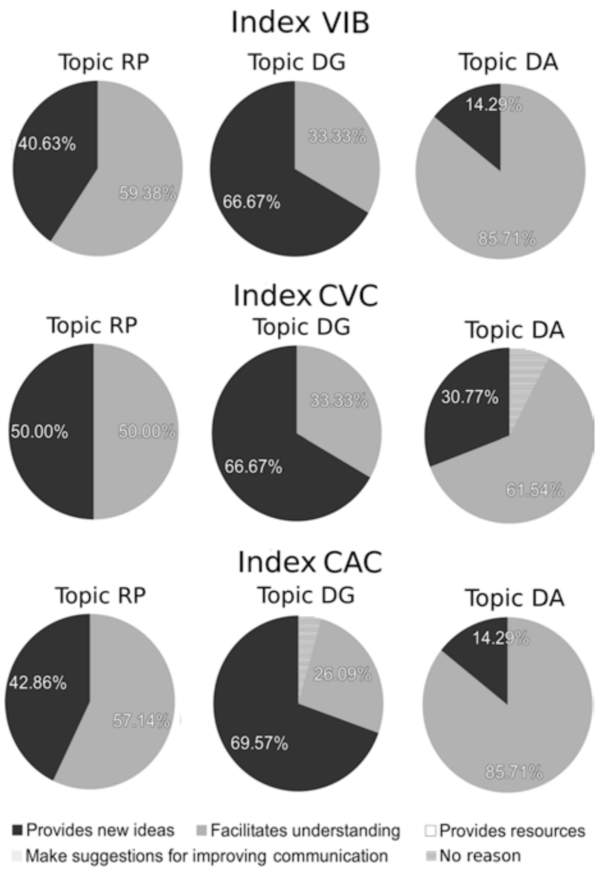

Fig. 4 Summary of the reasons why impactful builders' contributions were positively valued by the community

with communication of ideas. In this study we have not found any impactful builders who were selected by the community for contributing resources and tools nor for providing elements related to the communication of ideas.

With regard to the VIB Index, a total of 32 members (59.37% of the members in the community) selected impactful builders because they elaborated ideas which facilitated the comprehension about the topic RP. In the topic DG, from a total of eight members, 66.66% of them selected impactful builders because they contributed new and better ideas. And in the topic DA, from a total of seven members, 85.71% of them selected impactful builders because they facilitated the comprehension of ideas in the community. Regarding CVC Index, from 20 members in the topic RP, 50% of them selected impactful builders because they contributed new and better ideas. In the topic DG, from a total of six members, 66.67% selected impactful builders because they contributed new and better ideas. And in the topic DA, from a total of 13 members, 61.54% of the members in the community selected impactful builders because they facilitated comprehension in this topic. Finally, in the CAC index, from a total of 35 members in the topic RP, 57.14% of the members selected impactful builders because they facilitated the comprehension in this topic. From a total of 23 members in the topic DG, 69.57% of them selected impactful builders because they contributed new and better ideas. And, from a total of seven members in the topic DA, 85.71% of them selected impactful builders because they facilitated comprehension (Fig. 4).

5 Discussion and Conclusion

Knowledge Building (KB) is a SMART pedagogy that aims to foster collective responsibility for knowledge advancement in hybrid environments. This study explores the application of a new method to assess the emergence and evolution of *collective cognitive responsibility (CCR)* in a Knowledge Building SMART environment that fosters collective responsibility for knowledge advancement. Results are based on peer valuation of contributions, distribution of student efforts to advance community knowledge, and evolving member roles along various topics of discussion. In particular, indices from the fields of scientometrics and economics have been developed for the KB context and compared in order to achieve our objectives. Below, we restate the study objectives and summarize our findings.

O1: Developing and Comparing Measures of Impact Builders
We developed and analyzed three indices: value of impactful builder (VIB), community's valuation of contributions (CVC), and contribution to the advancement of ideas valued by the community (CAC). The VIB and CVC indexes allowed us to compare the impact per contribution between members within a community and topic of discussion. While VIB is useful to identify impact builders who get recognition from few impactful contributions, CVC is useful to identify students who generate many impactful contributions. However, both indexes have limitations to compare individuals along topics of discussion and communities. Indeed, two topics may generate different number of contributions. Likewise, some students might be more likely to contribute (or mention) than other students in one topic over another. In as much as the ranges of values of VIB and CVC depend on the number of contributions, members, and citations, it would be necessary to control these variables in order to compare members along various topics of discussion. Nevertheless, CAC is useful to identify students who generate many contributions, even if not all are considered impactful (i.e., the ratio of recognition they received from their peers). This last index of builders' impact allows us to compare across topics of discussion within a community but also across different communities, thus providing a perspective on the extent in which CCR is reached in a KB community.

O2: Exploring the Equidistribution of the Builders' Impact
The Gini coefficient and Lorenz curve were used to estimate the inequality in the distribution of impact by VIB, CVC, and CAC. Results demonstrated a relatively low level of CCR across the three topics of discussion, with generally 10–20% of students accounting for 66% of ideas. These results appear to mirror the Lotka's law (1926) or Pareto's law (1896), where productive efforts in a scientific communities are unequally distributed: a small prolific group of authors publish a great portion of the scientific productions, while the majority of authors publish a smaller number of scientific productions within a discipline. Similarly, we also found that the majority of impactful ideas generated in the community is concentrated in a minority of students. These results are aligned with those obtained by Gutiérrez-Braojos et al. (2017) in a similar cultural context (i.e., same university and subject about research methods in education). It is possible that lower levels of CCR occur in topics of discussion that involve more technical content (i.e., data gathering and data analysis) because it is more challenging and/or less interesting for students. In any case, it is likely that content difficulty could negatively influence student engagement with ideas. In this way, we suggest that CCR should not be intended to grow proportionally to time. On the contrary, features of the topic of discussion may influence the development of collective responsibility. Teachers' guidance may also play an essential role in order to suitably empower students to increase their levels of CCR.

O3: Defining Member Roles Based on Ranked Measures of the Builders' Impact
On the other hand, the reported CCR results lead to classification of students according to the amount of recognition provided by their peers. To do this, members of the community were organized into three levels of commitment per index (VIB, CVC, CAC) and topic of discussion (RP, DG, DA): impactful builders, collaborators, and less committed. The findings of this study expose small sets of both impactful builders and collaborators and wider groups of less committed members. Thus, these results confirm the above-mentioned trends exposed by Lorenz curves and Gini coefficients.

O4: Exploring the Flow of the Builders' Impact Across Topics of Discussion
Subsequently, the flow of roles were analyzed along the topics of discussion. Our results showed that few students were consistently impactful builders across the three topics of students, with many students remaining as collaborators and less committed participants. In addition, students' roles and flow of impact across discussions may be conditioned by the complexity of the topic. For example, less technical topics may have more students contributing as impactful builders and collaborators. What's more, "thematic" impactful builders may emerge based on students' interests in the topic of discussion. Thus, this method can be considered a multiscalar approach to know the commitment of the students. It would allow to understand the commitment of one student from several scales, e.g., for each topic of discussion, for closely related topics in a subject over time, even among unrelated topics of different subjects.

O5: Identify the Value of the Impact Builders' Contributions
In order to understand the value of the impactful builders for the community, the reasons why they were chosen by their peers were analyzed. Students indicated that a contribution from their peer was impactful because it provides new ideas; it facilitates comprehension; it makes suggestions for improving communication; or it provides resources. However, impactful builders' contributions were selected mainly because they facilitated comprehension or/and provided new ideas. During the discussions on research paradigms (RP) and data analysis (DA), impactful builders facilitated their peers' comprehension, whereas during the discussions on data gathering (DG), impactful builders provided new ideas that were valued by their peers. It is possible that students discuss more about the meaning and complexity of course content during the RP and DA topics but instead focus on understanding new techniques and approaches during the DG topic.

Future Directions
CCR is challenging to develop, especially in a university-level classroom context with challenging content to cover in a short period of time. While there are emergent impact builders and collaborators across the discussion topics, the majority of students in the class remain as less committed participants. These students were not very familiar with SMART pedagogies and perhaps even less so with KB, where the focus is shifted from acquiring knowledge for personal gain to creating knowledge for public good. Zhang et al. (2009) recommend the gradual release of agency to students so that they may assume higher levels of collective cognitive responsibility over time; that was the intention, but the course was only 16 weeks. In view of our results, we suggest that more effective feedback is needed, especially when complexity of topic is high and students are new to KB. We discuss ways in which teachers could take advantage of this evaluative approach to monitor and facilitate the engagement of students with CCR along different topics of discussion.

Our study suggests that peer valuation of students' contributions could be one way to advance students' engagement in CCR and potentially empower less committed participants to become impactful builders and collaborators. Therefore, one way to tweak the current pedagogical design with student portfolios is to use these indices as a way to promote deeper student reflections around how they have contributed to the advancement of community knowledge. For example, how are the self-reported impactful contributions similar to and/or different from the peer-nominated impactful contributions? Moreover, the equidistribution of students' commitment to CCR, as represented by the Lorenz curve and Gini coefficient based on CAC index, can serve as useful visual representations for teachers and researchers to compare the evolution of CCR across different topics and/or various classroom contexts.

Impactful contributions and impactful builders serve as useful constructs to help us to understand and analyze CCR during Knowledge Building (Gutiérrez-Braojos, 2011). The current study uses peer valuation and citation as one way to understand impactful contributions. Other criteria for identifying one kind of impactful contributions (i.e., new ideas) include the level of promisingness for advancing understanding (Chen et al., 2015) and the strength of connections between diverse ideas for improving conceptual coherence (Ma et al., 2016). Future studies should extend these ideas in various educational contexts, as well as develop new measures for understanding impact, such as the Hirsch-index, commonly used in scientometric research, or other indexes that weigh an individual's impact in the community by other relevant variables, such as the number of readings of peers' contributions, proper citation, and recognized quality of contributions of members who mentioned their contributions (see Gutiérrez-Braojos et al., 2017). In turn, these measures can be further refined through comparison of external evaluations by content experts in order to better interpret the quality of impactful contributions and, by extension, the characteristics of impactful builders, collaborators, and less committed participants. As a long-term goal, educational institutions will need to focus on preparing students to create knowledge for the public good (Bereiter, 2002; Tan, So, & Yeo, 2014). Whether it is at the university or the primary school, the importance of empowering each and every student to become an active knowledge creator remains an ever-pressing educational challenge (Scardamalia & Bereiter, 2010, 2016).

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The Italian Small School Toward Smart Pedagogy. A Cross-Reading of Opportunities Provided by the National Operational Program (PON) "For Schools 2014–2020 – Skills and Learning Environments"

Giuseppina Rita Jose Mangione and Samuele Calzone

Abstract School is increasingly protagonist of a process of renewal that is realized by rethinking the educational and training spaces according to principles supported by technological changes. In this context, a relevant program is the *Programma Operativo Nazionale (PON) per la scuola "Competenze per l'apprendimento" (The Italian National Operational Program "For School" – Skills and Learning Environments))* in that it promotes the upgrading of technology facilities and school learning environments, the strengthening of all key competences, and the adoption of innovative didactic approaches through a strong integration of investments funded by the European Social Fund (ESF) for training and skill improvement and the ERDF (European Regional Development Fund) for infrastructure interventions. In this chapter, we present a qualitative and quantitative analysis aiming to understand the dimensions that make it possible to set up a smart teacher training within the Italian small school context. The quantitative analysis will take into consideration the efficacy perceived by the training paths promoted by PON PNSD. Then, a qualitative study was conducted through group interviews administered to teachers

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Sections 2,3 Conclusions were written by Samuele Calzone.
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G. R. J. Mangione (✉)
National Institute of Documentation, Innovation and Educational Research, Naples, Italy
e-mail: g.mangione@indire.it

S. Calzone
National Institute of Documentation, Innovation and Educational Research, Florence, Italy
e-mail: s.calzone@indire.it

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of four schools – selected among those who had taken part in the training actions – so as to investigate those elements in the educational path that promote innovation, sustainability, and replicability.

Keywords Small school · Smart pedagogy · Teacher training

1 Small Schools in the Process of Teaching and Learning Improvement

School is increasingly protagonist of a process of renewal that is realized by rethinking the educational and training spaces according to principles supported by technological changes (e.g., mobility, interaction, and ubiquity). In this context, a relevant program is the *Programma Operativo Nazionale (PON) per la scuola "Competenze per l'apprendimento"* (The Italian National Operational Program (PON) "For School" – Skills and Learning Environments), active in the 7-year period between 2014 and 2020. It promotes the upgrading of technology facilities and school learning environments, the strengthening of all key competences, and the adoption of innovative didactic approaches through a strong integration of investments funded by the European Social Fund (ESF) for training and skill improvement and the ERDF (European Regional Development Fund) for infrastructure interventions.

In 2016/2017, 80,000 teachers were involved, and 5,670 schools were funded for the implementation of environments supporting smart pedagogy: alternative learning spaces (environments larger than classroom for diversified activities, with vertical and open groups, equipped with furniture and technologies that allow the remodeling of spaces in coherence with teaching activity), mobile labs (equipped with mobile devices and instruments for various disciplines, which can turn a "normal" classroom into a multimedia and interaction space), and "enhanced" classrooms (enriched with devices to integrate digital tools in everyday teaching).

Quite a large number of teachers trained in the use of new technologies and new environments for teaching are from those small schools. In Italy, over 10,000 for a total of 100,000 students – mostly attending the first cycle – are small schools located in mountain and island municipalities. Attracting and then ensuring that teachers remain in rural and remote community schools is one of the issues requiring attention for the improvement of teaching. The scientific community that is more closely connected to the issue of teaching and learning in rural schools, whether it considers rural schools as "lagging behind" and as unable to provide pupils desiring to achieve high levels of education with the same opportunities (Bouck, 2004) or it adopts an approach interpreting rural schools as the place for innovation and pedagogical experimentation (Kvalsund & Hargreaves, 2009), converges on the idea that training and professional development of teachers are at the basis of a change that leads small schools to be also smart schools. Teachers must be prepared and helped to understand the diversity of schools characterized by their geographical and territorial location and therefore to modify their teaching action (Darling-Hammond, 2005). The development of a "place-conscious teacher" rests on the definition and implementation of learning experiences that strengthen the context of rural pedagogy, using new environments and new technologies (Khan, Hadi, & Ashraf, 2013). "Smart" learning environments can be instruments of paramount importance not only for enriching, opening, and expanding the classroom but also for solving problems common in those schools, such as isolation, since they are normally found in places difficult to reach, and the extremely low number of pupils and learners who are part of them (Alpe & Fauguet, 2008).

2 The Italian National Plan for a Digital School and the PON "For School"

A renewal process in school is underway. In recent years, it has mainly been concerned with educational spaces, integration with local territory and production system, and instructional methodology, particularly related to the use of ICT.

The emergence of mobile technologies (wireless devices) – *spaces, materials, and technologies must adapt to users, not* vice versa (Ferri, 2013, p. 110–11) – has contributed to promoting a change in the educational paradigm as oriented to the adoption of laboratory teaching for acquiring knowledge and competences.

This change is described with the term *smart education* that indicates a framework based on three main elements:

> smart environments, smart pedagogy, and smart learner. Smart education emphasizes the ideology for pursuing better education and thus had better to be renamed as smarter education, which address the needs for smart pedagogies as a methodological issue and smart learning environments as technological issue, and advances the educational goals to cultivate smart learners as results. Smart environments could be significant influenced by smart pedagogy. Smart pedagogies and smart environments support the development of smart learners. (Zhi-Ting Zhu, Ming-Hua Yu, Peter Riezebos, 2016, p. 6)

In Italy, the educational renewal has recently been promoted by the education reform called "The Good School" (Law 107/2015, "La Buona Scuola") that through the National Plan for a Digital School (PNSD) (MIUR, 2015), which frames a cultural and system action (*creating a new vision of education in the digital era*[1]), moves in the perspective of *smart education* and of its elements (environments, pedagogy, learner). In fact, the reform addresses the need to provide the school staff with skills related to digitalization and technological innovation, helping an informed use of digital resources in the teaching practice and administrative activity.

In support of this Plan, the National Operational Program PON 2014–2020 "For School: skills and learning environments" has been involved. This, with the European Social Fund (FSE) and the European Regional Development Fund

[1] http://www.miur.gov.it/scuola-digitale.

(FESR), has intervened with two specific actions: "Infrastructural interventions for technological innovation, professionalizing laboratories and for learning of key competences" (Action 10.8.1, FESR) and "School staff training on innovative technologies and methodological approaches" (Action 10.8.4, FSE).

With the first action, schools across the country are invited to *build technologically advanced environments, well suited to support all research and update activities that can foster the development of the "net-school".*[2] There are three types[3] of funded interventions:

1. "Alternative learning spaces": these are environments that are generally larger than the classrooms to accommodate diversified activities, more classes, groups of classes (vertical, open, etc.), plenary meetings or small groups, etc. and are endowed with flexible furniture and technologies for individual and collective use to allow the continuous remodeling of spaces in line with the chosen teaching activity; a similar space can also be aimed at training teachers in schools or in territorial communities.
2. "Mobile labs": these are portable units or cabinets providing an array of specialized equipment and teaching tools (they can serve a variety of disciplines, including laboratory, scientific, humanistic, linguistic, and digital experiences), available to the whole school, which are able to make a "typical" classroom a multimedia and interactive space; in fact, the classroom is turned into a new space offering diverse functions and settings, from more traditional models to group work.
3. "Classrooms enhanced by technology": this refers to an appropriate number of traditional classrooms enriched with facilities for collective and individual use of the web and content, interaction of different aggregations in learning groups, whether wired or wireless, and integration of digital tools in daily instruction.

The participation rate[4] of schools on the national territory (Fig. 1) is high (over 83%): Puglia is the region that has the largest number of schools involved (compliance rate 93%), considering the network of active schools, while Sardegna is the least involved region (73%).

The second action is instead directed to the school staff and *aims to train them on issues of educational and organizational innovation* (Figs. 2 and 3)[5]:

Two specific types of instructor are also included in the training (introduced with "The Good School" reform), which involve teachers specialized in the use of technology in instruction. These profiles, i.e., "evaluation team" and "digital animator," respectively, are entrusted with experimenting and disseminating methodologies and processes of active and collaborative teaching, toward both learning evaluation and

[2] The actions are described in Avviso Ambienti Digitali (Digital Environments Notice) n. prot. 12810/2015, pg 4.

[3] Digital environments notice n. prot. 12810/2015, pg. 6.

[4] All data on the participation of schools and teachers, as well as on the results of the training satisfaction survey questionnaires were collected through GPUs 2014–2020, a system for the governance of the National Operational Programme – PON, http://pon20142020.indire.it/.

[5] Avviso Snodi Formativi Territoriali (Regional Education Hubs Notice) n. prot. 6076/2016, pg 4.

Fig. 1 Participation of schools. PON – Digital environments, Notice n. 12S10/2015

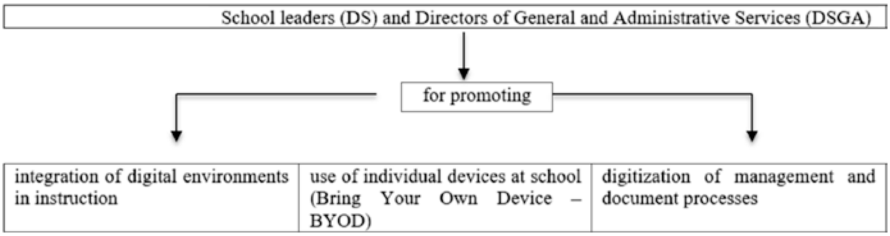

Fig. 2 DS and DSGA, PNSD-PON

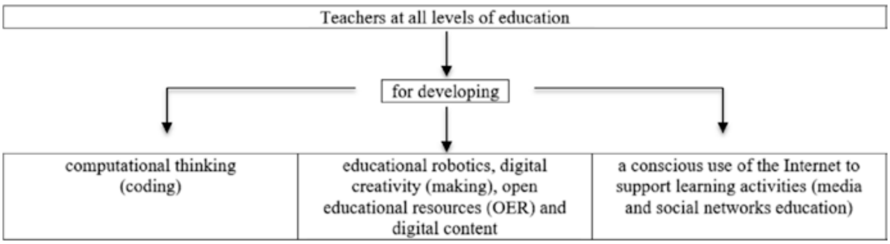

Fig. 3 Teachers, PNSD-PON

design of digital learning environments with particular attention to inclusion, computational thinking (coding), digital creativity (making), and the Internet of Things.

Training in digital innovation for the abovementioned profiles (PNSD-PON) has been activated since 2016 with the establishment of schools, called “Territorial

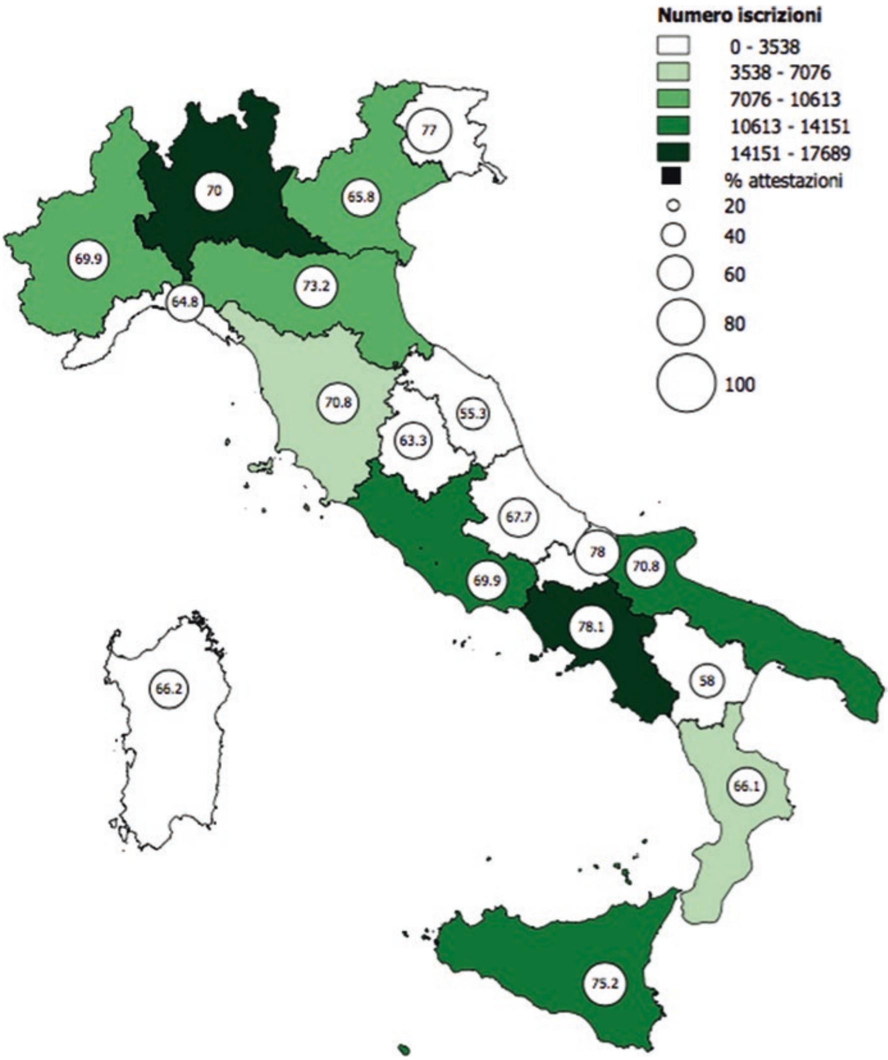

Fig. 4 Teacher's registrations and achieved qualifications by region, PNSD-PON. (They certify that the teacher has successfully completed the course)

Training Hubs", whose task is to manage and organize training activities through courses ranging from a maximum of 30 h for DS and DSGA to a minimum of 18 h for teachers. There are 276 hubs to date, involving about 118,000 among teachers and administrative staff. On the total, the highest concentration of hubs (55.1%) is found in more developed regions,[6] followed by less developed regions (37.7%), and, finally, by transition regions (7.2%) (Fig. 4).

[6]The PON 2014–2020 "for school", which is addressed to the entire national territory, is divided

3 Insight into the Small Schools Seen as a Privileged Field of Experimentation

Small schools represent a privileged field of experimentation for the actions promoted by PNSD and PON. In fact, they depict a situation of marginality in the Italian school system in which the reduced size of school staff, together with a teachers' greater propensity for experimentation, looking for innovative teaching models, allows a broader exploratory observation on the themes of *smart pedagogy*. In total, the teachers involved are 540 (465 women and 75 men) from 42 small schools, broken down according to the type of training chosen. As for the courses that require greater amounts of work experience, namely, digital animators and evaluation teams (which we will call *Level II courses*), the teachers are, respectively, 47 and 129, while they are 340 for more general courses (introduction to computational thinking, to educational robotics, etc., which we will call *Level I courses*) (Table 1).

Table 1 Schools and teachers from small schools involved in training, PNSD-PON

Regions	Total teachers
Transition Areas	**104**
Abruzzo	75
Molise	12
Sardegna	17
Less Developed Areas	**283**
Basilicata	11
Calabria	14
Campania	114
Puglia	6
Sicilia	138
More Developed Areas	**153**
Emilia Romagna	25
Friuli Venezia Giulia	64
Liguria	13
Marche	13
Piemonte	13
Toscana	25
Total	**540 Teachers**

Training	Total teachers
Digital Animators	**47**
Teachers	**364**
Evaluation Teams	**129**
Total	**540**

into three macro-areas: less developed, transition and more developed areas. The table (Fig. 1) shows a subdivision of regions by macro-areas.

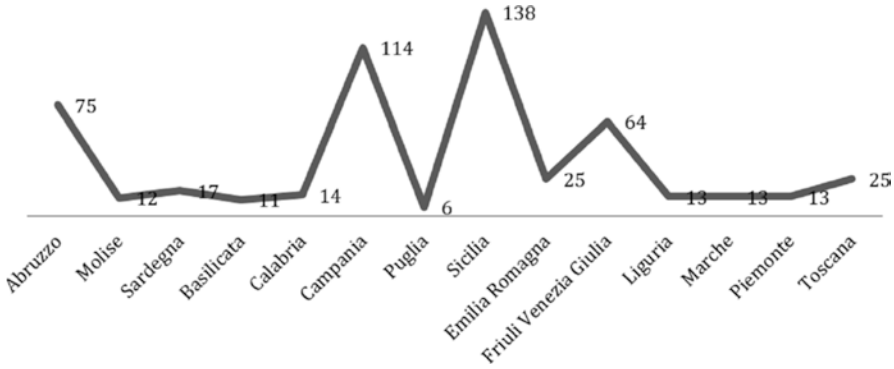

Fig. 5 Schools involved in training split by regions, PNSD-PON

The largest number of teachers involved in small schools (340) regards the general courses: this choice indicates the need to understand and experience a more inclusive pedagogy that utilizes technology to enhance learning and improve the school climate. With regard to the regional distribution, schools from Sicily (138 teachers) and Campania (114 teachers) demonstrate to be very interested in PNSD-PON training (Fig. 5).

As indicated in Table 2, for all types of training, mainly primary and lower secondary school, teachers have chosen to participate in PNSD-PON paths; these data are in line with those observed in other studies (Calzone & Chellini, 2016) on self-efficacy of teachers' professional skills. These two types of teachers demonstrate, when compared to others, a greater need for training and declare less confidence in their abilities.

To explore the issue of teachers' participation in the PNSD-PON training, as laid down in the evaluation plan[7] prepared by the managing authority in charge of the governance of the PON 2014–2020 "For School – skills and learning environments," some tools have been implemented for self-assessment. These are "online questionnaires on the perception of training," broken down into two phases: *before the course starts and after the course is finished.*[8]

Analysis of data reveals that the teachers involved in the Level I courses (more general courses on the use of ICT) are satisfied with the activity (66%) and believe the training to be suitable and useful for their skills; animators and evaluation team (Level II courses for more experienced teachers) are less satisfied (about 50%) and believe that the innovation proposed by the *smart pedagogy* should be transferred in other ways, such as interventions of peer education and of guidance to experimentation of innovative teaching methodologies (Table 3).

[7] The evaluation plan is provided by Regulation (EU) No 1303/13 art. 114.

[8] The expression "before the course starts" means to administer the questionnaire on the first day of class, while "after the course is finished," means the questionnaire is administered during the last class hour.

Table 2 Professions by type of training, PNSD-PON

Training	Number of teachers
Digital Animators	**47**
Technical and scientific disciplines in lower secondary school	16
Technical-engineering disciplines in upper secondary school	1
Humanities in lower secondary school	6
Information science in upper secondary school	1
Law, Economics and Social sciences in upper secondary school	1
Mathematics, Physics and Chemistry in upper secondary school	1
Primary school teachers	21
Teachers	**364**
Other	4
Technical and scientific disciplines in lower secondary school	39
Technical-engineering disciplines in upper secondary school	2
Humanities in lower secondary school	72
Information science in upper secondary school	1
Life and Health sciences in upper secondary school	2
Law, Economics and Social sciences in upper secondary school	7
Literary, artistic, historical, philosophical, pedagogical and psychological sciences in upper secondary school	14
Mathematics, Physics and Chemistry in upper secondary school	10
Pre-primary school teachers	46
Primary school teachers	167
Evaluation Teams	**129**
Other	1
Technical and scientific disciplines in lower secondary school	22
Humanities in lower secondary school	32
Information science in upper secondary school	1
Life and Health sciences in upper secondary school	1
Law, Economics and Social sciences in upper secondary school	2
Literary, artistic, historical, philosophical, pedagogical and psychological sciences in upper secondary school	1
Mathematics, Physics and Chemistry in upper secondary school	5
Pre-primary school teachers	9
Primary school teachers	55
Total Teachers	**540**

Table 3 Initial self-assessment

You are invited to self-assess the level of your digital skills regarding:
a) Information processing
b) Communication
c) Digital content creation
d) Safety

Concerning the initial self-assessment, 63% of the animators and 85% of the evaluation team's teachers report the importance of investing in content creation (digital competence) and cybersecurity; the purpose is to strengthen competence areas 3 and 4 of the DigComp 2.1 framework[9]:

Competence Area 3: Digital Content Creation

3.1 Developing digital content
3.2 Integrating and re-elaborating digital content
3.3 Copyright and licences
3.4 Programming

Competence Area 4: Safety

4.1 Protecting devices
4.2 Protecting personal data and privacy
4.3 Protecting health and well-being
4.4 Protecting the environment

To talk through the issues of *smart pedagogy* in depth means – in the first instance for expert teachers – dealing with the development and processing of digital content, paying attention to every aspect of copyright and more generally safety (*protecting devices, personal data, health, and environment*). Indeed, whether the teachers attending Level I courses are enthusiastic about the BYOD model – over 80% of those who intend to "strengthen personal motivation to implement didactic innovation through digital technologies" are in favor of its use in teaching – the animators, in light of security considerations, express strong doubts: only 71% believe it is good to promote school policies linked to BYOD.

4 Deepening and Case Study on Pilot Schools

The professionalization of training is an intention that highlights the need to strengthen a link between theory and practice, whereas professional practice, in its multiple facets, is the object of in-service training. The teacher training that is activated through the PNSD-PON actions should be finalized and related to the professional practice of reference, concretely and at the same moment in which it is put forward. This goal can be better understood from two different points of view or by key questions:

- How to make sure that what is learned from the theoretical point of view can actually be mobilized, in a real context, in a concrete act of teaching, making the learning experience innovative and safe at the same time.
- How to ensure that the practical experience is itself a training resource, which leads to reflection, to make explicit one's own routines, and to reorganize on a conceptual level overcoming the initial limits.

[9] *The Digital Competence Framework for Citizens* 2.1, 2017, JRS.

In a vocational training, practice has the double status of object and instrument. It is the training sphere of meaning, the very purpose of learning, being at the same time both means of learning and source of knowledge. But what practice is capable of instructing and under what conditions? In order to work more in detail on qualitative stability elements of the PON-PNSD paths, a study was conducted on four small schools selected on the basis of the following criteria:

1) Number of teachers[10] involved in the PNSD-PON training
2) Number of teachers trained, out of the total number of teachers of school staff

The first criterion allows a better understanding of the interest in digital innovations that small schools have; the second allows an understanding of the impact – in terms of dissemination of knowledge – which the PNSD-PON training has had in school (Table 4).

The in-depth study is aimed at identifying key elements to interpreting what the involved teachers declare in terms of *laboratory work*, *objective skills*, *visiting*, and *transferability*.

Laboratory Work in the Training Path The training situations referred to in the PON-PNSD paths should be guided by a common principle of action articulation and of reflection on action, that is to say, for channeling problems, analyses, experiences, and conceptualizations, functionally. The aim is essentially to implement a synergistic relationship between theory and practice, so that they can increase simultaneously (Mangione, 2018; Mottet, 1992). This call between theory and practice should not be understood as a bipolar balance, but, more specifically, as a three-time transformation movement that allows us to switch from practice to practice, through a mediation of theory, and from theory to theory, through a mediation of practice. All teachers should be able to resume their own practices and theories to

Table 4 Small schools with the highest number of teachers involved, PNSD-PON

Small schools	Number of teachers involved	Number of the total of teachers in school staff
I.C. BENEDETTO CROCE (AVIC807001) – VIA ALDO VIORO 83040 Flumeri (AV)	19	**140**
I.C.'L. PIRANDELLO – S.C.BOSCO′ (TPIC81800E) – PIAZZA ADDOLORATA 91021 – Campobello Di Mazara (TP)	16	**146**
I.C. FOGLIANISE (BNIC834005) Via La Riola 82030 Tocco (BN)	15	**80**
I.C. ORSOGNA (CHIC82300C) – CORSO UMBERTO 1 66036 – Orsogna (CH)	**15**	**84**

[10] The high number of teachers involved is due to the fact that the small schools are located within larger schools; it must be considered that such a broad involvement of teaching staff in these types of training activities has an impact in terms of dissemination of training results, even in places identified as small schools.

put them back into play through an investigation work. In this sense, the activities that should not be missing in these training paths are those related to solving a problem. Putting themselves on the line, through a fulfillment of theoretical and practical activities, could lead the teachers to mobilize knowledge and procedures and to test these latter for the management of specific educational situations in a small school.

Digital Skills for the Management of Teaching Innovation **B**ecoming a "digitally competent educator" requires not only to be able to use digital tools but also, and necessarily, to build up a theoretical-practical knowledge, which is closely interconnected either with disciplinary (content) or methodological (pedagogy) fields of teaching; in this sense we can speak of "technological pedagogical content knowledge" (Mishra & Koehler, 2006). A specific objective of the *PNSD* (National Plan for a Digital School) is the digital competence framework: "The challenge of digitalization is actually a challenge of innovation that must answer all questions related to a need to propagate innovation within an organization as complex as a school" (PNSD, 2015, p. 31). The issue of digital competence therefore becomes prevalent and important for the sustainability of educational innovations. *DigCompEdu*[11] is the first framework (Redecker & Punie, 2017) purposed to describe skills and competences that a teacher needs to have. The document, issued after input from the European Community, transposes the digital knowledge in a mature and more conscious way, by now heritage of innovative school's experiences carried out by the research world and the school. The levels of mastery (Ravotto, 2017) constitute a kind of manifestation of a competence; they should guide the construction of training paths, envisaging the development of skills through the digital content creation and paying attention to copyrights and, more generally, to safety.

Visiting as a Driver for the Maturation of Practical Knowledge and Transferability Visiting high-intensity innovative schools, where the quality of new "physical" learning environments (spaces, times, technologies, etc.) is combined with "quality relationships" between pupils and teachers, is an opportunity for enhancing the laboratory work formula within new training paths. In a mature idea of *visiting* or *training*, reciprocity should apply (Cerini, 2017), namely, learning is not only granted to those who visit a different environment but also to those who host, on the one hand, because they make contact with new points of view (in this case we would have the formula of "pedagogical" exchanges) and, on the other hand, because they need to reconstruct their own educational structure internally, to make it readable to the new interlocutors. An exercise in metacognitive distancing that can only benefit both parties. The *visiting* experience, already experimented in the Italian induction training, takes on a fairly shared model: presentation of school's innovative focus, meeting with referents and school heads, delivery of brief documentation, mutual observations in classroom while carrying out activities, and final

[11] DigCompEdu (Digital Competence Framework for Educators) is the acronym used by the European Commission working group and aimed at teachers/educators at all levels of education (including university and adult education) but, more gene to anyone working in the educational field, even in non-formal contexts.

moments of reconstruction and re-elaboration of the route. The visit can be equated with an "observational internship," which also occurs during the initial training of teachers but in the case of PNSD-PON training can have an added value due to the professional maturity of the teachers involved. The peer-to-peer relationship that a visit offers can support the progressive ability to read an educational context.

The teachers of the four selected schools were asked to provide "traces," i.e., their statements and/or responses indicating a propensity to accept the three areas mentioned and providing an authentic representation of the situations or reflections that may characterize the PON-PNSD path "soundness," or direct a new design.

The statements' positioning analysis on Likert scale and the subsequent narrative interpretation with regard to possible improvements of the paths facilitates the identification of which added-value elements to utilize into the system. The specific units of analysis were the teachers' answers in terms of desired target (*desiderata)*, placing the analysis in the field of grounded theory (Glaser & Strauss, 1967) and of interpretative principles that consider multidimensionality of the objects of investigation, and let the analysis emerge from these objects. The researchers shared a first interpretation of the texts by activating a process of analysis of what is perceived by the subjects involved in the analysis context.

The simultaneity of data collection and analysis has allowed a constant comparison of the labels generated by the first coding with observed events, categories and their properties, to continuously ask new questions to the data. The advancement stage of the analysis, that is, "open coding" based on the selection of minimum segments of text with a complete meaning for the research, led to the identification of areas that can determine organizational and educational changes in a laboratory work extended to the external territory.

A first reduction of the categories has been accomplished, also following discussions carried out within the INDIRE research group, and a transition to the "focused coding" phase has been achieved through a synthetic process aimed at finding coherence lines, previously distinct and fragmented.

The criterion for determining when to stop sampling of cases reported in each category was that of the theoretical saturation (Tarozzi, 2008). We chose to define a category as "saturated" when, proceeding further in sampling, the data become redundant. From the initial list of concepts (with their numerous sub-nodes), we thus reached a first synthesis of the following interpretive categories, namely, broader concepts able to connect more extensive portions of data occurring more frequently and conceptually dense.

5 Data Return and Reflections

A number of 56 out of 65 identified teachers answered the questionnaire as shown in Fig. 6. The involved school leaders supported the teachers to ensuring a good representation.

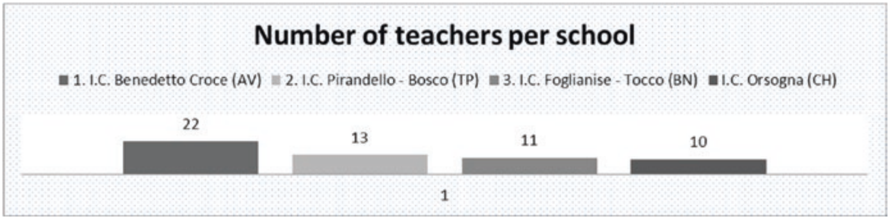

Fig. 6 Small schools involved in quantitative analysis

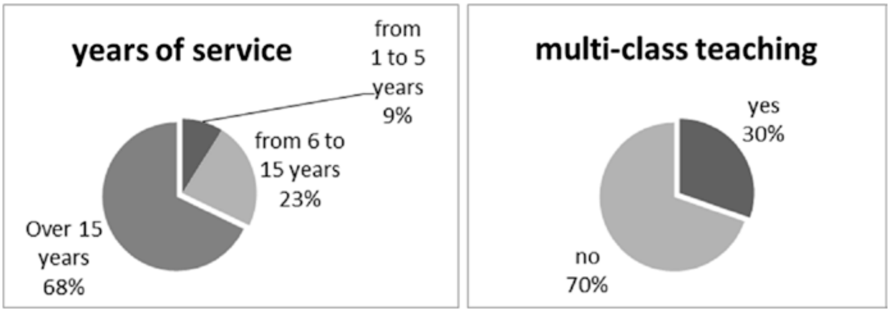

Fig. 7 Distribution of teachers by years of service in the small school and in multi-class teaching

67.86% of the teachers who took part in the PON-PNSD training declare over 15 years seniority, 23.21% from 6 to 15 years, and only 8.93 are teachers who place themselves at the beginning of their school practice. In particular, since these are small schools, 30.36% of teachers are in a multi-class teaching situation and therefore in a context that, in addition to the isolation of small schools, presents an extreme heterogeneity of the classroom, for age range and school level (Fig. 7).

Numerous and diversified have been the courses attended: from those dedicated to animators and evaluation team to those aimed at teaching staff in general and at improving educational capabilities through the use of resources and technological environments for learning, innovative teaching strategies (debate, coding, flipped learning), specific actions for inclusion, and competence-based education.

Laboratory work in the training path was the first area to be investigated through two stimulus-based questions that the teachers answered by positioning themselves along a scale of values. The first stimulus *not only coding but also putting yourself to the test* collects a positioning represented in Fig. 8 55.35% of teachers support the great usefulness of paths whose structure encourages "putting into practice" through the application of scenarios and situations based on a daily educational experience. The training courses should encourage a teacher to mobilize knowledge and procedures and test them for the management of specific educational situations. There is a 41.07% of them who considers "putting themselves to the test" very useful, with a minimum residual of teachers (3.57%) that, conversely, does not see any useful-

Fig. 8 Distribution of teachers by stimulus-based questions related to laboratory format of the path

ness in that during the training course. When questioned about "How would you imagine 'putting to the test' to be like?", the teachers respond by recalling a binomial of experience and innovation ("I imagine a challenge based on experience, but projected to innovation") able to provide tools for revising their own teaching method ("deepening and remodeling of the teaching method") and to involve them into a project activity ("an action of 'putting to the test' presupposes an important personal commitment in doing something, like a decision or a project, an action that implies a special mental effort whose result is not an aim in itself") and which accompanies them in new educational proposals ("teachers are continually called to put themselves 'to the test' rethinking their own knowledge and experiences to find new motivating situations suitable for any child's needs").

Again, with reference to a mainly laboratory training model, which makes the practice a moment of immersion and, at the same time, revision of the theoretical approaches, when questioned about the second stimulus *not only assimilating but also experimenting*, *66.07%* considers the training paths as places for pedagogical experimentation that allow them to define hypotheses, to create planning and rubrics for monitoring that may guide the didactic variations and the analysis of one's own practice. 30.36% of teachers deems it useful, and only 3.57%, as for the first stimulus, believes that it is not a fundamental component of the training courses.

Teachers were asked to express how they imagined a training path aimed at experimenting. What emerges is that experimentation is linked to a concept of laboratory work and dialogue, of focusing on the conflict among teachers' beliefs and routines ("maieutic method for the acquisition of complementary methodologies and for the enhancement of those already used"). Through the experimentation stages, teachers are under a constant observation and analysis of their practice ("defining hypotheses, planning by taking into account students' needs, constant monitoring and testing, varying one's own teaching choices, if necessary, and analyzing one's own practice"). In such a situation, those skills already gained can be enhanced and utilized as a motivational lever ("there is a need to start from a consolidation of teacher's competence but also from an implementation of their motivation, through functional training paths, and by planning, sharing, and monitoring all process areas"), combining tools and guidelines for the implementation of activities as well as monitoring grids ("by creating useful tools, as a result of the collaboration and guidance of experts"; "in-person activities where knowledge and procedures are tested; assisted development of monitoring rubrics").

Regarding the second area, i.e., *Digital Skills for the management of teaching innovation*, teachers were called to specifically reflect on digital competence related to safety.

37.50% of teachers regard as very useful and 37.50% useful the following: *Innovating pedagogy means taking care of development and processing of digital contents, paying attention to copyright aspects*. An innovative teaching should support a creation of materials made through digital technologies while still protecting the right of intellectual paternity of the original works and those works produced by the scholastic community. 21.43% of teachers, on the other hand, do not find it very useful to include these competence areas in the training paths, with a 3.57% who evaluates it as pointless. These teachers imagine a training where the educational practice is made central (*in a training path that is oriented to the creation of digital didactic content, teaching practice rather than technology should be placed at the heart and in favor of the development of skills, collaboration and active teaching, for problems and projects*). They imagine a context that encourages them to experiment with the digital creation through personal devices *(training should include laboratory activities and situations, preferably using the BYOD mode, also encouraging the experimentation of vertical curricula and the creation of communities of good practices*) and that fosters sharing within an environment and a collection of practices, which are built and replicable by accessing a database (*I imagine a training path aimed at creating digital didactic content that provides for the creation of a platform and a database for sharing of diverse digital didactic content*; *I think that this training path should provide for the sharing of digital educational contents*). A training program devoted to the creation of digital educational content should create platforms that are not limited to a simple storage of content, but must provide users with useful tools, in order to improve daily teaching and a collaborative construction of content (Dropbox, Google Drive, etc.).

Referring to the second stimulus: *Innovating teaching means paying close attention to security (protecting devices, personal data, health and environment) especially in the case of BYOD*, a different distribution with respect to the first stimulus is proposed. Eighty-three percent of teachers' answers is distributed between the very useful and useful, thus registering the need to develop skills that can bind innovation to security, with attention to children, their access to mobile devices, and also exposure of their personal data. Only 12% of them does not feel very useful to invest in a kind of competence-oriented training, and 3.57% does not see any benefit or need for the teaching practice. Our teachers emphasize a need for training paths that focus on increasing awareness about usage of specific digital resources, with attention to privacy security (*the training path should highlight all risks associated with the management of security and privacy and, at the same time, provide a guidance to teachers on possible immediate actions when such security is violated*). Important is also the attention to be paid to usage of given materials (*training must allow us to recognize risks and dangers behind the acquisition of materials transmitted through*

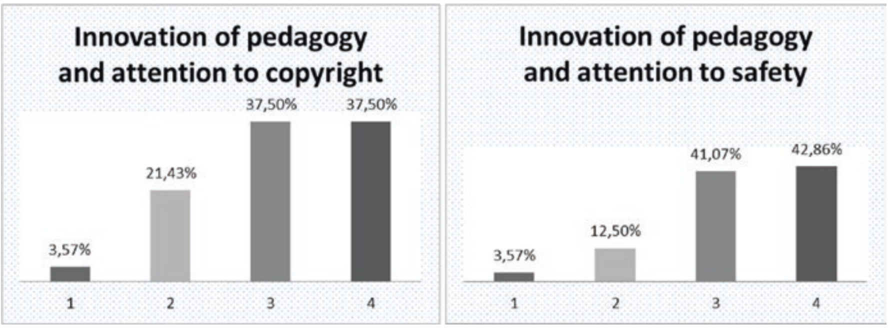

Fig. 9 Distribution of teachers by stimulus-based questions related to digital skills being trained

the Internet) so that teachers are given the best conditions to dare, from an innovation standpoint, with confidence that their action be easily and safely replicated (*it should be a path hinged on the belief that innovation in teaching, also based on digital content, can and should be an essential prerequisite for any school renewal initiative to become effective and secure*) (Fig. 9).

Finally, the last area associated with *visiting for acquiring practical knowledge and transferability* sees 51.79% of teachers is totally in favor of integrating their training paths with "peer education interventions" among trained teachers, in order to support an experimentation of innovative teachings and methodologies in school. 44.64% believes that learning and peer support are useful, while only 3.57% does not believe it is necessary to review and integrate the paths with such an educational pedagogical action.

The idea behind "visiting" in support of the practical application of innovation receives a high acceptance by teachers. 55.36% of respondents believe that it would be very useful to complement in-service training with situations of "visiting" or "observational internship" which provide trained teachers the opportunity to meet high-intensity innovative school realities with a view to reciprocity. 39.29% confirms the perceived usefulness of a training that makes distancing-immersion a fundamental axis of professional growth. Only 3.57% of teachers attribute little value to the visiting, with 1.79% who does not see any added value in the skills development process (Fig. 10).

The peer education experience has been introduced in the induction training and for many teachers is an element characterizing an added value of the in-service training (*peer education has already been designed and implemented in the training of newly employed teachers belonging to the same territorial scope as our school*). Such experience has involved both internal newly recruited teachers and external experts. *I have participated in a distance peer education activity, anonymously (competence-based planning, assessment, learning, and teaching experiences), and I feel very positive* because it helps confrontation and socialization practices as well as an appropriate systemization of them (*it is important to organize situations of peer education among trained teachers during the school year, so as to allow a peer-to-peer comparison that may act as socializing agents*). For this area, our

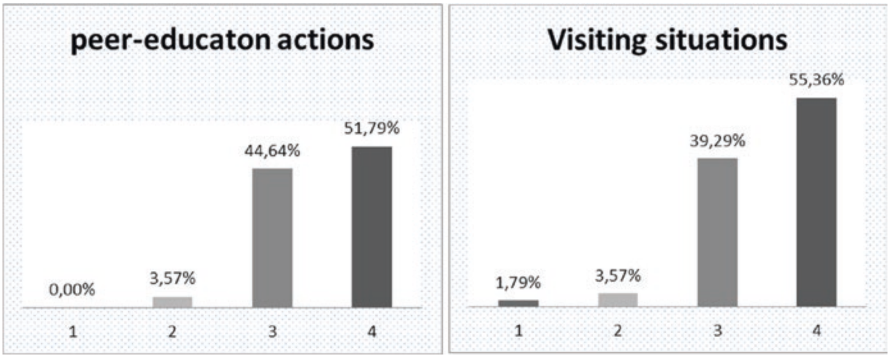

Fig. 10 Distribution of teachers by stimulus-based questions concerning visiting and innovation transferability

teachers imagine a path of peer education characterized by dedicated laboratory situations (*I see it as a workshop and as occasions for active confrontation*), which includes the creation of a "system of virtual environments" (creating a virtual peer classroom interaction that allows an exchange of information, learning material, and experiences) and regular meetings within the school *(the organization of a peer education situation among trained teachers should take place at fixed time periods during the school year*) as steps of the continuous training.

"Visiting" is another practice inherited from the Italian induction training and perceived by teachers as a moment of cultural and educational exchange that helps to become aware of the different teaching methodologies and their outcomes. They imagine visiting as an exchange oriented to practice (*I can imagine myself as a skilled teacher, who is sent to a school for cultural and innovative exchanges*) that takes on extended in-person internships (training weekends at innovative schools, alternating situations of simple observation with phases of higher involvement of the visiting teacher during laboratory activities) also for small groups (*these can be organized in small groups, also as laboratory work, involving teachers from the host school in playing the role of a training tutor*). In summary, an exploratory journey, a moment of confrontation, sharing, and mutual enrichment, as part of the networking of all teaching activity, is not a simple corollary of good practices but a flywheel for both planning and training through the examination of criticalities, potentials, and points of strength of others.

6 Conclusions

Smart education represents today an opportunity for a renewal of school. This involves educational spaces (in their integration with the territory), teaching methodology, and the use of ICT in classroom. A number of Italian small schools – which are considered a place of innovation and pedagogical experimentation where to promote a smart education – have been involved in national training initiatives on digital culture, investing in the development of digital environments: 59 schools for a total of 540 teachers participated in the activities of PNSD and PON expressing a general appreciation for the training they had received. From the analysis of the questionnaires provided to a sample of 56 teachers selected by the most participating schools in such training, the following indications emerge:

1. Teachers support the great usefulness of paths whose structure encourages "putting into practice" through the application of scenarios and situations based on daily educational experience.
2. Teachers consider the training paths as places for pedagogical experimentation that allow them to define hypotheses, to create planning and rubrics for monitoring that guide the didactic variations and the analysis of one's own practice.
3. Teachers are in favor of integrating their training paths with "peer education interventions" among trained teachers, in order to support an experimentation of innovative teachings and methodologies in school.

As for the digital innovation, teachers' attention, especially the more experienced ones, is primarily geared to the creation of content and to safety (*protecting devices, personal data, health, and environment*).

This study, therefore, suggests that promoting these types of digital activities may help schools to consolidate the educational renewal and to encourage a type of teaching (smart pedagogy) that is innovative and that helps students to become aware, active, and digital citizens.

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Children's Empowerment Through Digital Technologies in the Context of Smart Pedagogy: Case Study

Vilmantė Liubinienė and Ramunė Kasperavičienė

Abstract In collaboration with European academic partners, this chapter aims at exploring principles of teaching and learning in the context of smart technologies. The chapter addresses the basic question: In what ways are children empowered by the use of smart digital technologies? The research was conducted in the framework of the JRC's Project ECIT, Empowering Citizens' Rights in Emerging ICT (project no. 572). The research methodology was co-designed by the project partners and coordinated by the EU Joint Research Centre. The research aims at providing insights how children and parents perceive smart technologies, the pedagogical conditions under which these technologies are used, and the factors influencing children's digital experiences. This particular research is based on the results of ten family interviews with children aged from 7 to 10, conducted by researchers from Kaunas University of Technology (Lithuania) in May 2017. The contemporary context of smart pedagogy in Lithuania seems to be insufficient to assure integration and access to smart educational environments to all children. For the effective knowledge gain through digital technologies, the national education program should be updated.

Keywords Children · Digital technologies · Smart pedagogy · Primary education · Lithuania

1 Introduction

Nowadays, digital technologies permeate every sector of our daily lives, ranging from education to healthcare, transport, industry, social life, and even arts. The demand for information and communication technology specialists is growing fast. According to the factsheet from the Tallinn Digital Summit (2017), nine of ten jobs

V. Liubinienė (✉) · R. Kasperavičienė
Faculty of Social Sciences, Arts and Humanities, Kaunas University of Technology, Kaunas, Lithuania
e-mail: vilmante.liubiniene@ktu.lt; ramune.kasperaviciene@ktu.lt

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will require digital skills in the future. At the same time, 169 million Europeans between 16 and 74 years old – 44% – still do not have them. According to the recent Digital Society and Economy Index (DSEI), there are significant differences between Member States when it comes to citizens' digital skills. It is predicted that in 2020 the ICT (information and communication technology) sector will face a lack of 500,000 experts. Despite improvements in the data and clear commitment of the political side, Europe is still lacking the digitally skilled workforce needed to fill the gaps. Tallinn Digital Summit Expo (2017) implies that as the Fourth Industrial Revolution gears up, artificial intelligence, robotics, and the Internet of things will bring unimaginable changes in the near future.

Development of e-skills has been at the top of the European agenda since 2014. Among the most important tools to achieve this objective is the New Skills Agenda for Europe, endorsed in 2016. Recent initiatives include Code Week for many European schools and the Digital Skills Awards, assigned to the best initiatives encouraging the development of e-skills (Tallinn Digital Summit, 2017). However, Europe needs a comprehensive strategy and efficient solutions, close cooperation between education and business sectors to improve overall digital literacy and to stimulate economic competitiveness.

As automation and digitalization create smarter jobs, opportunities for acquisition of digital skills should be provided from a very young age. As outlined in the Tallinn Digital Summit (2017), digital workforce needs a broader skill set that includes learnability, problem-solving, critical thinking, and entrepreneurship. A total of 65% of children starting school today will land jobs in areas that do not exist yet. Europe's education systems must be reimagined to support that. According to Digital Skills in Europe Factsheet, issued during the Tallinn Digital Summit (2017), only 52% of the Lithuanian population possess basic digital skills, which is still below the average of the other 28 European Union Member States (56%), which calls for a deeper analysis of young children's engagement with digital technologies in the Lithuanian context.

The EU considers digital education as one of the priorities to be implemented by the end of 2020. After the Gothenburg Summit, the European Commission (EC) adopted new initiatives to improve key competences and digital skills of European citizens. Among the three initiatives proposed by the European Commission on January 17, 2018 ("New Measures to Boost Key Competences and Digital Skills, as well as the European Dimension of Education," European Commission, 2018), the second relates exclusively to digital education. Digital Education Action has three key objectives: making better use of digital technologies for teaching and learning, developing the digital skills needed for living and working in an age of rapid digital change, and improving education through better data analysis and foresight. Initiatives include supporting schools with high-speed broadband connections and a public awareness campaign on online safety, media literacy, and cyber hygiene. To further promote coding, the Commission works with the EU Code Week ambassadors, Member States, the eTwinning network, the Digital Skills and Jobs Coalition, the Digital Champions, and other interested bodies and organizations. The EC's goal is to involve at least half of schools in the EU Code Week by 2020.

Taking into account the general pan-European context, which is favorable for the development of smart pedagogy (Daniela & Lytras, 2018), the aim of this chapter is to research the state-of-the-art situation in the Lithuanian primary educational sector. The research data comes as a part of EC JRC's Project "Young Children (0–8) and Digital Technologies" (Chaudron, 2015; Chaudron et al., 2018), which involved 21 countries. Thus, the research methodology was co-designed by the project partners and coordinated by the EU Joint Research Centre. The study aims at providing insights on how children perceive smart technologies, concentrating mainly on the pedagogical contexts of use, the factors influencing their digital experiences, as well as the strategies employed by educators. This particular study is based on the results of ten family interviews with children aged from 7 to 10, conducted in Lithuania by researchers from Kaunas University of Technology in May 2017.

2 Research Overview of Digital Technologies and Their Perception by Young Children

If Plowman (2016) claims that "in the UK, the days when the technology was easily recognisable as the telephone on a table in the hallway, the television in the corner of the living room or a computer on top of a desk have gone" (Plowman, 2016, p. 194), in Lithuania we still live in a more diverse technological environment and can trace the combination of both traditional old media and smart, digital, and mobile technology. The dispersion and usage of smart technology largely depends on the age of users, which points to the gap in media literacy between the younger and older generations. The overall number of Internet users in Lithuania is constantly increasing and reached around 77% of the population by 2016, as compared with 68% of the population in 2013 (Lithuania Internet Users, 2018). But bearing in mind that in such a relatively small and close linguistic and cultural community as Lithuania, the connections between the households of parents and grandparents are still close, and the ties between young children and grandparents are still maintained; small children may spend time after school with their grandparents. Thus, they are directly exposed to traditional media and can have different perceptions as well as experiences of the home and family environment. On the other hand, Plowman makes a good point that "the boundaries between 'home' and 'technology' are now less distinct, so the devices that may once have been thought of as being located within the microsystem are distributed across the concentric circles from the child at the center to the outermost realm of the macrosystem" (Plowman, 2016, p. 194).

Many studies that focus on digital technologies and their perception by young children concentrate on the aspects of parent mediation and the risks as well as safety issues related to excessive Internet usage at the young age (Chaudron, 2015; Chaudron et al., 2018; Dias et al., 2016; O'Connor & Fotakopoulou, 2016; Smahelova, Juhová, Cermak, & Smahel, 2017). Findings related to negative experiences and outcomes (i.e., risks and harm) show, as outlined by Smahelova et al. (2017), that children's technology use can be associated with content risks (e.g., seeing upsetting pictures), contact risks (e.g., receiving unwanted messages from strangers), and conduct risks (e.g., online aggression) (Livingstone, Mascheroni, & Staksrud, 2018). Positive experiences and outcomes (i.e., opportunities and benefits) can also be divided into the same broad areas: content (e.g., learning new information), contact (e.g., enhancing social competencies), and conduct (e.g., identity expressions) (Smahelova et al., 2017, p. 2). However, it is not sufficient to discuss positive or negative influences; it is more important to discuss the wide range of educational tools and the principles of smart pedagogy as such that would enable a successful acquisition of digital literacy skills, alongside the basic literacy skills – *the former "3 Rs" reading, 'riting, and 'rithmetic* (Frau-Meigs, 2012, p. 21).

Jackie Marsh (2005), a leading researcher in the area of digital technologies, digital literacy, and young children's play in the twenty-first century, argues that the term digital literacy has become synonymous with the concept of competence in the encoding and decoding of a range of semiotic discourses (e.g., computer literacy or media literacy). In her book, she examines the literacy practices which are related to digital technologies, such as computers, television, and mobile phones, and explores the wider range of communicative practices which are mediated through new technologies and acknowledge the multimodal nature of young children's meaning-making (Marsh, 2005, p. 3). Accordingly, the focus of children's competences should not only be on written texts but also on multimodal multimedia texts in the context of the twenty-first century knowledge economy (Lankshear & Knobel, 2011; Marsh, 2005). Therefore, Marsh, Hannon, Lewis, and Ritchie (2017) as well as many other researchers (Frau-Meigs, 2012; Garvis & Lemon, 2016; Stephen & Edwards, 2018) are convinced that there is a need to ascertain that children from a young age are educated and professionally guided to get to know and understand the multimodal multimedia texts and practices. Marsh et al. (2017, p. 58) conclude that "the literacy landscape is changing for everyone and for very young children, this means that their initiation into literacy as a social practice is initiation into the practices of digital literacy." The study suggests that in the twenty-first century, "emergent digital literacy practices are developed in multilingual, multimodal and multimedia communicative acts and the children in these families are acquiring complex knowledge about the way in which communication takes place in a digital world" (Marsh et al., 2017, p. 59).

With regard to policy and practice in contemporary smart pedagogy, it has been concluded that "in early years' settings and schools should build on the digital literacy skills, knowledge and understanding that children acquire from a young age in order to extend their learning and prepare them sufficiently well for employment and leisure pursuits in the knowledge economy" (Marsh et al., 2017, p. 59). The young children who are to leave school in the second decade of the twenty-first century have to live and work in an absolutely different smart environment – they almost certainly are to be involved in daily practices which require flexibility, innovation, creativity, and problem-solving. Marsh et al. (2017) are convinced that these are the skills that need to be embedded in the language and literacy curriculum for the youngest children if they are to be successful communicators in the digital age. Omnipresence of technology nowadays means that we need to rethink and reconsider how children are educated both at home and family environment and at school or kindergarten.

3 What Is Digital Learning and Smart Teaching?

Digital learning is web-based learning which effectively makes use of the information technology to convey knowledge to learners and is also known as the smart teaching technique, and most of schools and educational institutions have adopted this method, bringing a great change in the educational system (Online teaching providing server eduCBA, 2017). Children are taught with the help of smart devices in addition to traditional teaching methods, which facilitate the learning process (Online teaching providing server eduCBA, 2017).

Stephen and Edwards (2018) draw our attention to the fact that the launch of the iPad in 2010 was a significant game changer for early childhood, having in mind technology and gradual involvement in "digital play." With the limitations of input devices such as the mouse and keyboard removed for children by the use of a touchscreen device, children's engagement with technologies increased rapidly in a very short period of time. Technology was increasingly integrated into the daily life experiences of young children (Stephen & Edwards, 2018, pp. 82–83). The notion of "digital play" immerses children in the educational environment, making use of play-based, child-centered learning. Focusing on the learning process, and understanding and developing learning dispositions, it reflects society's values and expectations in a digital age. Stephen and Edwards (2018, p. 148) are convinced that digital play and traditional play get confused. Observations of contemporary play episodes suggest that the concept of blended play offers a more fruitful approach for research and pedagogical development. "If educator understandings about what counts as play-based learning are based on a cultural position that predates the digital age, then they will struggle to incorporate digital technologies in their pedagogical practices" (Stephen & Edwards, 2018, p. 148).

Another important issue is to understand how contemporary learners are different from their predecessors. Daniel Dervin (2018) has made an attempt to provide a portrait of a digital child, stating that "nothing is more synonymous with the 21st century than the image of a child on his or her smartphone, tablet, video game console, television, and/or laptop. But with all this external stimulation, has childhood development been helped or hindered?". The question that Dervin raises is controversial. This stage of the digital child, according to the author, has emerged from current unprecedented and pervasive technological culture. In the prologue of his book, he raises the question "Where have all the children gone?" and provides the tentative answer – "today's children have retreated into their own digital comfort zones, venturing out only in the glass bubbles of their apps and ear puffs" (Dervin, 2018).

Thus, it seems that nowadays, the skills and the application of smart teaching techniques are essential for contemporary educators, to help them find ways to motivate the digital child to learn, discover and create, and ultimately leave "the glass bubble of apps and ear puffs."

4 Degree of Implementation of Smart Pedagogy Practices over Europe

Smart pedagogy practices are implemented to different degrees in various countries. Using robots in classrooms is not new. Teaching robots have been used in the Middle East, Asia, and the United States, but recently they have found the way into European classrooms as well. To name just a few, in Finland, Elias, the language-teaching machine, comprised of a humanoid robot and mobile application, has become one of four robots introduced in a pilot program at primary schools. The robot is equipped with software that allows it to understand students' requirements and helps to encourage learning. The robot recognizes the pupil's skill levels and adjusts its questions accordingly. It also gives feedback to teachers about a student's possible problems. Some human teachers who have worked with the technology see it as a new way to engage children in learning ("Techno Teachers: Finnish School Trials Robot Educators", 2018).

The Austrian educational program "School 4.0" also involves robotic toys (or smart toys) to promote computational thinking and media literacy, natural sciences, and engineering, and train the future workforce and support Austria's economic competitiveness. The pilot project "School 4.0" involves 100 schools all over Austria. At each school, one or two classes (25–50 pupils), mostly in the third grade (8 years old), are enrolled in this project over the 2017/2018 school year. According to Austrian Education Minister Sonja Hammerschmid, this digitization strategy is based on four pillars: digital elementary education, digitally competent pedagogues, infrastructure and IT equipment, and learning tools. Digital competence (the media, critical handling of information, Internet security, technology knowledge, coding, and problem-solving) is to be strengthened as early as the elementary school level. Children start learning about media in their third and fourth school years. Digital education is gradually incorporated in education across all subjects. Regarding infrastructure, the plan is to equip children from the fifth school year with tablets and from the ninth school year with laptops. For the minister, "school digitization represents a 'huge chance' to make teaching different, support talent better and increase participation by weaker pupils" ("Austrian Education Minister Presents School 4.0 Strategy", 2017).

The Spanish government's Council of Ministers supports the "Connected Schools" program and has provisionally approved the allocation of funds to bring broadband access at speeds of up to 100 Mbps to schools. In total, some 1.86 million pupils in 5991 state-funded primary and secondary schools will benefit from the expanded "Connected Schools" program ("Spain to Invest EUR 74 mln in Expanded Connected Schools Program", 2018).

In Portugal, the distribution of laptops for school children was one of the flagship programs under the "Technological Plan" by the government in power in 2005–2011. In September 2008, José Sócrates, then Prime Minister, announced the distribution of half a million laptops (for free or at reduced price). Unfortunately, the program was interrupted due to the financial crisis in the country after 2011 (Liubinienė & Jorge, 2018).

On the contrary, the Swiss parliament has rejected a motion for the national government to take a greater role in promoting digitization in primary and secondary schools. Government representatives said the motion was not needed, as it was already working on the issue under the Digital Switzerland strategy presented last year ("Swiss Parliament Rejects National Digital Education Policy", 2017).

In Lithuania, the initiative to donate a microcomputer to each child (to develop coding and programming skills) was announced by a group of stakeholders and business people in December 2016. The idea was taken up and further developed by municipalities all over Lithuania using the principle of crowdfunding and sponsorship. Thus, many stakeholders, business companies, and individual supporters got involved into the initiative to donate a microcomputer to each child in Lithuania. Overall, 26,562 children are to be supplied with microcomputers. So far (as by April 4, 2018), funds have been collected for 19,487 microcomputers, around 73% of the total number. The results of this initiative, the updated numbers, and the full list of supporters are available at the website "Kompiuteriukai vaikams" (2018).

5 Constraints of a National Program of Primary Education in Lithuania

Already in 2006, a national program of secondary education "Teaching about Information Processes and Human Rights" was established by the Ministry of Education and Science in Lithuania. The program was aimed at developing media literacy, but it was targeted at pupils of grades 9–11 (Juraitė, 2013). Although the Lithuania's Progress Strategy 2030 (adopted in 2012) states that introduction of media literacy programs in all education institutions is among the main priorities, there is no national strategy regarding development of digital literacy skills in primary education in Lithuania. However, a plan exists to implement the concept of media and information literacy in the curriculum of primary education before 2020.

At present, digital literacy is not part of primary education in Lithuania. The purpose of a primary education program is to develop *a healthy, active, and creative child who has acquired elementary literacy, social, informational and cognitive skills, which are necessary for proceeding to basic (lower secondary) education* ("General Education," 2018). This definition may imply development of digital skills. Digital literacy refers to digital competences and overlaps with media literacy

(Ilomäki, Paavola, Lakkala, & Kantosalo, 2016). It is defined as the ability *to access, select, use, understand, reflect, critically evaluate hypertext and creatively apply ICT while communicating and participating in online network* (Juraitė, 2013). So far, digital or media literacy has been obscurely addressed in Lithuanian primary education programs.

According to the Primary Education Program (2017), development of information technology skills is integrated into primary education through other spheres of education, which include languages, mathematics, social and life sciences, arts, and physical education. Teachers integrating information technologies into primary education improve the education process, i.e., they seek to organize the learning and teaching process and present the learning resources in nontraditional ways. However, the program obviously maintains that ICT integration is optional, based on the teacher's preference. Thus, we find a diversity of prevailing teaching practices. In some private schools, there are technologically equipped smart classes and professionally trained teachers who involve children in an entertaining educational process using tablet computers, smart boards, etc. Teachers may introduce educational computer programs and educational games, if possible, and apply these in the teaching/learning process. The only provision that is stated as obligatory in the Primary Education Program (2017) is related to the risks that are feasible online. Teachers who integrate ICT into their classroom are only required to discuss online risks and explain the consequences of revealing personal information and how to avoid such situations.

The Primary Education Program (2017) mentions information technologies in relation to guidelines for teaching languages, mathematics, social and life sciences, arts, and physical training. In grades 1–2, pupils may use computers, if they are available, when they start writing. In grades 3–4, pupils may learn how to prepare a short text document and print it. Information technologies may be used as stimuli among others, including text examples, visual material, and audiovisual technologies, to foster favorable learning environment for pupils in grades 3–4. They may learn to write on the computer keyboard. In classes of mathematics, educational computer programs, if available, may be used for illustrations. In grades 3–4, pupils may present projects for classes of social and life sciences prepared using computers, which implies that they may be encouraged to use information computer technologies at home. In classes of arts in grades 1–2, pupils may use computer games to decide on decorations and outfit details that express different emotions and mood. In grades 3–4, they may use particular computer programs (Groovy Jungle, Auralia, etc.) to create and learn music scripts. Information technologies may also be employed to show and explain physical exercises in classes of physical education.

In the past decade, there have been attempts to embed development of digital literacy skills into primary education. However, so far, the Primary Education Program does not practically address the issue of smart pedagogy and, in this area, Lithuanian primary education lags behind that of other European countries.

6 Implementation of EC Directives in Lithuania by 2020

This research on children's empowerment through digital technologies in Lithuania came as part of the European Commission's Joint Research Centre project "Young Children (0–8) and Digital Technologies," which has assembled a large data set based on 234 family interviews in 21 countries, reported by each national research team (Chaudron et al., 2018). For the purposes of this research, ten families from the two largest cities of the country were selected. For the sampling procedure, we followed the instructions and documents provided by the European Commission's Joint Research Centre (JRC) coordinating the project. The families were chosen using purposive sampling techniques, through contacts of the researchers from Kaunas University of Technology, with permission to conduct the research issued by Kaunas Regional Biomedical Research Ethics Committee. All families had been identified by the end of April 2017. The interviews took place in May 2017. The families were middle-to-high income. The interviews were conducted with parents having children aged from 7 to 10. The parents were asked questions about the use of smart technologies at school and home for the learning purposes. The questions focused on the ways smart online technologies were used in the school environment, i.e., what tasks and classes involved the use of smart online technologies and how they were perceived by parents. Children were not interviewed. All the interviews were recorded using voice recorders. During the interview, the researchers also took notes. The notes and transcripts of the interviews were analyzed. The data were coded and the qualitative analysis was performed. In analyzing the data, the researchers searched for patterns of children's empowerment through digital technologies and their use in the context of primary education.

The parents interviewed for the purposes of this research were generally positive about the use of digital technologies at school and at home. However, their responses overall show sparse and irregular usage of smart digital technologies for learning purposes. The majority of parents indicate that their children aged 7–10 do not use tablet PCs or other digital devices at school. In some schools, both state and private, smart technology classes or computer labs exist, but they are mostly for older children learning in grades 5–12. Only some parents claim that there are possibilities for their children to use digital technologies at school.

> *In grade 2, now they have to do tasks at school that require using a computer. They use tablet PCs at school and have started learning how to create a movie; they have tablet PCs at school. (LT8[1], father)*

Some parents claim that they have been asked by the teachers of their children in primary grades whether they would be willing to allow their children to bring personal tablet PCs to school once in a while. The activities to be done at school using a tablet PC involve searching for information, e.g., finding out the weather forecast, finding the maps of the world, or searching for national clothing examples of other countries, i.e., tablet PCs, in those rare cases when they are brought to school by

[1] Family codes

children themselves, are usually used in classes of life sciences. Other parents indicate that they know there are schools where children use tablet PCs and cell phones starting from grade 1.

> *There are schools where children are asked to bring tablet PCs and they do a lot of tasks with smart gadgets.* (*LT5, mother)*

Some parents claim that children have to use tablet PCs or computers at home to find some information as a task for classes or prepare for a project. For example, in one school, the children in grade 2 have been instructed by the teacher to find a singer and a song on YouTube and learn the song and the movements of the singer, i.e., to learn to imitate the singer, for a school concert.

> *He is preparing a song for a school concert; he has been watching YouTube in the evenings and has been acting as a singer. (LT1, mother)*

On the other hand, all the parents interviewed claim that their children's extracurricular activities at school involve the use of smart gadgets. Usually, these extracurricular activities are after-school robotics classes. Generally, robotics in Lithuania is an extremely popular extracurricular activity among children of different ages. Different robotics schools have been established; many of them operate after school hours on school premises. This is especially convenient for parents, and this supervised activity is seen favorably by both parents and children.

> *In after-school classes of robotics, they create robots. (LT1, father)*

> *My children attend a class of robotics and design robots, make moving nodes so that robots could move. They did not like it until it became more sophisticated and complex. They control the robots with a remote control. They don't know that smart toys exist. (LT4, mother)*

According to parents, in some primary schools, robotics classes are part of the regular school curriculum.

Almost all parents indicate that children use digital technologies at home as part of their extracurricular activities.

> *My son did not use a tablet PC for learning purposes when he was in grade 1; neither at school, nor at home. But he used it at weekends (LT1, mother)*

Children do many different things with smart technologies at home: they watch movies and videos, view photos, play games, etc. Some children learn more sophisticated things from their parents and/or older siblings.

> *They edit photos by drawing on them. They make video clips, have started doing this when they were about 4 years old. They have been watching, observing their mom working and took in this information. (LT4, mother)*

> *He knows how to use the YouTube search. Clips, editing, photos – he is oriented expediently towards all these things. (LT4, mother)*

Parents have different perceptions regarding the use of smart technologies at school and at home. Some parents see it as a positive thing and claim they would be glad if their children had a possibility to learn to use digital smart technologies at school, not only at home.

Technologies help to learn languages; they learn a lot from movies. (LT2, mother)

There will be no problems using computers in the future; he has already outpaced his grandparents, but has learned everything by observing his family and trying things out himself. (LT1, father)

It may imply that parents would welcome guided learning with smart technologies over uncontrolled (or parent-controlled) use, which may be perceived as a disadvantage. The current generation of children, like their parents, is a generation of self-learners, i.e., those who find out and learn by the trial-and-error principle. Learning to use different smart gadgets on their own may result in different levels of understanding and skills in the same age group, which may further spur social exclusion.

Other children may have better digital skills and bullying may start. My son said once that other children bring their cell phones to school. Why can't he also bring it? He says I will not play, I will only use it during breaks. He already wants a smart phone, like his mother's or father's. (LT1, father)

On the other hand, some parents are against digital technologies both at school and at home. They claim that children should first learn to read and write and parents see digital technologies as an obstacle to this.

We deliberately did not allow our children to the class where tablet PCs were used. We wanted them to learn to read and write. (LT5, mother)

Some schools also have a policy against digital technologies, usually cell phones, due to thefts and distraction. Teachers fear that children cannot take proper care of their belongings and authorities of schools do not want to be responsible for lost expensive gadgets.

7 Conclusions

With the current study, we aimed at researching the state-of-the-art situation in Lithuanian primary education, discussing the possibilities of children's empowerment through digital technologies in the context of smart pedagogy. The research reveals that in the Lithuanian primary education sector, encounters between children and digital technologies that foster learning remain scarce. Moreover, educators who wish to provide a digital learning environment in primary school and follow the recommendations of the Primary Education Program do so at their own initiative. Unfortunately, no solid national strategy to foster the development of digital literacy skills in primary education in Lithuania has been developed yet. So far, the Primary Education Program does not practically address the issue of smart pedagogy bringing Lithuanian primary education behind other European countries. The study has also revealed parents' diverse views toward the use of smart online technologies at school and home. In some cases, stereotyped perceptions have led to a reluctance to make benefit of smart technologies in the learning environment. To conclude, the joint efforts of policy makers, stakeholders, educators, parents, and children are needed to implement the contemporary content of smart pedagogy in Lithuania which is to assure not only the full-scale access to smart educational environments, but also effective knowledge gain through digital technologies.

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Tablets in Learning Mathematics for Kindergarten Students

Nicholas Zaranis and Vasiliki Valla

Abstract The aim of this study is to explore the impact on kindergarten children's mathematical competence after the implementation of a software application for comparison, classification, one-to-one correspondence, and counting with tablet computers. The application consisted of some comparison, classification, one-to-one correspondence, and counting activities, designed following the background of realistic mathematics education and more specifically that of the learning teaching trajectory for the domain of mathematics. Four kindergarten schools of Heraklion participated in the study, which was conducted during spring 2017. The research followed the pre-test and post-test model, using the Early Numeracy Test (ENT), an instrument measuring the early mathematical competence. The test comprises of questions for the concepts of comparison, classification, one-to-one correspondence, seriation, using counting words, structured counting, resultative counting, and general knowledge of numbers. The results of the study support a positive correlation between children's early numeracy competence and the integration of tablet computers in teaching and learning numbers.

Keywords Mathematics · Tablet computers · Kindergarten · Early numeracy test

1 Introduction

The integration of Information and Communications Technology (ICT) into primary education can play an essential role in achieving the objectives of the first grade curriculum in all sectors and subjects if supported by developmentally appropriate software applications (Brooker & Siraj-Blatchford, 2002; Fischer & Gillespie, 2003; Haugland, 1999; Lee, 2009). Research on the use of digital technologies in developmentally appropriate ways in mathematics education is not new (Larkin & Calder, 2016; Starkey, Klein, & Wakeley, 2004). For more than three decades, digital technologies are part of the repertoire of mathematics teachers of the tools,

N. Zaranis (✉) · V. Valla
Department of Preschool Education, University of Crete, Rethymno, Greece
e-mail: nzaranis@edc.uoc.gr

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knowledge, and processes used to enhance engagement and understanding in learning and teaching (Calder, 2015; Chen & Chang, 2006; Rikala, Vesisenaho, & Mylläri, 2013). Research focusing on best practices for the integration of technology in Early Childhood Education (ECE) has shown that the use of Information and Communications Technologies (ICT) can lead to improvements in engagement, motivation, insistence, curiosity, and attention of preschool children in mathematics (Clements, 2002; Desoete, Ceulemans, De Weerdt, & Pieters, 2010; Larkin, 2013; Lieberman, Bates, & So, 2009; Moore-Russo et al., 2015; Orlando & Attard, 2016; Schacter & Jo, 2017; Shamir, Feehan, & Yoder, 2017; Weiss, Kramarski, Talis, 2006).

Many early-year practitioners and researchers state that the interactive environment created in a kindergarten by using tablets is stronger in maintaining children's interest toward digital activities and encourages them to become more closely and effectively involved in digital mathematical activities (Fesakis & Kafoussi, 2009; Liu, 2013; Papadakis, Kalogiannakis, & Zaranis, 2018; Risconscente, 2012).

Progress in digital technologies and technological devices dramatically reduces the tools available to teachers and students, including in pre-primary education (Biancarosa & Griffiths, 2012; Chiong & Shuler, 2010; Falloon, 2013; Mango, 2015; Zaranis & Valla, 2017). Usability studies with tablets find that preschool children learn to use the devices quickly, independently, and confidently and explore freely (McManis & Gunnewig, 2012; Norris, Hossain, & Soloway, 2012). Also, tablets have three new features (Kucirkova, 2014; Zaranis, 2018) with the ability to make a positive difference in initial training: they are portable and lightweight; they eliminate the need for separate input devices, such as the mouse and keyboard; and they host a series from apps, many of which have a child-friendly intuitive design. Regarding the pedagogical use of tablets in childhood, recent studies have concluded that tablets may be able to function as a valuable tool for educational use (Fokides & Atsikpasi, 2017; Fokides & Mastrokoukou, 2018), especially in learning mathematical concepts (Pitchford, 2014; Shuler, Levine, & Ree, 2012; Zaranis, Kalogiannakis, & Papadakis, 2013).

2 Theoretical Background

Studies have shown that when computers are used in developmental ways (Kroesbergen, Van de Rijt, & Van Luit, 2007; Pelton & Francis Pelton, 2012) in mathematics education, new opportunities for understanding mathematical concepts and processes (Calder, 2015; Zaranis, 2018) are opened up and they reinforce the conceptual and procedural knowledge of mathematics, understanding numeracy, counting, shape recognition and composition, and sorting (Larkin, 2015). As mathematical activities using ICT combine "boring" aspects of mathematical learning instruction with animation, they attract the interest of young children, giving another dimension to the teaching of mathematics at ECE (Clements, 1999; Papadakis, Kalogiannakis, & Zaranis, 2016; Weiss et al., 2006). The benefits of using ICT in mathematics teaching include the application of a higher level of mathematical skills development, such as classification and numbering (Clements & Sarama, 2013).

The results of the various surveys relate the appropriate use of computers with the ability of students to more efficiently understand the different mathematical notions (Howie & Blignaut, 2009; Trouche & Drijvers, 2010; Walcott, Mohr, & Kastberg, 2009). Also, a large number of studies show a positive interrelation between the use of computers and the development of mathematical thinking at school (Clements, 2002; Vale & Leder, 2004). However, computer-based activities must reflect the theoretical ideas behind them (Clements & Sarama, 2004; Dissanayake, Karunananda, & Lekamge, 2007; Zaranis & Kalogiannakis, 2011; Zaranis & Oikonomidis, 2009). Although kindergarten teachers need to embrace ICT in the classroom of maths, they must remember that it should never be used to replace existing teaching of mathematical methods. The modern class is transformed, and ICT provides the perfect platform for teachers to adapt and improve their teaching practices with new methods such as blended learning (Zaranis, 2018).

Following the theoretical framework combining the kindergarten curriculum in mathematics and the use of ICT at the level of kindergarten, we designed a new model, referred to as the Kindergarten Tablet Mathematical Model (KTMM), consisting of four levels. The majority of previous studies examined the effects of various teaching methods for mathematics. However, a small number of studies have found in the kindergarten levels of comparison, classification, one-to-one correspondence, and counting using tablet computers.

Our study was based on the aforementioned international literature; we set out to investigate the following research questions:

Will the kindergarten students taught mathematical concepts with educational intervention based on KTMM have a significant improvement in

- General mathematical thinking
- Comparison
- Classification
- One-to-one correspondence
- Counting

in comparison with those taught using the traditional teaching method?

3 Methodology

This pilot study was conducted in three phases. During the first and third phases, students were given the pre-test and post-test. In the second phase, the teaching intervention took place. The study was carried out during the 2016–2017 school year in four public kindergarten schools located in the city of Heraklion on the island of Crete (Greece). It was an experimental research which compared the tablet computer teaching process to traditional teaching based on the kindergarten grade curriculum. The sample included 118 kindergarteners consisting of 55 girls and 63 boys aged 4–6 years old. There were two groups in the study, one control ($n = 51$, three classes) and one experimental ($n = 67$, three classes). In the control group, there was not a computer available for the students to use. The classes in the experimental group had tablet computers available for daily use by children as part of the teaching procedure. For the uniformity of the survey, instructions were given to the three teachers who taught in the experimental and the three teachers who taught the control groups, who had similar qualifications. Teachers in the experimental group were taught by the researchers explicitly the four levels of Realistic Mathematics Education.

Ethical considerations and guidelines on the privacy of persons and other relevant ethical issues in social research were carefully considered throughout the process of research. Requirements relating to information, informed consent, confidentiality, and use of data held were conducted both orally and in writing by informing preschool staff, children, and guardians for the purpose of the study and their rights to refrain from participation.

3.1 First Phase

In the first phase, it was given pre-test in the experimental and control groups at the beginning of February 2017 to isolate the effects of the treatment by looking for inherent inequities in the mathematical achievement potential of the two groups. The pre-test was the Early Numeracy Test (ENT) (Ginsburg & Baroody, 2003).

The ENT is based on a developmental view of early childhood arithmetic, particularly as defined by Ginsburg and Baroody (2003). It focuses on several aspects of numerical and non-numerical knowledge. The ENT is valid for children in preschool and early elementary school (ages 4–8). The ENT is an individually administered tool that takes about 30 min per child. The content domains are the following: (1) quantity, (2) comparison, (3) classification, (4) one-to-one correspondence, (5) seriation, (6) number words, (7) counting, and (8) understanding of calculating numbers. There are a total of 40 items. The first 20 items are based on the logical principles underlying children's understanding of quantities and relations. The last 20 items focus more explicitly on the use and understanding of whole numbers. Also, one of the purposes for developing the ENT was to provide researchers with a statistical test that was based on current research and theories about mathematical thinking. In particular, ENT's availability would stimulate the study of mathematical thinking in young children (Vale & Leder, 2004).

Because of the young age of the children, the test was given individually as an interview. Each work had a grade calculated from student responses. Scores were computed for each of the individual mathematical tasks of the ENT.

3.2 Second Phase

In the second phase, the control group was taught with traditional teaching according to the curriculum of the kindergarten. Groups and individual activities were given to children daily. The content of the teaching was 4-week syllabus according to the kindergarten curriculum. It comprised of mathematical activities focusing on comparison, classification, one-to-one correspondence, and counting. Additional activities were given to the student of control group in order to cover the time corresponded to the computer activities of experimental group.

Activities were assigned and collected daily; there were quizzes given periodically, to be carried out individually and in small groups. In the zoo activity, the teacher of the kindergarten asked Maria to take two animals for the basket and George three. Then, the teacher asks a child, “How many animals have George and Mary together?” (Fig. 1 – left). Another activity was the fisherman. The children had to fish one fish from the “lake.” Each fish had a price on it, and the child had to find out how much money the fish cost (Fig. 1 – right).

The experimental group covered the same material at roughly the same time according to the KTMM procedure. The content of the 4-week syllabus of the KTMM was divided into four levels. All software activities were designed using Flash CS6 Professional Edition and App Inventor application by the researchers and were presented with tablet computers in the classroom. The main difference among the KTMM procedure and the traditional method is that the KTMM model uses blended learning method with tablet computers and noncomputer activities under the umbrella of the theory of Realistic Mathematics Education.

The first level began with an activity that a child randomly picks up a number from the floor and starts counting up or down pointing out the correct number (Fig. 2). Also, in another activity the child picks up a number randomly and shows the cardinality of the number with his or her fingers. Finally, there was a computer activity with questions resolved by counting objects (Fig. 3).

Fig. 1 Students played the “Zoo activity” (*left*) and “The fisherman” (*right*) in exercising in counting and one-to-one correspondence

Fig. 2 The child has to count upward (first level)

Fig. 3 The child has to count the number of balls (first level)

At the second level of the teaching process, children are given balls of three different colors and are asked to separate the balls from the color and count the number of balls in each group. Then we took away a number of balls (e.g., one yellow, two greens, etc.) and asked the children to count them and indicate which group has the most or least (Fig. 4). In addition, the kindergarten teacher asks the children to write down the number of balls in each group. The last part of this level included a tablet-based group activity in which students had to count the players of each team and identify the group with the most players (Fig. 5).

At the third level of the teaching process, the kindergarten teacher gives medals to children. Then another child joins the team wearing medal. The children have to construct the calculation problem with printed cards on the floor (Fig. 6). Finally, a software activity with calculation problems was followed (Fig. 7).

At the last level of the teaching process, we do not use visual material at first. The kindergarten teacher presents verbally a mathematical problem such as the following (Fig. 8). There are five players in a basketball team, and two of the players were

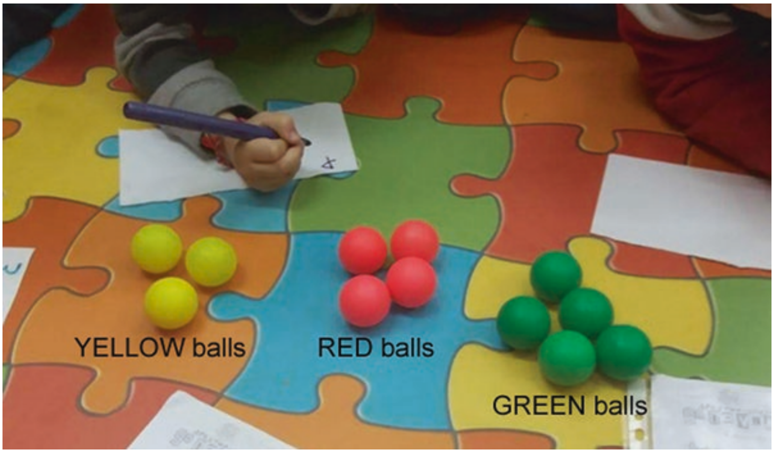

Fig. 4 The child has to count the balls in each group and write it down (second level)

Fig. 5 The child has to count the basketball players of each team (second level)

injured. How many players are able to continue playing? Afterward, there were computer activities where the children had to solve an addition problem without counting objects (Fig. 9).

3.3 Third Phase

Similarly, during the third and final phase of the study, after the teaching intervention, the same test (ENT) was given to all students in both the experimental and control groups as a post-test at the beginning of April 2017 to measure their improvement on general mathematical ability, counting, and calculation.

Fig. 6 The child has to solve the mathematical problem using numbers (third level)

Fig. 7 The child has to calculate the number of children on the carousel (third level)

Fig. 8 The child has to solve an math problem presented orally (fourth level)

Fig. 9 The child has to solve the addition without counting objects (fourth level)

4 Results

Analysis of the data was carried out using the SPSS (ver. 21) statistical analysis computer program. Initially an independent sample t-test was conducted in order to determine if the experimental group and the control group are at the same level of total mathematical achievement before the teaching procedure. The independent variable had two levels: exposure to educational software (experimental group) and no exposure (control group). The dependent variable was the student's pre-test score for the total mathematical achievement.

The t-test for equality of means was not significant ($t = -0.573$, $p = 0.568$), indicating no significant differences initially, in the total score of mathematical achievement between the experimental and control groups. Though the control group had a mean score higher than the experimental group, the mean difference in the pre-test scores was −0.807. The results of this test show that the experimental and control groups started from the same level before the teaching intervention.

In order to determine if the performance of the experimental group for the total mathematical achievement is significant than the control group after the teaching intervention, an independent sample t-test was conducted between the post-test values. The independent variable had the same two levels as in the previous test: experimental and control. The dependent variable was the student's post-test score. The t-test for equality of means was significant ($t = 10.161$, $p < 0.001$) indicating significant differences in scores between the experimental ($M = 30.25$) and control groups ($M = 17.04$), as summarized in Tables 1 and 2. Interpreting the results of the previous statistical tests, we found that the experimental group was at a higher level than the control group in total the mathematical achievement.

Similarly, to determine if the performance of experimental group started from the same level as the control group at comparison, we conducted an independent sample t-test between the pre-test of the two groups. The dependent variable was the student's pre-test score for comparison. The t-test for equality of means was significant ($t = -2.027$, $p = 0.045$), indicating significant differences initially, at mathematical achievement for comparison between the experimental and control groups.

In order to determine if the performance of the experimental group in mathematical achievement of comparison is significant than the control group after the teach-

Table 1 Group statistics for the total post-test scores

Group	N	Mean	Std. dev.	Std. error
Experimental	67	30.25	7.768	0.949
Control	51	17.04	6.350	0.889

Table 2 Independent samples test of the total post-test scores

Post-test	t	df	Mean difference	Sig. (2-tailed)
t-test	10.161	115.376	13.215	0.000

Table 3 Group statistics for the post-test scores in comparison

Group	N	Mean	Std. dev.	Std. error
Experimental	67	4.88	0.409	0.050
Control	51	4.51	0.784	0.110

Table 4 Independent samples test of the post-test scores in comparison

Post-test	t	df	Mean difference	Sig. (2-tailed)
t-test	3.073	70.567	0.371	0.003

Table 5 Group statistics for the classification post-test scores

Group	N	Mean	Std. dev.	Std. error
Experimental	67	4.58	0.700	0.085
Control	51	3.16	0.880	0.123

Table 6 Independent samples test of the classification post-test scores

Post-test	t	df	Mean difference	Sig. (2-tailed)
t-test	9.800	116	1.425	0.000

ing intervention, an independent sample t-test was conducted between the post-test values. The independent variable had the same two levels as in the previous test: experimental and control. The dependent variable was the student's post-test score. The t-test for equality of means was significant (t = 3.073, p = 0.003) indicating significant differences in scores between the experimental (M = 4.88) and control groups (M = 4.51), as summarized in Tables 3 and 4. Interpreting the results of the previous statistical tests, we found that the experimental group was at a higher level than the control group in mathematical achievement of comparison.

Moreover, to determine if the performance of experimental group started from the same level as the control group in classification, we conducted an independent sample t-test between the pre-test of the two groups. The dependent variable was the student's pre-test score for classification. The t-test for equality of means was not significant (t = 0.880, p = 0.381), indicating no significant differences initially, in mathematical achievement for classification between the experimental and control groups. Though the experimental group (M = 3.39) had a mean score higher than the control group (M = 3.20), the mean difference in the pre-test scores was 0.192. Also, to determine if the performance of control group acted significant than the experimental group in classification, we conducted an independent sample t-test between the post-test of the two groups. The t-test for equality of means was significant (t = 9.800, p < 0.001), indicating significant differences, in mathematical achievement for classification between the experimental and control groups. Though the experimental group (M = 4.58) had a mean score higher than the control group (M = 3.16), the mean difference in the test scores was 1.425. The results of this test are summarized in Tables 5 and 6. Interpreting the results of the previous statistical

Table 7 Group statistics for one-to-one correspondence post-test scores

Group	N	Mean	Std. dev.	Std. error
Experimental	67	4.25	1.247	0.152
Control	51	2.08	1.278	0.179

Table 8 Independent samples test of one-to-one correspondence post-test scores

Post-test	t	df	Mean difference	Sig. (2-tailed)
t-test	9.285	116	2.175	0.000

tests, we found that the experimental group was at a higher level than the control group in the mathematical achievement of classification.

In addition, to determine if the performance of experimental group started from the same level as the control group in one-to-one correspondence, we conducted an independent sample t-test between the pre-test of the two groups. The dependent variable was the student's pre-test score for one-to-one correspondence. The t-test for equality of means was not significant ($t = -0.346$, $p = 0.664$), indicating no significant differences initially, in mathematical achievement for one-to-one correspondence between the experimental and control groups. Though the control group ($M = 2.43$) had a mean score higher than the experimental group ($M = 2.30$), the mean difference in the pre-test scores was −0.133. Also, to determine if the performance of control group acted significant than the experimental group in one-to-one correspondence, we conducted an independent sample t-test between the post-test of the two groups. The t-test for equality of means was significant ($t = 9.285$, $p < 0.001$), indicating significant differences, in mathematical achievement for one-to-one correspondence between the experimental and control groups. Though the experimental group ($M = 4.25$) had a mean score higher than the control group ($M = 2.08$), the mean difference in the test scores was 2.175. The results of this test are summarized in Tables 7 and 8. Interpreting the results of the previous statistical tests, we found that the experimental group was at a higher level than the control group in the mathematical achievement of one-to-one correspondence.

Correspondingly, to determine if the performance of experimental group started from the same level as the control group in counting, we conducted an independent sample t-test between the pre-test of the two groups. The dependent variable was the student's pre-test score for counting. The t-test for equality of means was not significant ($t = -0.288$, $p = 0.774$), indicating no significant differences initially, in mathematical achievement for counting between the experimental and control groups. Though the control group ($M = 2.333$) had a mean score higher than the experimental group ($M = 2.209$), the mean difference in the pre-test scores was −0.124. Also, to determine if the performance of control group acted significant than the experimental group in counting, we conducted an independent sample t-test between the post-test of the two groups. The t-test for equality of means was significant ($t = 7.002$, $p < 0.001$), indicating significant differences, in mathematical achievement for counting between the experimental and control groups. Though the experi-

Table 9 Group statistics for the counting post-test scores

Group	N	Mean	Std. dev.	Std. error
Experimental	67	5.835	2.957	0.361
Control	51	2.470	1.993	0.279

Table 10 Independent samples test of the counting post-test scores

Post-test	t	df	Mean difference	Sig. (2-tailed)
t-test	7.371	114.472	3.365	0.000

mental group ($M = 5.835$) had a mean score higher than the control group ($M = 2.470$), the mean difference in the test scores was 3.365. The results of this test are summarized in Tables 9 and 10. Interpreting the results of the previous statistical tests, we found that the experimental group was at a higher level than the control group in the mathematical achievement of counting.

Results of this study expand the research on the effects of the appropriate software embedded in tablet computers as a tool for mathematical reasoning used alongside with specially designed noncomputer activities (Chiong & Shuler, 2010; Dimakos & Zaranis, 2010; Falloon, 2013; Ginsburg & Baroody, 2003; Kroesbergen et al., 2007; Mango, 2015; McManis & Gunnewig, 2012; Starkey et al., 2004; Trouche & Drijvers, 2010; Zaranis, 2018; Zaranis & Kalogiannakis, 2011; Zaranis et al., 2013). Also, the outcomes of the present study helped create a new teaching model using tablet computers and noncomputer activities.

5 Conclusions

This study emphasizes the need to combine technology and tablets in specific cases with a change in pedagogy to maximize its impact on learning (Cochrane, Narayan, & Oldfield, 2013, Henderson & Yeow, 2012). We must move away from the teacher-centered model (Rikala et al., 2013), but we also need to change the way technology is incorporated into teaching and see it as a basic tool rather than as a supplement (Norris et al., 2012). We embraced the above points of view, and we investigated how tablets – together with an application – could be used for teaching math concepts. Specifically, the general purpose of the study was to investigate the impact of instructional intervention using the Kindergarten Tablet Mathematical Model (KTMM) for the purpose of teaching the mathematical concept of comparison, classification, one-to-one correspondence, and counting in regard to the mathematical competence of the kindergarten level.

In this research, we found that the students who were taught with educational intervention based on KTMM had a significant improvement on their general mathematical achievement to those taught using the traditional teaching method according to the kindergarten curriculum. Our findings agree with similar researches

(Judge, 2005; Papadakis et al., 2018; Starkey et al., 2004; Walcott et al., 2009; Zaranis, 2018; Zaranis & Kalogiannakis, 2011) which implied that ICT helps students to understand mathematical notions more effectively. As a result, the first research question was answered positively.

Moreover, we found that the students that were taught with the educational intervention based on KTMM had a significant improvement on comparison comparing to those taught using the traditional teaching method according to the kindergarten curriculum. Our results overlap with the results of other analogous studies which indicate the positive effects of a computer-based model of teaching math (Bobis et al., 2005; Dimakos & Zaranis, 2010; Dissanayake et al., 2007; Kroesbergen et al., 2007). Therefore, the second research question was confirmed.

In addition, we found that the students that were taught with the educational process based on KTMM had a significant improvement in classification comparing to those taught using the traditional teaching method. These results are in agreement with the results of other studies which indicate the positive effects of a computer-based model of teaching math (Clements, 2002; Fesakis & Kafoussi, 2009; Papadakis et al., 2016; Zaranis et al., 2013). As a result, the third research question was confirmed.

Furthermore, we found that the students that were taught with the method based on KTMM had a significant improvement on one-to-one correspondence comparing to those taught using the traditional teaching method according to the kindergarten curriculum. Our results overlap with the results of other analogous studies which indicate the positive effects of a computer-based model of teaching math (Starkey et al., 2004; Zaranis & Oikonomidis, 2009). Therefore, the fourth research question was confirmed.

Moreover, we found that the students that were taught with the educational intervention based on KTMM had a significant improvement on counting comparing to those taught using the traditional teaching method according to the kindergarten curriculum. Our results overlap with the results of other analogous studies which indicate the positive effects of a computer-based model of teaching math (Calder, 2015; Larkin, 2013; Larkin & Calder, 2016; Zaranis & Valla, 2017). As a result, the fifth research question was confirmed.

The above discussion should be referenced in light of some of the limitations of this study. Although all the necessary precautions have been taken, one cannot be sure whether the test has accurately recorded the students' knowledge. Also, another limitation of this study is that the data collected was from the participants residing the city of Heraklion. Moreover, an additional limitation of the study is that the data collected was from a very small sample, because this research was designed as a pilot research. We also had time constraints imposed by schools, which did not allow us to extend the teaching of each subject; almost certain issues require more hours of instruction. However, as the study was of small scale and context specific, any application of the findings should be done with caution. Also, since our focus was on students' performance, we did not collect data on how well teachers were able to implement each teaching method. Finally, we did not check students' misconceptions prior to the beginning of the project; therefore, we cannot be absolutely certain for the effectiveness, in this area, of any of the teaching methods that were examined.

Further studies are needed in order to identify differences and similarities to the findings of the present study. Research can be conducted with a different timetable and age group, to investigate possible advantages or disadvantages in teaching with tablets. Future studies can check whether there are gender differences in learning outcomes. Also, additional data collection tools can be used, for example, interviews with students and teachers, which will allow us to understand in depth how they see the tablets. It would also be interesting to conduct research that maximizes the role of the teacher, using computers and other mobile devices, and compares the results. In this way, it would be possible to determine whether the results can be attributed to the instrument or method used.

Regarding the educational value of the present study, its findings should be taken into account by a range of stakeholders such as students, teachers, researchers, and curriculum designers. Specifically, our designed teaching approaches could be set up as a broad-range study in order to examine to what extent they help children understand mathematics. We as instructors of educators will certainly try to inform our students about these results, which they will need to keep in mind when designing activities for children. Moreover, the learning method based on Realistic Mathematics Education (RME) using ICT can interfere in various mathematical subjects as a research plan. The result of this research can be extended by developing various similar studies in geometry and mathematics in the kindergarten and the first classes of the primary education.

Nevertheless, taking all limitations into consideration and in conclusion, the experimental data that were obtained reinforced our view that tablets have a positive impact on learning. Not only students were more motivated and engaged in the learning process, but, more importantly, the learning outcomes were good, compared to the other methods. Considering the discussion and the above limitations of this work, we conclude that the educational process supported by tablet-based computers is an ongoing challenge for the reflective teacher to decide how this technology can best be used at the level of kindergarten.

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Developing Smart Learning Environments Using Gamification Techniques and Video Game Technologies

Ioannis Deliyannis and Polyxeni Kaimara

Abstract The development of Smart Learning Environments is a complex software engineering process combined with pedagogical principles. Smart pedagogy requirements have advanced beyond the delivery of interactive-adaptive content, which in the past was delivered through single-media systems and applications, to complex multisensory experiences. Contemporary systems are designed to offer customized media-rich interactive scenarios often implemented over various media, featuring technologies that include augmented reality, virtual reality, and holograms. This chapter proposes the combination of gamification with game technologies in order to produce smart learning environments. Within that scenario one may employ the developmental flexibility of game engines in order to achieve high-level content delivery offered by video game environments. This approach offers advanced capabilities to content experts and their targeted audiences. However problems are introduced as the development process is complex and content experts often do not possess programming experience or application development knowledge. This chapter presents how common problems may be resolved via the development of media-rich smart learning environments with the use of proprietary multimedia development environments that do not require advanced programming experience.

Keywords Augmented reality · Cross-media educational content · Digital game-based learning · Gamification · Mixed-reality applications · Virtual reality

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I. Deliyannis (✉) · P. Kaimara
Department of Audio & Visual Arts, Ionian University, Corfu, Greece
e-mail: yiannis@ionio.gr; a16kaim@ionio.gr

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1 Introduction

The evolution of Smart Learning Environments (SLEs), particularly those who employ state-of-the-art technological innovations, is affected greatly by the developments in gaming technology (Hitchens & Tulloch, 2018; Visvizi, Lytras, & Daniela, 2018). The term “smart” implies learning efficiency, adaptation, and personalization (Gros, 2016). This is not uncommon for the wider domain of learning approaches that often employ state-of-the-art tools and applications (Pavlidis & Markantonatou, 2018) particularly when those are employed within multisensory multimedia-enabled learning environments, combining cross-media content. Clearly smart education relies on the implementation of smart technologies. Devices and software are inseparably linked, as one supports the other. However, today the process of design and realization of smart learning environments is not fully standardized (Hoel & Mason, 2018), a fact that introduces developmental problems. The limited availability of characteristic examples when combined with the lack of openness in their design is both limiting factors that do not aid into the evolution of the domain. As a result we can only examine case studies that happen to be the “first to market” (Hoel & Mason, 2018).

The development of SLEs relies heavily on the technological competence and programming knowledge of content experts (Tuomi, Multisilta, Saarikoski, & Suominen, 2018), who in order to design systems that offer the required and engaging media-rich user experiences have to assess first the availability of technology, envisage a realistic design, and then communicate their ideas with developers who will ultimately construct the SLE. Within the software engineering domain, this process is not uncommon (Nardelli, 2010; Trifonova, Ahmed, & Jaccheri, 2009; Trifonova, Jaccheri, & Bergaust, 2008). Similar problems are faced in other domains such as interactive digital art (Nardelli, 2010), where technologically illiterate content experts (artists) often rely on developers to realize their end systems. This lack of technological competence often results in the development of systems featuring reduced functionality, a factor that reduces the intended content presentation experience (Deliyannis, 2007). In the past we have successfully presented novel design and development techniques within various application areas such as archaeology (Deliyannis & Papadopoulou, 2017) and the area of interactive new media artwork, enabling artists to create interactive-adaptive artwork able to capture, evaluate, and react meaningfully to dynamic multisensory user input (Deliyannis, 2016). The designer of smart learning environments has to overcome similar obstacles to those faced by interactive artists (Deliyannis & Honorato, 2016) where developmental models and frameworks are currently being developed (Deliyannis, 2012; Deliyannis, Giannakoulopoulos, & Varlamis, 2011; Deliyannis, Karydis, & Anagnostou, 2011; Deliyannis & Papaioannou, 2014); thus nothing is standardized in both software engineering, user interaction design, user experience, standards of interactivity, cross-media support, sensing, programming platforms, and media types.

This chapter discusses the development process of such systems, allowing the design of cross-media end-user experiences that encapsulate all the above characteristics: cross-media delivery, interactive narratives, aesthetics, adaptability, and evaluation of various sensing technologies at a high level without the need of complex programming. We focus particularly at the sensing capabilities of modern portable platforms such as mobile phones and tablets, which with the use of modern game engines enable the realization of a number of case studies which support the delivery on various media from a single base system, in the area of sensing, and the application of sensing technologies within smart learning environments (Deliyannis, 2013). The development process is discussed in detail from the perspectives of both content experts and developers, in an attempt to bridge the gap that often results in the development of systems with reduced functionality and capabilities. It is imperative to furnish the future technology-enhanced learning systems with the appropriate tools and methods that enable the development of media-rich, highly responsive, and customized user experiences designed to offer the end user a rewarding, interesting, and captivating learning process.

2 Understanding Smart Learning Environments Through the Evolution Content, Software, Hardware, and Users

The development of SLEs is a process that may be described from different perspectives. Some choose to examine the evolution of SLEs by focusing on the availability of hardware/software and their use on content development (Riyukta, Connie, & Anne, 2018), while others look into interaction design and user experience in their attempt to reveal the human aspects of the process and its evolution over time (Mavroudi, Giannakos, & Krogstie, 2018). In this chapter, we take into account both those perspectives in our quest to identify the design characteristics that are important for the development of SLEs. Identifying the key factors involved in this process and analyzing how they influence the end system describe the approach followed in this work. For methodological purposes and for better understanding of how smart learning technologies function, we first discuss the role of users, content, and learning and subsequently discuss how software and hardware influence the field. Indicatively, we refer to the most well-known and most frequently used hardware and software that have entered the classrooms as, due to the rapid evolution of technology, new and innovative devices are constantly emerging.

2.1 Users, Content, and Learning

The basic role of an SLE is to accommodate the learning needs of its users and provide the learning tools for the educators. However, today with the wide availability of the information society technologies and content, education itself has adapted. Formal education, which was integrated in the educational system, for both minors and adult learners, can take place into or outside the classroom. Teaching within this reality poses challenges that can clearly be supported by state-of-the-art SLEs, particularly when the learning scenario is modeled in the form of an interactive game. This process involves the introduction of gamification design for the classroom (Hitchens & Tulloch, 2018), where content is organized in a modular basis and in the form of either serious games (Becker, 2007; Blumberg, Debby, Almonte, & Hasimoto, 2013; Jarvin, 2015) or more generalized edutainment scenarios (Deliyannis, Giannakoulopoulos, & Oikonomidou, 2013; Deliyannis, Giannakoulopoulos, et al., 2011; Jarvin, 2015).

Learning can also be achieved in a nonformal manner, i.e., learning can be the product of a process that takes place at any time and in any place, for example, in museums and in environments that associate with tourist activity. Hacking groups may also be considered a nonformal educational environment, while anyone may be considered a potential student. Under the new circumstances, a new pedagogical approach rises, which is called worldschooling. The term is credited to Gerzon (2007) who is a traveler and writer and defined it as "… *when the whole world is your school, instead of school being your whole world*". The worldschooling is the positive version of unschooling (Holt & Holt, 2004), i.e., the condition in where anyone can access to learning resources freely and outside of the school context and can apply to anyone even those are beyond school age. Such learning resources are the world that surrounds us, both natural and man-made: home, family, friends, strangers of all backgrounds, libraries, parks, sports, forests, schools, towns, and the World Wide Web.

SLEs seem to possess the ability to support this new pedagogical approach (worldschooling). Findings indicate that regardless of demographic characteristics and personal interests, worldschooling promotes development at three areas: social and personal development and experiential academics (Ferraro, 2016). As personal development is related to the cultivation of everyday life skills, and of lifelong learning, and knowledge is constructed through out-of-class experiences, trips can be educational because they broaden the mind as people learn and interpret experiences (Stone & Petrick, 2013). In addition, several times, the traveler, a minor or an adult, travels without intending to learn anything and does not even plan visits to museums or archaeological sites, for example, but he chooses to travel to rest and to walk freely. Nevertheless, through this nondirected tour, he can learn many interesting things about the place he has visited. So, by coming into contact with new environments, he learns without first seeking it. This process is called incidental learning. The "learner" learns incidentally, as an informal learning through an activity quite unrelated to the educational process and thus not directly perceived by the learner himself but also by others (Marsick, Watkins, Scully-Russ, & Nicolaides, 2017). The opportunity of travel to promote skills, knowledge, and wisdom relies on Aristotle's approach when referring to *techne*, *episteme*, and *phronesis*, respectively, and is considered to be a theoretical framework for learning and travel (Falk, Ballantyne, Packer, & Benckendorff, 2012). SLEs can also aid into this direction, via appropriate content organization and intelligent avatars that direct the process and provide a customized learning path within the wide availability of sources.

Cutting-edge technologies such as SLEs can support and reinforce the random or incidental learning and transform it into deliberate learning. This can be done easily and effortlessly, as most people always carry small portable devices such as mobile phones and tablets, especially the latest technology that supports “smart” technologies. And while they have their mobile phones to communicate and/or take pictures, they are very likely to find points of interest with QR Codes in their tour or AR-enabled sites. Mobile apps based on virtual and augmented reality allow visitors to access either a QR Code marker or an AR-enabled exhibit to discover additional information (Deliyannis & Papadopoulou, 2017; Deliyannis & Papaioannou, 2016, 2017). There is also the possibility for visitors to add their own information and their own content and from simple visitors to transform themselves into product designers as expert content, a process that activates the principles of learning by design. Thus, symptomatic learning is transformed into deliberate. Learning by design is not simply an exercise in applying the new digital media to learning but is an attempt to create social relations of learning and collaborative relations of pedagogical design (Kolodner, Hmelo, & Narayanan, 1996; Kolodner, Crismond, Gray, Holbrook, & Puntambekar, 1998; Kalantzis, & Cope, 2010).

The uses of digital cultural products, which are basically constructed with interactive 3D models, are autonomous and offer interactive experience, creating new conditions for cultural tourism. This interaction takes on elements of game experience (Poulimenou, Kaimara & Deliyannis, 2017). Such digital cultural products is the virtual guide for physical visitors which will be able to learn by exploring, guided by virtual agents (Lepouras & Vassilakis, 2004) and virtual tours, aimed at remote visitors – the Internet users (De Carolis, Gena, Kuflik, & Lanir, 2018). According to Alexis (2017), 3D holograms and telepresence devices promise to eliminate geographical distance enabling travelers to be virtually present in any location at any time. An interactive system with virtual tours does not just offer visitors – physical or remote – a dynamic tour experience but the opportunity to get to know the presence of a robot that is programmed for guided tours (Gobee & Durairajah, 2015).

2.2 Software

Software provides the ability to control the delivery of content using single or multiple media. Technology is “smart” if and when it is effective, efficient, innovative, engaging, and flexible (Spector, 2014), and to our view, software is the key for this process. Software is employed to control all kinds of learning systems, learning tools, online resources, educational games which using social networking, learning analytics, visualization, virtual reality, etc. (Zhu, Yu, & Riezebos, 2016). In the literature, modern technologies that bring together those features, virtual, augmented, and mixed reality and holograms, are often distinguished. However this is not always the case, as our systems often evolve to include some or all of them, designing cross-media experiences. The use of these technologies in classrooms adds new possibilities for tracking learners' activity and offers them more immediate feedback about their learning performance.

From the time of Jaron Lanier (Lanier & Biocca, 1992) who first referred to virtual reality in 1986 to MIT researchers who are talking about virtual environments, many technological tools have been developed. From simple games and devices that support them to complex applications requiring specialized equipment, the possibilities of virtual reality serve many areas of human life (arts, museum tours, entertainment, flight simulators, military, medical, with disabilities, etc.). *The virtual reality (VR) technology* can be defined as a high-tech human-computer interface that includes real-world simulation and interactions through multiple sensory channels. VR is the sum of hardware and software, which enables the visualization and interaction with data and is a situation created in the mind that can hold human attention in a way similar to that of the natural environment (Fokides & Tsolakidis, 2008). Virtual environments are mostly audiovisual and are usually presented with the use of special stereoscopic displays, spectacles, and speakers, without excluding conventional computer screens or portable devices (Deliyannis, 2006). The integration of VR in school is associated with an understanding of design and use of composite multimodal digital material, which combines motion and static images with text and sound that emphasizes spatial experience (Serafini, 2013). The characteristics of VR, also known as 3i, are *immersion*, that is, the extent to which the user of the virtual reality application feels that they are in the virtual world and not in the real; *interaction*, that is, the computer's ability to respond to the user's wishes and the speed of that response, which to the user is arguably the most important part; and *intensity*, which refers to the volume of information and to the variety of communication channels (visual, haptic, audio) (Deliyannis, 2007; Heim, 1995). Alternatively, literature refers to the third "I" as *imagination*, which relates to the users' ability to perceive nonexistent things and their willingness to believe they are in a virtual environment, even when knowing they are in another environment physically (Rebelo, Noriega, Duarte, & Soares, 2012). The technological tools, which affect user's body through all senses and movement, as well as a simultaneous control of the environment, enable various forms of interaction, involving users sensorially, cognitively, and emotionally within a hybrid space (Poslad, 2009; Zhou, Duh, & Billinghurst, 2008).

Augmented reality (AR) is an interactive technology that allows the reproduction of computer-generated imaging information and includes detailed information about locations, events, or activities from the real world by combining sound, picture, video, and animation (Kidd & Crompton, 2016). AR, as an emerging interactive technology, allows the fusion of virtual and real objects and gives the opportunity to apply mobile technologies in collaborative learning (Ke & Hsu, 2015). AR technology and its supporting devices have the ability to recognize items, spaces, and conditions and subsequently present information. The technology offers interaction capabilities and virtual-physical experiences through a flexible environment. It is especially suitable for teaching unsafe, complex, or abstract concepts and for presenting objects that students can't see. It also improves understanding, problem-solving, creative thinking, and motivation (Reisoğlu, Topu, Yılmaz, Yılmaz, &

Göktaş, 2017; Yilmaz & Goktas, 2017). According to Billinghurst (2002), AR technology has matured to such an extent that it can be applied in various areas, education being one to which this technology can be especially valuable. Unlike VR, AR interfaces allow users to see the real world at the same time as virtual images that are associated with real sites and objects. The educational experience offered by AR is supported by the smooth interaction between real and virtual environments.

Virtual and augmented reality systems can form combined higher-order systems using software-based content linking, interchange, and adaptation. In addition, the use of adaptable avatars designed to facilitate learning and improve collaboration through mixed reality (MR) is clearly emerging. Several researchers have explored the collaboration between MR spaces, as a system in which an expert user in VR shares viewpoint and gesture cues with an AR user in order to help him complete a real world task. Recent work in telepresence has "demonstrated realistic full-body reconstructions of distant persons, placed in a local environment, and viewed through AR" (Piumsomboon et al., 2018). In the same research, it is stated that "in such mixed systems, the integration of a remote user is often represented by a graphical persona, or avatar, which creates an illusion to both the user and the collaborator of being present in the environment and co-present with their partner".

The future work in this area targets the improvement of empathy in remote cooperation through the recognition of facial expressions in the avatar (Lara-Cabrera & Camacho, 2018). The application of such systems to education seems to have the effect of teaching recognition and expressing feelings to students, particularly students with special educational needs and/or disabilities (da Cunha, Neiva, & da Silva, 2018), where we often find a lack of realistic recognition of nonverbal communication and thus develop inappropriate social skills and attitudes.

2.3 Hardware

Laptops and tablets providing students with new tools for learning followed the use of desktop computers in the classroom. Today, personalized communication devices used by the majority of the population such as mobile phones and phablets form an ecosystem that can support the use of technological learning tools. Those devices are actively being employed today for multiple uses: they can be used as an augmented reality device enabling users to explore their spaces and link real-life information to virtual links or information overlays. Our research work on learning systems actively employs user-sourced hardware to implement games based on everyday objects sourced from real life (a restaurant paper matte and plastic letters from the game Scrabble ™). Following the gamification analysis, content design and development of the augmented reality-based learning environment resulted in the development of a multimedia-enabled game that was actively used as a tool for teaching local history (Kaimara, Deliyannis, Oikonomou, & Aggelakos, 2018; Kaimara, Kokkinomilioti, et al., 2018).

The same hardware is also used to facilitate the deployment of virtual reality applications that feature stereoscopic-immersive audiovisual content. We currently explore the capabilities of Google Cardboard SDK for the development of interactive VR and 360° educational video content. The content is delivered in noninteractive format through YouTube that supports VR and 360° video delivery, while interactivity is facilitated via Unity game engine. Details about the development of those case studies will be provided below.

Ultimately, mobile phones and tablets can also drive the development of holographic information systems which may also feature interactivity through the device. Under this scenario, content represented in video or interactive format is displayed on screen and then reflected within the holographic surfaces, presenting the information to the user.

Researchers have already identified that "smart" devices, which are small, portable, and affordable (e.g., smartphones and tablets), support and engage learners anytime, and anywhere, and improve learning, in many times in playful context (Gros, 2016; Zhu et al., 2016). When such technologies are utilized in the classroom, many questions arise, and researchers investigate how learning can be improved within all educational levels: primary, secondary education, university, and military schools. Take for example Carter, Greenberg, and Walker (2017) who found through their research that students had lower performance when using laptops. This negative effect observed when laptops and tablets are permitted without restriction. They clarify that they cannot relate their results to the effect of laptops into classrooms in which portable devices are deliberately used in teaching, as it can enhance the ability of students to maintain the material. Negative results are mainly attributed to the distraction and use of the Internet. Student engagement with the laptop and without control of the content resulted being distracted, starting to communicate via messaging, having fun, and pretending to be working on something related to the lesson (Jeong, Shin, & Park, 2015). On the other hand, assuming control over the use of in-classroom technologies allows students and teachers to access information via high-speed Internet, and the capability to link their systems to *interactive whiteboards* makes the lesson more flexible and highly interactive. Clearly, careful use of laptops can enrich the learning process, giving the opportunity for peer and teacher interaction, while increasing engagement and learning (Zhu et al., 2016).

Since mobile devices are light, portable, and intuitive to use as they provide a touch screen, they are preferred over the use of laptops or desktop computers (Van Thienen, Sajjadi, & De Troyer, 2015). Devices, such as *tablets and smartphones*, enable users to have unparalleled access to communication and information, facilitating what has been termed "anytime, anywhere learning" or seamless learning, due to their increased affordability and functionality, their small size, and portability (Clarke & Svanaes, 2014; Fokides, 2018). Tablets also *represent a space for entertainment and a space of freedom and escapism from the "world of adults"* (Dias et al., 2016). Nowadays, most children are familiar with digital tools and applications, and many of them use them within their mobile devices every day. Mobile digital tools can support both individual and social constructions of knowledge simultaneously in virtually any context. Students need to be given more control over their own learning. Teaching students inside and outside the classroom with the same devices they use in their everyday life is engaging and motivating and promotes personalized learning, collaboration, and learning among peers (van't Hooft, 2008; Kaimara, Deliyannis, Oikonomou, Papadopoulou, & Fokides 2018). In a classroom environment, students cooperate best if they focus and collaborate in a common workplace. This is a difficult task to implement at a desktop-based lecture. Students working on separate computers do not easily interact despite the fact that they sit next to each other. On the converse with the use of mobile devices, new opportunities for a highly interesting interactive learning experience are emerging (Billinghurst, 2002). An experience like that enhances collaborative learning, since students can sit together and see each other. Moreover, when students work together, the space between them is used for nonverbal communication, such as glances and gestures. This results in a conversational behavior that is more similar to physical face-to-face cooperation than display-based cooperation (Billinghurst & Duenser, 2012). A remarkable contribution of mobile devices is also mentioned in their use in the field of education of people with special educational needs and especially of students in the autism spectrum. New possibilities have emerged with touch screen technologies bringing new opportunities to users to facilitate the handling and to enhance self-communication through and message composition (Billinghurst & Duenser, 2012; Gonçalves et al., 2014). To extend the capabilities of SLEs further, one may choose to employ virtual environments for the development of collaboration. The technology is ready for deployment, and researchers may be interested to employ systems such as Mini-Me supporting mixed reality collaboration (Piumsomboon et al., 2018).

Activities with *robotics* for the promotion of learning have been employed worldwide for a rather long period of time (Benitti, 2012). Robots used as nonhuman agents can improve positive attitude to the learning process in general, can reduce risks of early school leaving (Daniela & Strods, 2018), and can improve collaboration skills with peer and teachers, problem-solving skills, learning motivation, and students' willingness to improve their academic achievement and knowledge. Robot-student interactions shouldn't be strictly controlled. Teachers should allow students to experiment with robots (Chang, Lee, Po-Yao, Chin-Yeh, & Gwo-Dong, 2010), and they should provide assistance only when students cannot overcome learning problems themselves. Telepresence robots have the potential to expand access to primary school education and enhance the learning experience and cognitive and social outcomes for students absent from the classroom (Cha, Greczek, Song, & Matarić, 2017). There is evidence in support of peer-robot behavioral personalization having a positive influence on learning when embedded in a learning environment for an extended period of time (Baxter, Ashurst, Read, Kennedy, & Belpaeme, 2017). Robotics provides an effective way for children to learn, impacts on children's social skills, helps them to develop teamwork skills, and encourages them to use their imagination, creativity, and innovation in design. It may motivate children to write more easily, as they document their designs and experiments

(Johnson, 2003). Researches also have shown robots do a great job of engaging students on the autism spectrum (Feil-Seifer & Mataric, 2008).

To enable users, including students, to control devices, such as robots, various innovative Human-Computer Interaction (HCI) controllers have emerged (Savosin, Prakoonwit, Tian, Liang, & Pan, 2017), allowing advanced sensing scenarios to be realized. *Leap Motion* is one of the controllers, a hands movement sensor designed to sense and immerse the user's hands in a virtual environment. It can be placed on a flat surface in front of the user. This technology resulted from the need to manipulate objects of the virtual environment, which due to the use of masks was impossible to handle. The Leap Motion Controller represents a revolutionary input device for gesture-based human-computer interaction (Guna, Jakus, Pogačnik, Tomažič, & Sodnik, 2014).

However, what we consider today novel is already outdated as the hardware sector moves toward the nano-level, making hardware invisible and self-sufficient. Sensing technologies pave the future in many interdisciplinary fields (Deliyannis, 2016), and we expect that our devices will soon be able to collectively evaluate user data, actions, and behavior, a process that will be orchestrated using artificial intelligence (Arnaldi, Guitton, & Moreau, 2018; Cena, Rapp, Likavec, & Marcengo, 2018; North & Kumta, 2018). On the view of those developments, the openness of SLE standards and the availability to include new technologies will define the technological capabilities of such systems and influence their use and adoption by the users.

3 Game Development Environments and Gamification

If we approach SLEs from the software engineering perspective, they can be classified as information systems, i.e., a system that combines hardware, software, content, and users. Since users are an integral part of the system, it is informative to examine their roles within this structure. We identify different categories of users each with a distinct role within such a typical system: *Content Experts*, *System Developers*, and *End Users*. Typically in such an organization, content experts provide the knowledge and the learning methods, and system developers capture those functional requirements and subsequently implement the content and a functional system, which is then used by the end users. This process has proved to be problematic for many reasons. Often, the lack of communication or awareness of the requirements and capabilities between the developing parties results in systems, which are dysfunctional and limiting, thus become unusable. This is a typical software engineering deficiency that needs to be resolved using a different approach.

Recent developments in the area of video game production allow us to merge the gap between content experts and developers, as new prototyping methods require less specialization in terms of content production. In addition, rapid prototyping techniques and visual authoring environments allow early previews of the functionality and the aesthetics of the end system, permitting changes to be implemented before the actual system is built. This process is highly supported within game engines such as Unity and Unreal3D, which are both used to build cross-platform games for a wide variety of systems. The unification of multimedia content, such as video, 2D and 3D models and graphics, particles, lighting and dynamic effects, audio processing, 360° panoramas and videos, scripting, coding, and libraries that extend their functionality, enables developers to move beyond specifications and create early system prototypes that the content experts can test and modify. In addition, specific new specializations such as user experience and interaction designers following state-of-the-art technological trends permit the development of environments with full end-user functionality and professional look and feel.

Gamification is an integral part of every game, and it does not necessarily require the use of technology, as it may be applied to everyday objects using gamified scenarios. For example, getting students to clean up a beach full of garbage can be realized through a gamified scenario in the following manner: students are separated in teams, and they are provided with equipment (bags for separation and collection of items and protective equipment such as gloves, boots, etc.). Then the hidden treasure scenario is introduced where all garbage is treasure, and they have to collect the treasure in order to prove that they are the most worthy team to rule the kingdom. So they have to collect as much treasure as possible and then they can rule the place forever. This process may be also implemented using only technology, through a computer game, where, for example, gamers can learn virtually how to sort garbage or, in mixed-reality mode, where students holding AR-enabled tablets will be able to collect common rubbish and identify their properties and how long they take to dissolve in nature.

The use of applications to implement gamified scenarios does not have to be complex. For example, programming an AR system to identify items is a process that does not require programming. However, when one requires higher-level interaction, say when two objects are collected, the system to be able to congratulate the student, this can either be achieved without programming via the creation of a third item which combines the other two or via programming. This is the case employed within the second case study described below.

3.1 Sensing for Smart Learning Environments

In the past, the main way a user could communicate with a device was with the use of standard input-output devices: keyboard, screen, and mouse. More specific input devices were introduced for specific purposes including track pads for laptop computers, touch screens, interactive pen displays and tablets, different types of mouse, keyboards, gaming controllers, laser keyboards, and voice- and camera-based gesture recognition. Today the number of communication components contained within a relatively standard smartphone or laptop is phenomenal and includes gyroscope, high-definition cameras, accelerometer, laser projector, gesture recognition, augmented and virtual reality projection modes, Amphiotik 3D Audio, and many more.

4 Developing Case Studies Through New Media

The *first* case study is a typical cross-media implementation where access to the material is provided in a multimodal manner (Kaimara, P., Deliyannis, I., Oikonomou, A. & Aggelakos K. 2018). The material presented here focuses on inclusive education. In a pilot project, the goal was to demonstrate to teachers a material, which, according to literature (indicatively FitzGerald et al., 2013; Hwang, Hong, Chuang, & Kiu, 2017; Kerawalla, Luckin, Seljeflot, & Woolard, 2006; Mikropoulos, 2006; Wu, Lee, Chang, & Liang, 2013; Yuen, Yaoyuneyong, & Johnson, 2011), could be an alternative way for teaching, to show how augmented reality can help students with special educational needs (SEN) due to a disability, and, at the same time, to promote the possibilities that AR offers to bridge the gap between SEN and students of typical development. By aiming on the book cover of the Greek language textbook (Fig. 1) used at school for first grade students, the heroes of the book emerge as an interactive overlay enabling students to click on their phone screen and watch the displayed story unfold.

Similarly, the same method is used for the second instance. When the student aims the phone toward the letter "A," video animations projecting audio information about the pronunciation of the letter /ˈa̠/ is heard through the phone speakers. At the same time, an animation is displayed demonstrating how the letter α is written (fine mobility of writing; Fig. 2), while an animation of a cow, which in Greek is called /a.ʝɛ.ˈla.ða/ and is used to demonstrate the use of the letter α, slides in the frame shouting /ˈa/ (Figs. 3 and 4).

Ultimately, the name Anna written as *Άννα* in Greek is both written via animation and pronounced. The development of this case study is simple, and it uses an

Fig. 1 The student can aim the AR-enabled phone either toward the laptop screen that contains the trigger or the actual textbook to enable content delivery

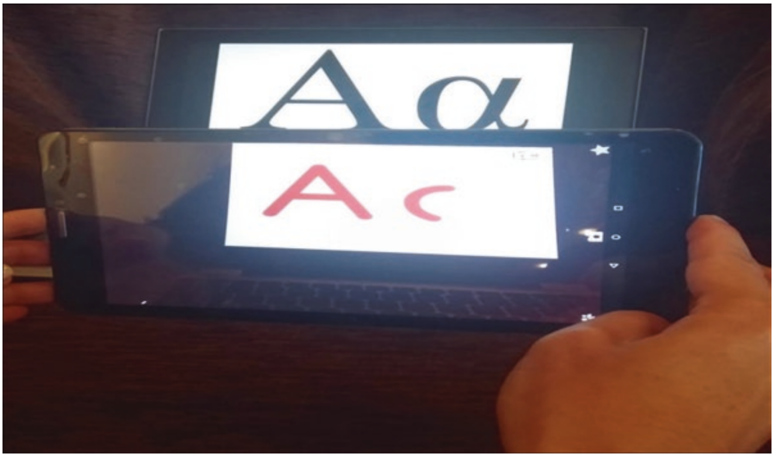

Fig. 2 Demonstrating the way that the Greek letter α can be written

Fig. 3 Demonstrating how the Greek letter α sounds

easy augmented reality environment for its implementation. Our interaction requirements were basic, and the students could only interact with the characters of the book that were used as avatars in order to explain how the presentation works.

The *second* case study was designed and developed as a complementary tool designed to allow teachers and students with special learning difficulties, such as dyslexia, to approach the subject in an alternate, multisensory, and playful way (Kaimara, Kokkinomilioti, et al., 2018). The gaming experience that is being developed is an interactive gamified process that, in its traditional form, has been proven

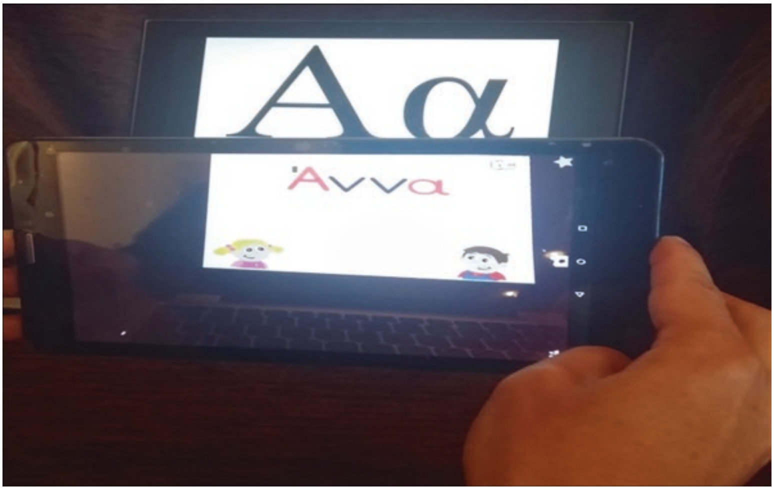

Fig. 4 Forming and reading the name *Άννα* (in english: Anna)

to support both individual and collaborative learning. The theoretical study is framed by the design and development of an interactive exploration system to gather data from participants so that through this action they can get to know historical facts and discover new elements with interactive game play. Action is implemented using augmented reality. Students with special learning difficulties are called upon to critically explore historical content and then to place a series of elements that act as a trigger on a "historical map." Each element triggers additional historical information, and when all elements are placed in the right order, aspects of historical name emerge, which until now was unknown to them, enabling them access to further historical content that complements the story.

The presentation follows gamification featuring specific rules. Students of the third grade of Greek Secondary School are divided into six teams (about four students in each team), and they are randomly assigned an equal number of plastic letters which are linked to specific video-based historical content clues (Fig. 5). They have to assign those letters to specific locations on the map, after watching each video content item triggered by each letter. Placing the letters in the correct positions results in the formation of the name of "Kapodistrias," who was the first governor of Greece to the newly established Greek state after 1821. Then, by scanning this new item (Fig. 6), a video is displayed about the life of this historical figure that completes the story and congratulates the historical investigators.

The system features printed cards featuring a summary of the video content for each letter, each featuring short historical paragraphs, short sentences, a content summary, and well-structured text with headings, highlighting important terms in bold notation; Scrabble™ game letters and augmented reality enabled audiovisual content for enhancement and animation of the game, video, audio/text narratives, Map, and clear navigation guidelines (rules) described using video instructions at

Fig. 5 Cards referring to historical content

Fig. 6 The "Map" that contains predefined locations for letter placement. Here letters from the surrounding points have been merged to the center, and it is used as a new trigger for content

the beginning of the game. In that respect, we have seen how individual triggers can be combined in higher-level order triggers, enabling the development of more complex gaming scenarios. The same technique may be employed with other physical items such as pictures, toys, etc., provided that they feature sufficient contrast that allows recognition by the AR system.

The *third* case study utilizes the fairy-tale paradigm (Kaimara, Renessi, Papadoloulos, Deliyannis, & Dimitra, 2017). In Greek educational system and in the school framework, the project "Love of Reading" was promoted through the collaboration of the Ministry of Education and the National Book Centre and was approved by the Pedagogical Institute. The fairy tales, modern and traditional, have been proved to be a very helpful factor for love of reading, especially for kids in primary school, as children of this age have lots of fantasy and love fairy tales, myths, and fantasy stories (Christodoulou-Gliaou, 2007). Fairy tales appear to aid the desire of students for joyful reading, with the active support of both multimodality and the activities of creative writing. The purpose of fairy tale presented here which is entitled "Fantasy creates history" is to introduce folklore as well as the life's values of previous years to the children of the first three grades of primarily school. The main aim is to transfer knowledge concerning traditional professions that are either dying out or no longer exist. Within this example the new generation is presented with information for which they are not able to create images and use their imagination. Technology has the ability to link the past to the present and make the revival of past activities possible in the classroom. By using digital storytelling, animation, and augmented and virtual reality information inclusion (Fig. 7), the characters of the fairy tale become alive and transition from the mythical to the real world, and in a playful way they recapture the past. The final goal is for the children to create their own fairy tale. Thus, they get motivated to seek information and visualize their thoughts, with the support of writing, gaming experience, and dramatization.

A learning scenario is typically regarded as the description of a learning process that is characterized by a focused module, specific educational goals, principles, and

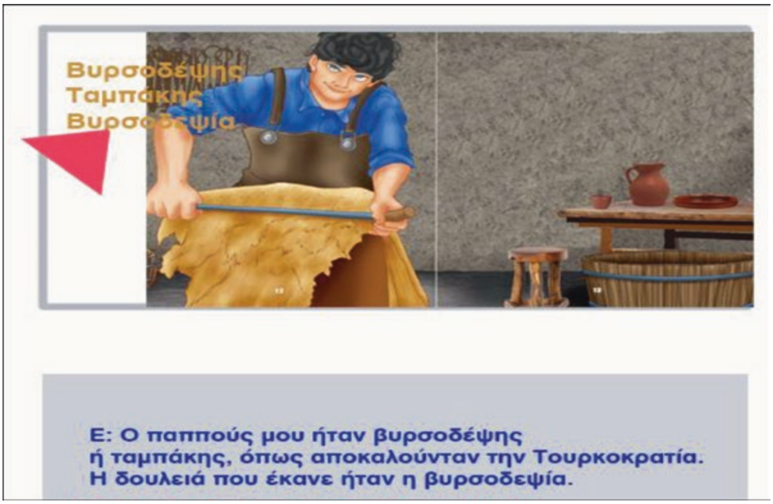

Fig. 7 Integration of the digital dialogues into a *digital VR game* supporting Oculus, Gear VR, Unity, Cardboard, Android, and iOS systems

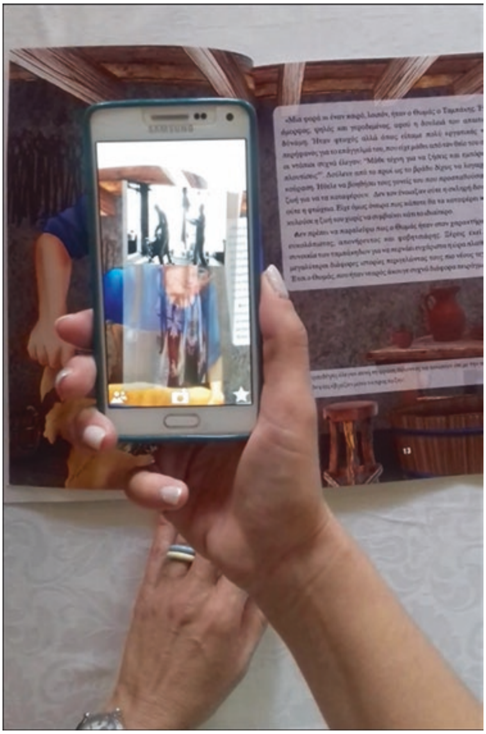

Fig. 8 The "talking" book in action using AR

practices. A learning scenario is implemented, in traditional systems, through several educational activities. The suggested scenario implemented here adopts the general principles of the Cross-thematic Curriculum Framework and the analytical curriculums. It deploys traditional learning methods such as reading the book and incorporates Information and Communication Technologies (ICT) into the classroom. The process is constructive for students who first listen to the fairy tale in the classroom, and then they were asked to record their voice impersonating various character dialogues and integrate them within a VR digital game and ultimately use AR to discover new information through the talking book (Fig. 8).

The final stage of the learning scenario included the dramatization of the story, which was reproduced as a theatrical play (Fig. 9) based on the text of the "talking" book.

5 Conclusions

We have discussed how smart learning environments may be realized through the combination of gamification and mixed-media applications involving augmented reality and virtual reality media. The importance of this approach is that it is

Fig. 9 The "talking" book in action as a theatrical play

technology-agnostic, meaning that it can be adaptively applied to scenarios ranging from total absence of technology to cases where the whole experience is fully virtual and fully immersive. This is particularly useful for the evolution of smart learning environments as they prove to provide a solid theoretical basis for scalable learning experiences both in terms of content and technology. Thus, Smart Pedagogy is very much based on the theoretical framework Technological, Pedagogical, and Content Knowledge (TPACK), which refers to the dynamic association of the three categories of knowledge: (a) content, (b) pedagogy, and (c) technology. The future of the domain is to develop complex gamification systems that do not require programming skills, allowing content experts to use them with ease and confidence.

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Technology-Mediated Collaborative Learning: The Bridge21 Activity Model in Theory and Practice

Jake Rowan Byrne, Sharon Kearney, and Kevin Sullivan

Abstract This chapter explores the Bridge21 activity model designed to support the development of an innovative twenty-first-century learning environment in second-level schools. Over the past 10 years, the model has been developed, trialled and tested with over 14,000 students and over 2000 teachers, both in informal and formal educational scenarios. Research conducted at Trinity College Dublin has evaluated and underpinned the development of this learning model.

The Bridge21 learning model is a pragmatic approach to team-based technology-mediated learning. It is designed to leverage current technology and to release students' potential through a structured move away from individualised, teacher-led learning. Essential elements of the model include technology-mediated, project-based, teamwork and reflection.

This chapter introduces the Bridge21 activity model and provides approaches and techniques to those who wish to design Bridge21 learning experiences. It empowers schools to build on what already works well for teachers and students while creating the space for innovative ideas and alternative approaches to teaching and learning. It presents a shift in focus from the teaching of individual subjects, to the teaching of key competencies and twenty-first-century learning skills.

Keywords 21C learning · 21C skills · Teamwork · Technology-mediated learning · Project-based learning

1 Introduction: Bridge21 Background

Working and learning in a way that helps students develop a set of skills and knowledge relevant to modern living is a broad aim of many education systems. Approaches to twenty-first-century technology-mediated learning ("21C learning") and the

J. R. Byrne (✉) · S. Kearney · K. Sullivan
Centre for Research in IT in Education and School of Education, University of Dublin, Trinity College Dublin, Dublin, Ireland
e-mail: jake.byrne@tcd.ie

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development of "21C skills" are frequently discussed in educational literature (Ananiadou & Claro, 2009; Dede, 2007; Fullan & Langworthy, 2013; Rotherham & Willingham, 2010; Yelland, Cope, & Kalantzis, 2008). There are various definitions of which skills could be included, but there is a large overlap among them. Definitions of 21C skills often include the capabilities to use information and communication technology (ICT) proficiently, access and filter large amounts of information online, work alone or as part of a team, communicate effectively to a wider audience using a variety of digital media, think critically and creatively and solve problems that do not have a single neatly defined solution (Dede, 2010; Voogt & Roblin, 2012).

Consistent with these capabilities, Ravitz, Hixson, English, and Mergendoller (2012) defined a discrete list of 21C skills, including a list of subskills for each. These definitions provide further clarity about the content of each skill category and allow for a measurement of how often students use each skill. They include:

- Collaboration skills
- Communication skills
- Creativity and innovation
- Critical thinking
- Learning with technology
- Self-direction skills

Several of these skills are not necessarily new to the twenty-first century (Silva, 2009); however, the focus on the role of technology within them is new, and they are increasingly relevant to how people work and learn in a digitally connected, information-rich world (Dede, 2010; Voogt & Roblin, 2012). Thus, it's argued that educators should emphasise acquiring these skills through curricular integration and aim to develop these skills among students in a manner that is deliberate and effective (Dede, 2010; Spiro, Coulson, Feltovich, & Anderson, 2004; Voogt & Roblin, 2012).

The phrase "21C learning" refers to approaches to education which aims to integrate 21C skills into student learning, in both process and outcome. These approaches often include ideas such as constructivism, teamwork, problem-solving and working and learning with modern technology. In fact, many of the pedagogical approaches used to develop them have been promoted over the past century by people like Vygotsky (1978) and Piaget (1964). Despite the development of theoretical approaches to integrating technology into the curriculum and developing students' 21C skills, there continues to be a lack of practical, pragmatic pedagogies for integrating technology and developing these skills in students' educational experiences (Conneely, Lawlor, & Tangney, 2013; Donnelly, McGarr, & O'Reilly, 2011). As Bruenig (2005) argues, "educational theories are theory rich but experience poor…lacking in practical information about instructional strategies" (p. 107).

The goal of this chapter is to address this issue by providing practical information and instructional strategies while also building on a rich theoretical foundation. It presents the Bridge21 model of teaching and learning—a content agnostic approach which incorporates technology-mediated learning, collaborative learning and project-based learning. Underpinned by a social constructivist ethos (Vygotsky, 1978), the Bridge21 model integrates these ideas in a structured manner. It was first developed in an out-of-school setting and now has more than 10 years of practical and instructional experience.

Bridge21 is not only a pedagogical model but an ongoing empirical research project, following a design-based research approach (Wang & Hannafin, 2005). It has been used across a wide range of subject areas both in the formal and informal learning environments: digital media (Lawlor, Marshall, & Tangney, 2016), cross-curricular (Sullivan, Marshall, & Tangney, 2015), computer science (Byrne, O'Sullivan, & Sullivan, 2017; Tangney, Oldham, Conneely, Barrett, & Lawlor, 2010), history (O'Donovan, McCrea, Gallagher, & Tangney, 2016) and teacher professional development (Byrne, Fisher, & Tangney, 2015; Conneely, Girvan, Lawlor, & Tangney, 2015; Girvan, Conneely, & Tangney, 2016).

Research has shown it to be effective in increasing student motivation and developing their confidence in a range of skills (Lawlor et al., 2016). Students working in the Bridge21 learning space took increased responsibility for their learning and showed an improved ability to learn with and from their peers. Student surveys, carried out using an adapted version of the Ravitz et al. (2012) 21C skills framework, showed that students who had spent 4 days taking part in Bridge21 workshops reported large increases in confidence in all six skill categories (Sullivan, Kearney, O'Kelly, & Tangney, 2017). Increases in similar skills were reported when the model was deployed within the formal education system (Johnston, Conneely, Murchan, & Tangney, 2014).

This chapter shares the practical facilitation strategies that are usually left out of research papers, which favour the reporting of data. Throughout this chapter, each element of the Bridge21 learning model is introduced in theoretical terms, followed by a facilitator's guide to that element. These elements can be considered the "ingredients" or "what is" necessary for a successful Bridge21 learning experience. After that, the chapter explores the Bridge21 activity model in detail, and this can be considered the "recipe" or the "how to" guide for a successful Bridge21 activity. Combining both the learning model and the activity model should produce an effective twenty-first-century learning experience.

2 Bridge21 Learning Model in Theory and Practice

This section describes the theoretical underpinnings for each element of the Bridge21 Pedagogical Model (Fig. 1) and provides practical facilitator guidelines for enacting these elements in a learning experiences. It will demonstrate how the elements of the model link together and, when used in combination, can help facilitators create a 21C learning experience for students.

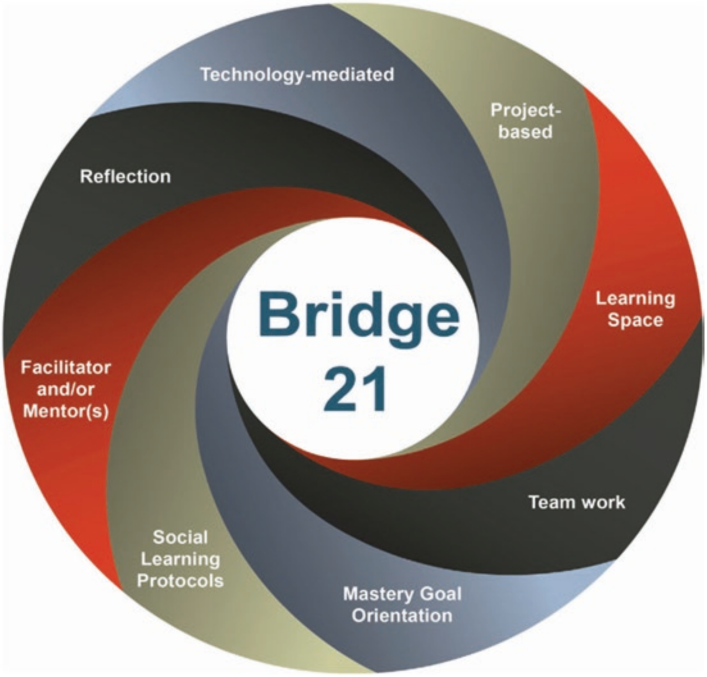

Fig. 1 The Bridge21 learning model

2.1 The Facilitator

The role of the facilitator is central to the Bridge21 model: the facilitator creates the conditions and environment which allow the students to work and learn together. The facilitator designs the projects/activities/tasks students will complete; sets up the learning space to encourage teamwork and collaboration, project-based learning, technology-mediated learning, and a social learning environment; introduces activities and provides appropriate scaffolds, where necessary, throughout a project; manages the time and keeps teams on task; intervenes in teams, where necessary, to help find solutions to any issues; and leads students in reflecting on their progress and learning. Throughout a Bridge21 learning experience, the facilitator is a supporter, guide and co-learner; s/he acts as a "guide on the side" (King, 1993), helping the students to work throughout a project, yet allowing students to lead their own learning process.

2.2 Teamwork

Teamwork is central to the Bridge21 pedagogical model. The model is based on a Vygotskian social constructivist perspective to learning, where students learn from each other (Lawlor, Conneely, Oldham, Marshall, & Tangney, 2018). Vygotsky's idea of the zone of proximal development (ZPD) positions learning in a space where, with help from others, the learners can learn new things not possible on their own (Vygotsky, 1978). ZPD is an approach that advocates a heterogeneous team where each member can bring their own expertise, whether this is technical/domain knowledge or transferable "soft" skills. This diversity provides each team member to grow individually and contextualise their learning. This means that no two learning experiences within that team are necessarily the same.

Building a team, however, is a process that involves establishment, development and nurturing (Katzenbach & Smith, 1993). It's the role of the facilitator to select team members and to facilitate, when necessary, in the process of helping the team work together.

Choosing a Team

Adhering to Michaelsen and Sweet's (2008) recommendation, the facilitator chooses students for each team, in order to ensure diverse teams and to avoid students' previous interpersonal relationships getting influencing the team dynamic. If the facilitator is familiar with the group of students, some recommended guidelines to follow, where appropriate, are:

- Teams of four to five students.
- Mixed-gender groupings.
- Mixed-ability groupings.
- Mix students from different classes or schools.
- Pair students with special educational needs a trusted or responsible peer.
- Place "leaders"/forthright personalities on different teams.

If a facilitator is meeting a group for the first time and has no other information about them, one simple strategy (to form five teams) is to give each student a number between one and five. The students with matching numbers should be in the same team. The idea is that students are likely to sit beside their friends or students they know. This method is fair and transparent in the eyes of the students but creates teams that are well mixed.

Team Roles

In the Bridge21 model, all teams have a leader, chosen at the start of the learning intervention by the other members of the team. The team leader system allows the students to take ownership of their work in a way that would not be possible with direct interventions from an adult. A clear understanding of what the role entails will allow students to feel comfortable volunteering to take on the job or to decide which of their team-mates might make a good leader.

These responsibilities can include:

- Being a link between the team and the facilitator
- Encouraging everyone to contribute, keeping the team positive
- Keeping the team on task and communicating with each other
- Ensure everyone understands what is expected of them
- Supporting their team-mates

With a younger or less experienced group, the expectations of the leaders will be fewer. As students become more capable, the leaders can take on more responsibility in terms of managing their team-mates, assigning or coordinating roles and scheduling the project work.

The facilitator regularly communicates with the team leaders to discuss their progress on their projects and to make decisions. These meetings allow the facilitator to keep track of progress, discuss anything they noticed while the students are working and share problems and solutions found in one team with the other leaders.

In addition to the team leader, the facilitator may choose to designate roles to the other members of the teams—usually this is done with a younger group or students less accustomed to teamwork/the Bridge21 model. The roles can, for example, include timekeeper or researcher.

Developing and Nurturing

The same teams are maintained throughout the Bridge21 learning activity/intervention to allow the teams to develop. The facilitator should be available to intervene and help resolve any issues that arise; however, they should encourage the teams to attempt to find solutions to their problems before seeking external intervention (Lawlor et al., 2018).

If intervention is needed, sometimes a brief discussion with the team, while they work, will suffice. If the team is fractured (e.g. two pairs of students working separately), it may be useful to speak to the team leader alone to find out if there is a problem. A team meeting with the facilitator might help get them back on track. The facilitator can also raise an issue, without addressing any individuals directly, by speaking to the whole group before or after a break.

Though the facilitator aims to foster team independence, it is important for the facilitator to observe team dynamics and progress throughout the project cycle. The facilitator can move from team to team, checking in, asking questions, helping to solve problems and generally guiding the teams though the process.

2.3 Project-Based Learning

The Bridge21 model involves project-based learning (PBL): teams are challenged to complete projects that test and develop the team and ultimately help students develop various key skills. Bridge21 utilises a common understanding of a project-based learning approach: projects should be both challenging and complex, require collaboration among team members, have time limits, and be situated in authentic, real-world scenarios (Savery & Duffy, 1995). The use of ICT is also a common element in contemporary PBL, and is utilised in the Bridge21 model, as well, which will be further explained in the following section. Moreover, the projects require the production of an artefact, presentation of the artefact and a reflection component (Lawlor et al., 2018). These concepts of PBL and teamwork in the Bridge21 model go hand-in-hand. The projects should be complex enough to appropriately challenge a heterogeneously mixed team of students, providing opportunities for students with different skill levels to both thrive and learn something new—and ideally to teach the other team members along the way. The projects should also be complex enough so that one person cannot take the lead and complete the project on his/her own; teams must distribute tasks and set deadlines in order to produce their artefact. Typical artefacts include short videos, edited audio recordings, computer programmes, or presentations.

The facilitator's role is to design the project and to support (but not necessarily direct) students in completing it (Thomas, 2000). In designing the projects, it is recommended to keep the "SMARTER" acronym in mind: the project and its goals should be specific, measurable, attainable, relevant, time-bound, engaging, and recordable (Lawlor et al., 2018). They should be team-oriented and scaffolded when and where necessary.

Providing the right amount of scaffolding for a group for any given task relies on the judgement on the facilitator and their knowledge of both the topic and their students. The facilitator will provide guidance to the teams as they work and model what they see as best practice and approaches to project work at the various stages of the process. For example, in early projects, the facilitator might choose the type of artefacts they will create as part of their project, such as a sound recording or a movie. As students progress, the focus can shift so that the facilitator allows students to choose the artefact they create, encouraging them to think about the message they want to communicate and choosing the medium which best achieves this.

As the students are working, the facilitator can guide them, help them solve problems and highlight things they may have missed. Students should be encouraged to try things for themselves and to ask their team-mates for help. The facilitator should help the students find the answers they need rather than immediately telling them or doing it for them. The facilitator may also need to intervene by setting intermediate deadlines in order to help students manage their time, especially on a more complex project, and to keep students on schedule.

2.4 Technology Mediated

In the Bridge21 model, technology is an integral *tool* in mediating the learning process. This draws inspiration from Vygotsky's (1978) idea where activity can be mediated by sign and tools. The tools of technology can take a variety of forms—from something as simple as a whiteboard and markers to a guiding worksheet or to a video camera and editing software. It is designed to leverage current technology and to release its potential through a structured move away from individualised, teacher-led learning.

Somewhat paradoxically, "technology is both integral and ancillary…[the use of ICT] is not in itself the object of the learning but their use is central to the model" (Lawlor et al., 2018, p. 6). Indeed, the emphasis is not placed on developing enhanced ICT skills, but rather on learning key skills and subject content.

The facilitator must choose the technology students will use throughout the activity and/or to create their artefacts; the choice will often be limited by the resources available. It is recommended to design activities that utilise the technology in an authentic way—as it's used in the real world (which also supports the development of the project-based learning concepts). It is also recommended that students share resources; it is typical in Bridge21 experiences that a team of four of five members has two to three devices. In this way, team members are encouraged to share, collaborate and teach one another, thus strengthening their team and learning important collaboration skills.

The facilitator is available to guide students and help them learn to use different technologies or certain features of a piece of technology. Choosing the right level of scaffolding here will depend on the students themselves and the complexity of the technology being used. The Bridge21 approach usually involves minimal introductory instruction and "light-touch" guidance (Wu, 2002). For example, the students may be tasked with making a short video. If the software is relatively user-friendly, they could be told that editing software is available, and there may be a short discussion about the basic functionality. They would not receive any instruction on how to use it. If the software is more complex, a brief overview or introductory video, for example, can help establish some base skills. Essentially, the aim is that students have a chance to explore the new technology or applications themselves; they can learn with and from one another as they discover the possibilities and potential of new software (Mitra & Quiroga, 2012).

2.5 Mastery Goal Orientation

Bridge21 aims to encourage participants to do their best—rather than establish whom among the group is the best. This element emphasises the development of key 21C skills and subject content knowledge for all students but places the value on the growth in individuals' skills and the effort involved in the learning (Lawlor et al., 2018). It favours a "mastery" goal orientation, which values developing competencies, and disfavours a "performance" goal orientation, which aims to establish superiority over others (Chiaburu, 2005). Thus, Bridge21 promotes "an assimilation of skills rather than a normative performance based approach" (Lawlor et al., 2016), recognising the need for differentiated teaching and learning, which supports progress made rather than a particular objective outcome.

The facilitator encourages and challenges each team relative to their own ability and experience; this could be accomplished through the use of the other elements of the model. For example, the Bridge21 model of teamwork supports the tailored development of key skills and content knowledge, as students are encouraged to learn from each other. The concepts of the "more-able other" and peer learning is particularly important here, as students are encouraged to help their team members develop the skills they need to complete a project and in the process develop their own skills. There may be a natural tendency for teams to compete, but instead the facilitator encourages teams to help, support and applaud each other and to even constructively critique one another to encourage an atmosphere of "inter-team cooperation" (Lawlor et al., 2018). There is no competition or prizes awarded to teams, as the idea is that each team's level of achievement and success will look different.

The design of the learning activity should allow scope for some teams to take on greater challenges than others. Project-based learning can provide a rich context and allow for differentiation, as a complex activity would require a variety of skills: students can work to improve upon skills they have, teach others skills and/or develop new skills. Differentiation can be provided through setting varied goals for each team or by providing scaffolding, depending on the needs of each team. This might include a printed resource, a video or website or simply some guiding questions or advice. Furthermore, the tools for learning that the facilitator selects use of technology should support this idea of mastery goal orientation; the technology tools used in the Bridge21 approach have a "low-floor" but a "high-ceiling"; in other words, the tools are not too complicated for beginners to use, but they are sophisticated and have high potential for more experienced users to still learn new skills.

2.6 Social Learning Environment

To support the social constructivist pedagogy underpinning the Bridge21 approach, effort is made to create a social learning environment (Blatchford, Galton, Kutnick, & Baines, 2003; Dangel & Guyton, 2003), one in which people collaborate to learn together (peers, mentors and facilitators). The aim is to create an atmosphere underlined by trust, respect and personal responsibility (rather than policing and control), in which learners feel comfortable and motivated to engage in challenging activities. To create such an environment, a certain level of social informality, as compared to a typical formal school classroom, is desired.

A facilitator aims to build a rapport with students based on trust and respect. For example, students usually call adults mentors/facilitators by their first names; this is to emphasise the idea that the adults are co-learners in this process and that the learning is truly student-led. Moreover, the noise level in a Bridge21 activity may be higher than the typical instructor-led class, as learners are constantly communicating with each other/the facilitator. These efforts can help maintain a respectful environment while allowing the students the space to think and speak for themselves.

The facilitator's use of the other elements of the Bridge21 model also contributes to creating a friendly atmosphere, where participants feel comfortable and are encouraged to learn together. Teams are also encouraged to build rapport (and a level of informality/comfort) by participating in icebreakers/team-building activities, determining a team name, establishing guiding principles to work by and identifying a leader/particular roles. Using a project-based approach also fosters a social learning environment, as team members must collaborate to complete the project within the given time frame. The projects are complex enough that multiple participants are needed to complete them but open-ended enough that students' voices and interpretation can move the project in different ways. The shared use of technology also can support a social learning environment. Finally, a mastery goal orientation philosophy is designed to support a social, supportive learning environment; the facilitator praises students for assisting each other in developing new skills, rather than singling out individuals or teams for achieving an objective marker of success.

2.7 Learning Space

In the Bridge21 model, the physical learning space is flexible: it's designed and configured to support team-based, collaborative learning, as well as the different tasks and activities involved in completing a project. In a collaborative learning environment, the furniture is arranged so that students can easily and comfortably work together, share resources and interact. This can include dedicated learning spaces for each team, so the students can feel a certain amount of ownership of and privacy within their working area. For example, in the Bridge21 learning laboratory, there are partitioned learning spaces called "team pods," equipped with PCs, desks, and swivel chairs (Lawlor et al., 2018). The Bridge21 laboratory also has an open space for conducting plenary sessions, where the whole class/group can come together to, for example, complete warm-up activities, discuss key aspects of the project and present their projects.

The facilitator organises the learning space to support the implementation of the Bridge21 learning model. A designated area for each team helps solidify the group and their working relationships: they share and take "ownership" of their space. These "pods" or team spaces give teams the opportunity to work comfortably, semi-privately and collaboratively to complete their project. As teams work in designated areas, it's essential that the space also allows the facilitator to move freely between groups to monitor progress. Within their learning space, teams are also only given a limited number of devices to encourage the technology-mediated approach used in the Bridge21 model. Furthermore, social learning protocols are reinforced through the learning space; students are trusted to be respectful of the space and to move freely within it. The facilitator fosters student-led learning, as students are given the space, as well as the tools, to complete their projects in their own way.

2.8 Reflection

Finally, students' reflection is a key element of the Bridge21 model and should be included as a regular part of learning activities. Students can reflect both in teams and individually. Team reflection serves the purposes of building and strengthening the team (Hills, 2001). Individual reflection on one's own learning and progress is also beneficial as it can help develop understanding, aid metacognition and cement learning (Dewey, 1933; Kolb, 1985). The reflection process allows students to think about their learning but also helps a facilitator to see where students feel they are thriving or struggling. This information can support activity planning or facilitating the students through subsequent projects.

It is ideal for students to have some quiet, semiprivate space to think and reflect. Structured questionnaires can help guide students in reflecting on how well they are collaborating and what challenges they are facing. Individuals can be encouraged to reflect on their development of key skills/content knowledge and/or the personal experience in general. This reflective approach supports the mastery goal orientation of the Bridge21 model, as facilitators and students have the opportunity to assess their progress and attainment of individualised learning goals.

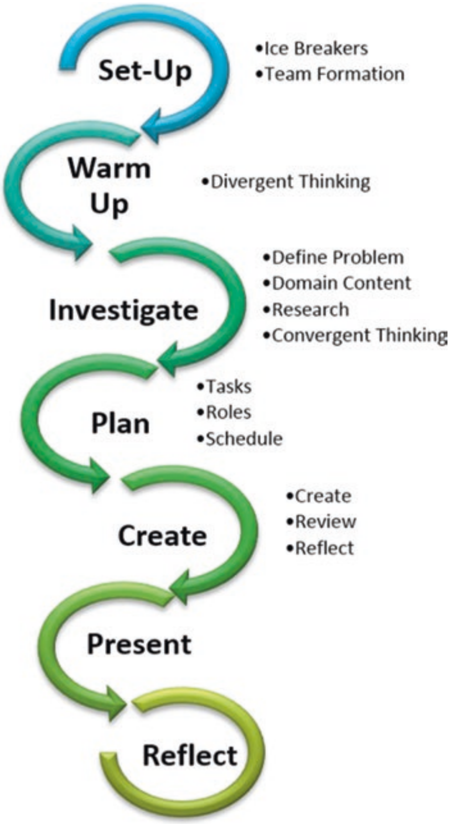

Fig. 2 The Bridge21 activity model

3 Bridge21 Activity Model

This section explores the Bridge21 activity model phases and steps in detail; see Fig. 2. We explain the motivation for each step, what is involved, what resources are needed and whether it is optional or recommended. We also outline the key competencies and twenty-first-century learning skills that are catered for in each step. The following details are generic in nature but can easily be adapted to a wide range of activities.

3.1 Set-Up

This initial phase can include a number of different activities, depending on whether this is the first time the group is working with each other or the teacher. Some of the activities may be skipped if the group has lots of prior experience working together and/or in teams, but are recommended if the group is not familiar with each other and for groups new to teamwork.

These activities focus on developing team dynamics and are important if a group is not familiar with each other or if they are not experienced in working in teams. It is also where teams are formed and they start thinking creatively about the topic that the activity will focus on.

Ice-Breaker

This step is especially important for groups who don't know each other or if there is low energy in the room (e.g. early morning or late afternoon classes). Ice-breaking activities[1] usually involve sharing personal information such as names, hobbies, etc. and/or an active game which has people on their feet and moving around. This helps in the development of intra-group communication and is a precursor to effective team communication.

- **Optional**: usually for new classes and groups not familiar working together
- **Technology and resources**: ice-breaker plan and associated resources
- **Skills**: collaboration skills and communication skills

Team Selection/Formation

As discussed above, teamwork is essential to the Bridge21 approach to learning. It is recommended that the facilitator put the students into their teams in order to make sure that they are mixed-gender/mixed-ability. This usually involves the team getting to know each other, deciding on a team name, developing a set of guiding rules (can help them resolve conflicts later) and select a team leader (this can be temporary if they don't know each other well). See Sect. 2.2 above for more details.

- **Optional**: only required if new teams need to be formed
- **Technology and resources**: paper or whiteboards and pens
- **Skills**: collaboration skills and communication skills

3.2 Warm-Up

General Divergent Thinking Activity

Once the teams are formed, their first task is a general divergent thinking activity (e.g. 30 things to do with a paperclip/orange). This helps the teams warm up and start to develop a working relationship while also getting them to think creatively. It is important to monitor the team's progress with this task making sure that everyone is engaged and contributing. This activity sets the precedent for the team's

[1] Examples here: http://tft-project.eu/index.php/set-up-activities/

behaviour in the following tasks and activities making it crucial to encourage full participation.

- **Optional**: encouraged for groups who need to relax and need to get into a creative mode of thinking
- **Technology and resources**: paper, pens, whiteboards, markers, scissors or online tools such as realtimeboard.com or padlet.com
- **Skills**: collaboration skills, communication skills, creativity and innovation

3.3 Investigate

This phase is the preparation for the main activity and is recommended for every Bridge21 activity. It sets up the problem/context of the activity or lesson to follow. It provides the opportunity for teachers to loosely define the problem area, leaving enough scope for the teams to develop their own perspective on the problem and thus make the problem their own.

The investigate phase usually starts by defining the problem context followed by ideation and some optional research. Ideally this phase elicits students' prior knowledge of the topic or context, helping them to identify with the content or problem.

Problem Context/Brief

The teacher outlines the activity by explaining the activity brief or problem context. A balance should be made between making it clear to the students what they have to do, but leaving enough scope that they can take ownership and tackle the topic in a creative manner.

- **Recommended**
- **Technology and resources**: can depend on topic/context. Usually revolves around multimedia presentation material but may simply be delivered orally
- **Skills**: communication skills and critical thinking

Divergent Problem Thinking

Whole team engagement in the stage is essential. The divergent thinking is a useful stage to elicit students' knowledge around a given topic. This can be useful for two reasons. The first is that it helps students identify prior knowledge related to the topic. The second is it can give the facilitator an insight into how well the students understand the topic and how much additional scaffolding might be needed later. This might affect whether the next two steps (content knowledge development and additional research) are required or not. It also provides the teams and wider group to explore and think laterally about the problem. It is important that the student "thinking outside the box" in a playful manner, as this affects how students share and contribute ideas throughout the activity.

- **Recommended**
- **Technology and resources**: paper, pens, whiteboards, markers, scissors or online tools such as realtimeboard.com or padlet.com
- **Skills**: collaboration skills, communication skills, creativity and innovation

Content Knowledge Development Exercise

This optional stage might be required if more content/domain knowledge or experience in skills is needed during the main activity. This can entail the use of exercises or mini-activities to develop the necessary knowledge and/or skills. For example, an activity might elicit a number of questions that then might be used in the research stage that follows or it might be appropriate to offer direct instruction.

- **Optional**: beneficial when the teams have very limited knowledge of the problem context
- **Technology and resources**: can depend on topic. Should be activity based where possible but may include delivery using multimedia material
- **Skills**: collaboration skills, critical thinking, and self-direction skills

Research

As an alternative to direct instruction, this optional stage is useful for training teams in best practices in how to access and evaluate content and materials. Through this process the teams can learn more about the problem space and can explore the ideas that emerged from the divergent problem thinking stage.

- **Optional**: beneficial when the teams have very limited knowledge of the problem space
- **Technology and resources**: pen and paper, computer/device with Internet connection, word processor for note taking and WebQuest for scaffolding
- **Skills**: learning with technology, critical thinking and self-direction skills

Problem Refinement/Framing/Design

For this phase the objective is for the teams to focus and refine their problem context so that they have a clear, self-directed, idea about what they are going to do. It is good practice for the teams to consider at least three potential directions/topics and critically analyse them before they choose the direction/topic they consider the most interesting and plausible/practical considering the time and resource constraints they will have for this activity.

- **Recommended**
- **Technology and resources**: paper, pens, whiteboards, markers, scissors or online tools such as realtimeboard.com or padlet.com
- **Skills**: communication skills, creativity and innovation and critical thinking

3.4 Planning

The planning phase provides an opportunity for the teams to develop their project management and organisation skills. The goal is to develop a plan of action through the development of a comprehensive list of tasks, a timeline or schedule and a breakdown of roles and tasks assigned to each team member.

Develop Task List/Outline

For this stage the team should decompose or break down the larger project into a set of smaller tasks. The facilitator can scaffold the activity through the use of templates (e.g. using a storyboard sheet and crew roles templates for video production). The goal here is to have the teams take ownership of the activity, thinking pragmatically about how they are going to complete the task.

- **Recommended**
- **Technology and resources**: paper, pens, templates, word processor or online tools such as realtimeboard.com or padlet.com
- **Skills**: collaboration skills, critical thinking and self-direction skills

Task, Role, Scheduling, Resource Assignment

Once a list of task has been developed, the teams need to consider who will complete the task, what resources will be needed and how long/when does it need to be completed by. This can either be scaffolded by the facilitator, using templates/worksheets, for inexperienced groups, or alternatively they maybe can develop their own templates, guided by the facilitator. Tasks, roles and resources are then assigned to individual team members (multiple team members can collaborate on tasks, but a single individual should be encouraged to make sure that the task is completed).

- **Recommended**.
- **Technology and resources**: templates, paper, pen and word processor. For longer projects, task management tools such as Trello.com or Slack.com might be useful.
- **Skills**: collaboration skills, communication skills and self-direction skills.

3.5 Create/Execute

The main activity can see the teams work through a number of iterations of execute, review and reflect. Throughout this phase the facilitator and team leaders should meet regularly (every 20–50 min, depending on activity duration) to review their progression and reflect on any issues that might have arisen. If the activity or lesson permits, these steps can be repeated, and this can involve iterations that might refine their work before completion.

In the create/execute step, the teams plan is put into action. Where possible, time should be made available to revise their plan.

- **Recommended**
- **Technology and resources**: depends on activity (pen, paper, whiteboard, camera, computer, video editor, Scratch, Python, micro:bit, Raspberry Pi, etc.)
- **Skills:** learning with technology, collaboration skills, self-direction skills

Review/Evaluate/Test

Reviewing and evaluating the progression of the teams plan is critical for success. During this step the teams review their progress and update their plan and tasks if required. This can either be achieved within the team or facilitated by the facilitator through the team leaders.

- **Recommended**
- **Technology and resources**: paper, pen, review template (sample or teacher created) and task list/task management tool
- **Skills:** communication skills, critical thinking and self-direction skills

Reflection in Action

Reflection during the activity is important; this can be achieved either through the use of explicit worksheets or through Socratic questioning by the facilitator. The flexibility of the questioning approach is useful when trying to get a student who is struggling to reassess their engagement and approach by reflecting on their teamwork and overall contributions to the project.

- Recommended
- **Technology and resources:** review template (paper based or digital)
- **Skills**: communication skills, critical thinking and self-direction skills

Iterate/Repeat (if There Is Time Available)

If there is time available, the team should return to the execute/create step. This allows the team to either continue as they were, work on a revised plan or refine their output for presentation. If allocated time does not permit another execution phase, the teams should move onto the next presentation step.

3.6 Present

The finale is the final and essential phase of the activity. Teams present their work to the whole group, reflect both individually and in teams on their learning experience and feedback any comments or observation in a whole class discussion.

Presentation plays a crucial role in the activity model as it develops important communication skills and confidence with public speaking. The whole team should contribute to the presentation, and they should describe both the final artefact and what role each team member played in completing the activity.

- **Recommended**
- **Technology and resources**: digital projector, computer and whiteboards
- **Skills:** communication skills, critical thinking and self-direction skills

3.7 Reflection on Action

Reflection on action can take two forms, in teams and individuals reflection. This is usually best achieved through a scaffolded and structure worksheet. It should focus on how well they worked together and what they personally got out of the experience and what they might like to improve on next time.

- **Recommended**
- **Technology and resources**: reflection template (paper based or digital)
- **Skills:** communication skills, critical thinking and self-direction skills

Whole Group Discussion

The final step is to provide an opportunity for a whole group discussion. This provides a space where, based on their reflections, students may share what they learnt, found difficult, enjoyed or would recommend doing differently if the activity was to be repeated. This is also a good opportunity for the facilitator to get some insight into how the activity went overall and might provide some feedback on how to improve the activity should it be repeated again.

- **Recommended**
- **Skills:** communication skills and critical thinking

4 Summary and Conclusion

As discussed in the introduction of this chapter, educational theory can be heavy on the academic rigour but can have limited or less obvious practical examples that educators can directly apply to the design of technology-mediated learning experiences for their students (Bruenig, 2005; Conneely et al., 2013; Donnelly et al., 2011). This chapter explained in detail the various elements which comprise the Bridge21 approach to twenty-first-century teaching and learning, as well as a step-by-step activity model and guide for planning and implementing the approach in formal or informal educational settings. The chapter represents a fusion of academic theories and practical experience gathered over the last 10 years by the Bridge21 programme team. The model has been used effectively in a wide range of contexts and with various groups of students, and it has been developed and refined over the course of this time. Research into the use of the approach has consistently demonstrated an improvement in student motivation in learning (Lawlor et al., 2016) and an increase in confidence in key 21C skills such as learning with technology, communication, critical thinking and self-directed learning (Johnston et al., 2014; Sullivan et al., 2017).

A practical approach is an important step to implementing technology-mediated, 21C learning experiences in the classroom, yet education systems require development in a number of areas in order to fully support educators in adopting such practices in their teaching. For example, teachers need more professional development and training (Donnelly et al., 2011), particularly involving experiential learning with this type of model. From the authors' experience of working with teachers in a variety of contexts, it is clear that teachers need the opportunity to learn within the model, experiencing first-hand the skills and content knowledge one can develop while engaging in this approach. Moreover, teachers need professional development to help them develop their understanding of how to teach curriculum content, as well as key skills, through a technology-mediated approach such as Bridge21. As the old adage goes, "you teach as you've been taught". Thus, educational administrators—at the school and state level—need to provide teachers with the opportunity and funding for quality professional development to help them fully realise and integrate the Bridge21 approach into their classrooms.

Moreover, policy-makers and curriculum writers need further alignment with 21C teaching and learning approaches. Without the support and alignment with policy and curriculum content, this type of learning model, which has shown to be powerful and effective among students in a variety of areas, will remain on the fringes. Related to this area, educators need guidance in terms of assessment and determining how one can assess students using such an approach. For example, there exists questions around summative vs. formative assessment, evaluating teams vs. individuals, and awarding the best performance compared to the rest of the group vs. mastery of skills and individual progression by each student; these are subjects of much debate, as internationally, educators are trying to determine how best to assess 21C skills (Geisinger, 2016; Griffin, Care, & McGaw, 2012). It is challenging for classroom teachers to implement a 21C approach to learning, when they are still required to evaluate students based on a system linked to a more traditional approach to teaching and learning.

Despite these challenges faced by educators, through this chapter, the authors hope that the detailed practices outlined offer a balance of both theory and practice, and thereby fulfil a need, as highlighted in the literature, for a practical approach and guidelines for implementing an effective technology-mediated, 21C teaching and learning approach in the classroom. Over the past 10 years, the authors have seen the Bridge21 model used in a variety of contexts and accommodate new technologies which have emerged. Moving forward, the authors believe the model will continue to be flexible and can adapt to new contexts/technologies, continuing to be a powerful model for teaching and learning.

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Developing Technologically Enhanced Mathematics Pedagogical Content Knowledge in Initial Teacher Education

Floriano Viseu and Laurinda Leite

Abstract Nowadays perspectives on mathematics education argue for student-centred maths teaching that enables students to engage into learning activities and to play an active role in learning. Information and communication technological evolution provides teachers with an ever-increasing diversity of digital and smart tools that may successfully promote students' deep engagement with the learning tasks. However, mathematics teachers need to learn how to integrate mathematics pedagogical content knowledge with technological knowledge so that they can develop technologically enhanced mathematics pedagogical content knowledge (TEMPCK). TEMPCK is required for teachers to select the best technological tool to teach a given content in the best way to a certain group of students in a specific social and cultural context. Initial mathematics teacher education has a key responsibility on this issue as it is expected to form updated teachers, able to effectively cope with the technological challenges of the moment as well as with the unanticipated challenges of future technology advancements. This chapter presents a few attempts of prospective mathematics teachers to use digital tools to teach different mathematics topics to secondary school students. Suggestions are made to increase the smartness of the learning environments used by the prospective teachers.

Keywords Mathematics education · Prospective mathematics teachers · Smart technologies · Pedagogical content knowledge · Technological knowledge

1 The Role of Technology in Mathematics Education

It is a matter of consensus among educators, curriculum designers and politicians that mathematical competences are necessary for active citizenship, social inclusion and employability (Eurydice, 2011; Wolfmeyer, 2017), as they may empower citizens to think and act for themselves (Ernest, 2015) in an advanced knowledge society (Danesi, 2016).

F. Viseu (✉) · L. Leite
CIED/IE, University of Minho, Braga, Portugal
e-mail: fviseu@ie.uminho.pt; lleite@ie.uminho.pt

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However, over the last two decades, international assessment studies (e.g. PISA) have been showing that schools in many countries (including Portugal) are not succeeding in developing students' mathematical competences required for a mathematically literate citizen. Being aware of the implications of this failure, the European Union settled the goal of having less than 15% of 15-year-olds under skilled mathematics by 2020 (European Council, 2009). Besides, it recognized that achieving this goal would require strategic actions to ensure high-quality teaching, to provide adequate initial teacher education (ITE) as well as continuous professional development for teachers and trainers and to make teaching an attractive career choice. This recognition is reinforced by a recent review of research (Haara et al., 2017) which showed that teaching for developing mathematical literacy requires other than 'traditional teaching methods in which individual task solving and a well-defined classroom structure prevail' (p. 293). In a way, this conclusion is aligned with some survey results published in a recent European Commission report (European Commission/EACEA/Eurydice, 2018) on teacher careers. Those results show that whatever the age group, experience, school subject and country, high proportions of in-service teachers expressed a moderate or high level of training needs in areas (other than content knowledge) that may strengthen their professional skills and teaching techniques. Those areas include 'ICT skills for teaching' and 'new technologies in the workplace' (Daniela et al., 2017).

The importance of using of technology to promote mathematics learning has been widely recognized for a few years now (Bennison and Goos, 2010) and has been supported by several research studies (Huang and Zbiek, 2017) even though not in a straightforward way (Drijvers et al., 2016; OECD, 2015). Opposite to what might be thought, the issue is not one of replacing the traditional 'board and chalk' or textbook-based teaching (Ponte and Serrazina, 1998) by technology-based teaching. Besides, teaching tools alone, even if they are modern digital tools, can hardly make a difference (McKnight et al., 2016; Passey, 2012). In fact, taking educational profit from technology is about a radically different way of conceptualizing the teacher-student relationship, in which teacher's and students' roles change deeply (McKnight et al., 2016). In fact, instead of keeping on telling knowledge (Roscoe and Chi, 2007; Scardamalia and Bereiter, 2010) to passive students, teachers need to become providers of conditions for students to learn by themselves as well as students' learning supporters. Thus, teachers need to acknowledge students' knowledge, experiences and interests (Viseu, 2008), to design appropriate learning contexts and mathematics tasks (Hegedus and Tall, 2016) and to monitor students' ongoing learning activities in order to foster in-depth analyses, comparisons and syntheses (Drijvers, 2013) which are required for meaningful learning to take place. Thus, both the theory and practice of student-centred teaching should be included and/or enhanced in ITE to better prepare future teachers to teach mathematics in a way to make it relevant for their students as citizens (European Commission/EACEA/Eurydice, 2018; Schneckenberg and Wildt, 2006).

Technological tools have a key role to play with regard to the required classroom changes referred to above, as they may facilitate and mediate students' learning. A large diversity of such tools is available nowadays (Drijvers, 2013; Hegedus and

Tall, 2016; Moreno-Armella and Santos-Trigo, 2016; Watson and Fitzallen, 2016). They can be used in a variety of ways (McKnight et al., 2016) to enhance learning (Kirkwood and Price, 2014). Enhancement may occur at three different and complimentary levels, some more focused on content knowledge than others, as follows:

(1) operational improvement (e.g., providing greater flexibility for students; making resources more accessible)
(2) quantitative change in learning (e.g., increased engagement or time-on task; students achieving improved test scores or assessment grades)
(3) qualitative change in learning (e.g., promoting reflection on learning and practice; deeper engagement; richer understanding). (Kirkwood and Price, 2014: p. 14)

However, there is some agreement on that teachers tend to teach as they were taught (van Driel and Abell, 2010) and that the successful integration of technology in the teaching practice is not a straightforward process (Hāwera et al., 2017; Hegedus and Tall, 2016). Hence, as Ponte and Chapman (2016) would put it, teachers 'should engage in learning or relearning the mathematics they will teach consistent with current curriculum recommendations' (p. 280). Besides, this means that, if prospective teachers are expected to use technology in their future classes, to help their future students to learn mathematics, then, they should also use technologies to learn mathematics and to learn the basics of how to make the use of technologies to become a benefit for students from a mathematics learning point of view. This means that they would need to learn how to integrate technology with mathematics pedagogical content knowledge in order to use technology properly in their mathematics classes in their future as teachers. In addition, it is consistent with findings obtained by Bennison and Goos (2010) which show that teachers clearly prefer to engage into professional development initiatives that help them to integrate technology in their classes to improve student learning of specific mathematical topics rather than to learn how to use technology for its own sake. As most of the equipment is of no use without software, for a matter of simplification, and following Goodyear and Retalis (2010) and UNESCO (2017), the word technology is used in such a way as to embrace sets of hardware and software that work together and may be used for specific purposes.

Initial teacher mathematics education has a key responsibility on preparing prospective teachers to learn how to both use technologies to learn mathematics and teach mathematics with technologies. These are requirement for prospective teachers to be able to prepare their future students to become informed, active and critical citizens, as required in the twenty-first-century knowledge society. They are also necessary conditions for prospective teachers to become updated teachers, able to cope effectively with the technological challenges of the moment as well as with the unanticipated challenges of future technology advancements.

Thus, this chapter describes a few attempts of prospective mathematics teachers to simultaneously teach mathematics with technology and to learn how to use technology to teach mathematics. The technology selected bears some features of what has been addressed as smart technology as it will be shown later in the chapter.

2 Technologically Enhanced Mathematics Learning Environments: Issues, Tools and Goals

Technologically enhanced learning environments are not simply equipment- and infrastructure-rich educational settings. Likewise, in such environments, hardware and educational software are not expected to be tools employed to just 'make it easier or quicker to perform tasks otherwise completed by hand' (Watson and Fitzallen, 2016: p. 563). For a learning environment to be technologically enhanced, technology has to improve the circumstances in which educational activities are undertaken as well as the teaching practices so that it ultimately improves students' learning outcomes both qualitatively and quantitatively (Kirkwood and Price, 2014).

Nowadays a large amount of equipment and software is available. As far as equipment is concerned, several devices that were formerly developed to be used outside the school (e.g. smartphone) have silently entered the classroom and soon became educational useful tools and started being used for teaching purposes. Examples of equipment used for mathematics teaching are laptops, tablets, smartphones, graphic calculators, mp3, data logging (sensors and interface) hardware, etc.

Most of the technology that actually pervades our daily life was not available 10 years ago (Hegedus and Tall, 2016). The pace of change in technology has been too fast for technological innovations to be incorporated into the school curriculum (Hegedus and Tall, 2016) as well as in teacher education in a reasonable time. Mathematics teachers can use a variety of software, which is becoming more and more independent of a specific type of hardware, to offer students better learning opportunities, as shown by Oldknow et al. (2010) and Kilicman et al. (2010). The kinds of software include educational games, simulations, modelling programmes, applets focused on a specific content, 3D manipulatives, etc.

Nowadays, notwithstanding the flexibility in structuring learning activities that technology offers to teachers and its potential to transform teaching and learning, most mathematics teachers are still used to direct teaching and to provide detailed guidance to students (Burkhardt, 2016). Raising this issue is not a strategy to reject the past. Rather, as Danesi (2016) argues, teachers should use 'a form of integrated teaching that connects new and old media, new and old practices (methodological and curricular), and new and old views of the teacher-student relation' (p. 157). Nevertheless, it is still unclear how technology can and will be used in classrooms in mathematically meaningful ways (Hegedus and Tall, 2016).

It is a commonplace to state that changing practices is not an easy task. This also applies to mathematics education practices, which require much more than knowing mathematics content knowledge. Rather, it requires knowing mathematics in ways that enable its use in teaching (Ponte and Chapman, 2016), in a given context. However, educators have the duty to stand up for things that are important for students (Oldknow et al., 2010), as it may be the case of integrating technology with mathematics and education in an appropriate way. In fact,

> Transforming learning is a complex activity that frequently necessitates reconsideration by teachers of what constitutes 'teaching' and 'learning'. It requires sophisticated reasoning

> about the goals of any intervention, the design of the evaluation and the interpretation of the results within the particular educational context. (Kirkwood and Price, 2014: p. 26)

It should be noted that the mathematical concepts and processes that students may learn during an activity do not depend only on their age and mathematical background. Rather, they depend moreover on the approaches that teachers choose to use (Oldknow et al., 2010). Besides, advances in hardware and software applications require teachers to perceive that 'learning from computers has shifted to learning with computers' (Watson and Fitzallen, 2016: p. 563) or other technological equipment. Consequently, the emphasis has to shift from learning how to use technology to learning with technology. This change is fostered by recent developments of multimodal technologies that offer alternative input (speech inputs, gesture-based interactions, bodily motion) or combined input/output methods (Hegedus and Tall, 2016) to give feedback to students.

Mathematics teachers may be willing to use technology for three different reasons:

- Pedagogical reasons, which have to do with the possibility of helping to teach content, to develop concepts, to increase knowledge, to improve understanding, to practise and to reinforce skills
- Mathematical reasons, which have to do with the possibility of computing results, to produce tables, to draw graphs, to solve problems, to manipulate expressions and to compute statistics
- Organizational reasons, which have to do with the idea of producing materials more efficiently, keeping records, managing time, communicating with others and finding resources (Oldknow et al., 2010)

As far as pedagogical reasons are concerned, it can be argued that the integration of technology in mathematics teaching is desirable (from students', teachers' and schools' point of view), inevitable (conventional alternatives no longer exist or impose such obvious restrictions that their use cannot be rationally supported, etc.) and an issue of public policy, as there has been a remarkably consistent acceptance of the educational benefits of technology, since the last decade of the twentieth century (Oldknow et al., 2010). In fact, technology may offer students learning opportunities that can hardly be encountered in non-technological educational environments. In mathematics classes it can facilitate learning from feedback, observation of patterns, uncovering connections, developing visual imagery, exploring data and 'teaching' the computer (Oldknow et al., 2010).

However, any technology should be expected to have potential and constraints. The potential depends mainly on the quality of the software used and the way it is used. Therefore, it is useful to consider whether the constraints support or inhibit other aspects of the software that are considered of educational value (Watson and Fitzallen, 2016). Answering this question may be a challenge to both in-service and prospective teachers, as well as to teacher educators. Based on a review of literature, Huang and Zbiek (2017) argued that engagement with interactive, dynamic tools could enhance prospective mathematics teachers' understanding of content knowledge and develop their positive attitudes towards using technologies in their further teaching. In addition, Strutchens et al. (2017) argue that a consistent use of technology in content and methods courses and field experiences could help prospective mathematics teachers to develop an awareness of the benefits of implementing technology-based instruction.

Using technology in mathematics classes is not a guarantee of educational success. ‘Technology can amplify great teaching but great technology cannot replace poor teaching’ (OECD, 2015: p. 4). However, if well selected and appropriately used, technology can make a significant contribution to students’ learning in mathematics. Oldknow et al. (2010) listed a set of goals that technology can help students to achieve. Those goals range from content knowledge to procedural knowledge and to management issues, including:

- practise and consolidate number skills, e.g. by using software to revise or practise skills and to give rapid assessment feedback;
- develop skills in mathematical modelling through the exploration, interpretation and explanation of data, e.g. by choosing appropriate graphical representations for displaying information from a data-set; by experimenting with forms of equations in trying to produce graphs which are good fits for data-plots; by using a motion sensor to produce distance–time graphs corresponding to students’ own movements;
- experiment with, make hypotheses from, and discuss or explain relationships and behaviour in shape and space and their links with algebra, e.g. by using software to automate geometric constructions, to carry out specified geometric transformations, to perform operations on coordinates, to draw loci;
- develop logical thinking and modify strategies and assumptions through immediate feedback, e.g. by planning a procedure in a sequence of instructions in a programming language, or a sequence of geometrical constructions in geometry software or a set of manipulations in a spreadsheet;
- make connections within and across areas of mathematics, e.g. to relate a symbolic function, a set of values computed from it, and a graph generated by it to a mathematical or physical situation, such as the pressure and volume of a gas, which it models;
- work with realistic and large sets of data, e.g. in using box and whisker diagrams to compare the spreads of different data-sets; to carry out experiments using large random samples generated through simulation;
- explore, describe, and explain patterns and relationships in sequences and tables of numbers, e.g. by entering a formula in algebraic notation to generate values in an attempt to match a given set of numbers;
- learn, and memorize, by manipulating graphic images, e.g. the way the graph of a function such as $y = x^2$ is transformed by the addition of, or multiplication by a constant: $y = a. x^2$, $y = x^2 + a$, $y = (x + a)^2$, etc. (pp. 100–101)

According to Daniela et al. (2017), using technologically enhanced mathematics environments may be expected to promote students’ interest in the learning process, which leads to active participation of the students and cooperation of students and teachers.

3 Technologically Enhanced Mathematics Learning Environments and the Smart Technology

It was mentioned previously that school cannot ignore technology because citizens are increasingly dependent on it, as it facilitates their daily lives (Zhu et al., 2016a) in several ways. Hence, when children start learning mathematics at school, they are already familiar with a plethora of technological devices that cannot be rejected and should rather be integrated in teaching and learning activities (Hoel and Mason, 2018).

Besides, in the previous section, it was argued that mathematics education could benefit from technology given that it is used in such a way that it promotes students' engagement in valuable learning activities. However, the fact that children get highly involved with technological tools since very young ages does not mean that they are able to learn from technology the mathematics that teachers and curricula want them to learn at school. This may offer a challenge to mathematics teachers who may need to perceive that both recreation and knowledge may be more intertwined than one might think (Danesi, 2016) and children need to learn how to enjoy using technology for learning purposes. Then, teachers may need to succeed on developing children's enjoyment with technology to attain specific mathematics learning goals building on their previous enjoyment with technology for playing.

Technological educational environments have become more and more open, enabling personal, social, flexible and dynamic learning, based on a logic of 'anytime, anywhere' access to knowledge (Gros, 2016). This logic was greatly strengthened by Internet-based technologies, which changed our ways of communicating, living, working and thinking. As Danesi (2016) puts it, the emphasis moved from the individual brain and print materials to the global brain (of the global village) and the classroom without walls which are heavily dependent on networking. 'It is in promoting a sense of connectivity to the wider world outside the classroom that technology-based education can be truly effective and relevant today' (Danesi, 2016: p. 34).

Nowadays, 'learning environments would ideally be adaptive, personalized, and technology-driven, with the ability to provide immediate feedback and guidance along the way' (UNESCO, 2017: p.5). Educational environments that are able to do so are said to be smart. Smart learning environment (SLE) is a new term, which has not yet a completely clear definition (UNESCO, 2017; Zhu et al., 2016a) due the recent incorporation of SLE into the technologically enhanced learning environments. However, according to Spector (2014), a SLE 'automatically makes appropriate adjustments to what a learner knows, has mastered, and wants to learn next' (p. 2). Thus, in a recent report, UNESCO (2017) assumed that:

> a SLE is an adaptive system that puts the learner at the forefront; improves learning experiences for the learner based on learning traits, preferences and progress; features increased degrees of engagement, knowledge access, feedback and guidance; and uses rich-media with a seamless access to pertinent information, real-life and on-the-go mentoring, with high use of AI, neural networks and smart-technologies to continuously enhance the learning environment. (p. 9)

Hence, a SLE combines smart devices that include some kind of smart material which can detect certain signals, adjust sensitivity according to environmental changes or restore degraded sensitivity (Uskov and Sekar, 2015) and artificial intelligence principles which are able to 'customize the learning experience the student receives based on factors such as pre-existing knowledge, learning style, and the student's progress through the content material' (UNESCO, 2017: p. 7). Thus, this combination allows greater flexibility, effectiveness, adaptation, engagement, motivation and feedback for the learners (Spector, 2014). In fact, the goal of a SLE is to provide learners rich, personalized and seamless learning experience, by encompassing formal and informal learning (Zhu et al., 2016a). This is why Gros (2016) argues that the most important characteristic of a smart educational system is that it will be able to advise and predict learners' needs because 'Smart learning is a learning system that provides advising to learners to learn in the real world' (p. 3).

Zhu et al. (2016b) identify three key elements in a SLE: the teaching presence, which concerns the instructional design, facilitation and direct instruction and technological support; the learner presence, which has to do with the learners' abilities to being autonomous and collaborative learners as well as efficient users of technologies; and the technological presence, which concerns to what extent technologies can create connectivity, provide ubiquitous access to learning resources and adapt to personal needs. As Crook (2016) pointed out, smartness 'depends on not just creating a ubiquity of resource, it depends also on targeting the information it provides: achieving the "right" patterning of access' (p. 12). Therefore, learning taking place into a SLE has some features that may not be enabled by a normal technological environment. Hence, according to Zhu et al. (2016a), smart learning shows the following ten key features of:

1. Location-aware: in smart learning the location in real time is important data that the systems need in order to adapt the content and situation to the learner;
2. Context-aware: exploring different activity scenarios and information;
3. Socially-aware: sensing social relationships;
4. Interoperable: setting standards for different resources, services and platforms;
5. Seamless connection: providing continuous service when any device connects;
6. Adaptable: pushing learning resources according to access, preference and demand;
7. Ubiquitous: predicting learner demands until clearly expressed, providing visual and transparent access to learning resources and services;
8. Whole record: recording learning path data to mine and analyse in depth, then providing reasonable assessment, suggestions and pushing on-demand service;
9. Natural interaction: transferring the senses of multimodal interaction, including position and facial expression recognition;
10. High engagement: immersion in multidirectional interactive learning experiences in technology-enriched environments. (pp. 11–12)

Adaptivity, as the ability to detect pertinent details of a situation and then select, modify and activate or deploy an appropriate response (Spector, 2016), is the key feature of smart learning technology. In fact, it is a necessary condition for a SLE to be able to provide self-learning, self-motivated and personalized services (Zhu et al., 2016a) in both formal and non-formal or non-intentional situations (Spector, 2016), as it should be expected within a smart learning framework. However, the smartness of things will often need to be enveloped by an overarching intelligence. Within the contexts of smart-enabled educational activities, this must be a responsibility of teachers (Crook, 2016) who should keep in mind that technologies are embedded within learners' habitual life experiences and become willing to introduce new and innovative pedagogical approaches (Gros, 2016).

4 Smart Learning and Mathematics Teachers' Technological Knowledge

The use of SLE is not just a matter of injecting smart technology into the syllabus and the classrooms. Rather, it relies heavily in aligning the teaching practices with the potential of those new technologies (UNESCO, 2017). This alignment requires allowing students' active engagement in their own learning, as well as learners' responsibility and metacognitive skills use subsumed under a dialogical, collaborative model of teaching and learning (Gros, 2016). Hence, in a SLE, both students and teachers need to be proactive in knowledge building with and from technology: the teacher needs not only to provide knowledge but also to help learners recognize individual ability and stimulate personal talents and skills; the students need to prepare learning material and to critically reflect and contribute to the overall individual and collective learning (Zhu et al., 2016b).

As the level of smartness of a SLE increases, from adapt and sense to self-organize (Uskov and Sekar, 2015), its complexity also increases (Spector, 2016), and the more demanding its development and educational management become. Hwang (2014) listed a set of 16 operations that a SLE should be able to do. They go from detecting and taking into account the real-world contexts to providing support to learners with adaptations that facilitate moving across real and virtual contexts. Seven of the operations have to do with context-awareness, and four of them have to do with adaptive learning. However, Hwang (2014) argues that a SLE is more than a combination of context-aware and adaptive learning. It is an environment that:

> guides learners to do the right thing (i.e., the tasks that are most feasible and important to the learner at present) in the right way (i.e., with effective learning tools or strategies) at the right time and in the right place based on individual learners' online and real-world learning status as well as their personal factors. (p. 8)

As Spector (2016) emphasizes, the most critical one is the SLE ability to adapt, either by itself or by means of the users' orders, to the learner's characteristics, to the learning task, to the context, to historical developments, etc. The goal is to provide effective and efficient learning that requires individually engaging experiences and activities, metacognition and self-regulation, skills development and provision of meaningful feedback (based on progress and performance monitoring) and guidelines for specific changes and courses of action. Based on the analysis of recent or ongoing experiments, Hoel and Mason (2018) highlight two models of smart learning: a SLE reference model, which highlights how learning is initiated and takes place, and a SLE context model, which stresses how the learning environment is set up and what affordances are to be expected from it. In any case, smart education encourages a 'high-level' use of technology, utilizing it as a 'mind tool' or 'intellectual partner' for creativity, collaboration and multimedia productivity (Gros, 2016). Therefore, embracing smart resources creates distinctive responsibilities for teachers (Crook, 2016).

However, in a recent review of literature, Crompton (2015) concluded that most mathematics teachers do not know how to integrate technology effectively and that negative teacher beliefs about technology inhibit its use. Preparing prospective mathematics teachers to teach with technology is an important endeavour (Strutchens et al., 2017), but it should be integrated with mathematics to ensure that they will use it properly in the future (Crompton, 2015).

Mishra and Koehler (2006) identified three areas of knowledge, which are required for teachers to incorporate technology into mathematics: content knowledge, pedagogical knowledge and technological knowledge. Following Shulman (1986), they defined content knowledge as the subject matter that is to be learned or taught, that is, mathematical content knowledge; pedagogy knowledge as the process, practice or methods used in teaching and learning; and technology knowledge as the understanding of digital and non-digital standard technologies.

Crompton (2015) concluded that pedagogical knowledge was critical for a prospective teacher lesson to be effective, as it is required to link together content and technological knowledge. As these three types of knowledge have to be interconnected for smart technology to be effectively incorporated into the curricula, what is worthwhile concentrating attention on is the type of knowledge that results from the overlap of technological, pedagogical and content knowledge. Mishra and Koehler (2006) address this complex, situated, dynamic and socially constructed form of knowledge that goes behind the three types of knowledge separately, as technological pedagogical content knowledge (TPCK). Other authors (see Yigit, 2014) used the acronym TPACK to address the common overlap of technological, pedagogical and content knowledge.

However, it can be argued that this acronym does not emphasize the integration of knowledge that emerges from the overlap previously mentioned. In addition, TPCK and TPACK are broad acronyms, which stand for all disciplines. Hence, it should be noted that mathematics TPCK or TPACK is different from TPCK or TPACK of any other discipline. Besides, the ultimate goal of integrating technology, namely, smart technology, into teacher's practices is to improve their pedagogical content knowledge of the discipline. Therefore, notwithstanding the fact that we argue for mathematics borders with other disciplines and the outside world being blurred (for the sake of meaningful learning that requires knowledge integration), we would like to argue for an acronym that captures these two key ideas, that is, the idea of enhancing teachers' content knowledge with technology and attending to the requirement of a given discipline. In the case of mathematics, this concern leads to technologically enhanced mathematics pedagogical content knowledge (TEMPCK). Thus, TEMPCK is a form of knowledge that, consciously or not, mathematics teachers bring to play anytime they teach with technology even though they may not use all its components at once, as it was found by Bibi and Khan (2017). However, teachers become more aware of their need of TEMPCK when using emergent technologies which require them to reconfigure not just their understanding of technology but also of the way it relates to content and pedagogy.

Teacher education context-neutral approaches are likely to fail to fulfil those needs because they overemphasize technology (Mishra and Koehler, 2006) and tend to ignore content. Besides, as pedagogy plays a key role on the use of technology (Benson, Ward, & Liang, 2015), it can be argued that mathematics teacher education should concentrate on developing TEMPCK, as it is required for teachers to select the best technological tool to teach a given content in the best way to a certain group of students in a specific social and cultural context. Following Niess et al. (2009), teachers' TEMPCK should be expected to develop gradually, from the most simple (recognizing technology) to the most elaborate (advancing which involves evaluation) level, as follows:

1. *Recognizing* (knowledge), where teachers are able to use the technology and recognize the alignment of the technology with mathematics content yet do not integrate the technology in teaching and learning of mathematics.
2. *Accepting* (persuasion), where teachers form a favorable or unfavorable attitude toward teaching and learning mathematics with an appropriate technology.
3. *Adapting* (decision), where teachers engage in activities that lead to a choice to adopt or reject teaching and learning mathematics with an appropriate technology.
4. *Exploring* (implementation), where teachers actively integrate teaching and learning of mathematics with an appropriate technology.
5. *Advancing* (confirmation), where teachers evaluate the results of the decision to integrate teaching and learning mathematics with an appropriate technology. (p. 8)

A literature review carried out by Yigit (2014) showed that prospective mathematics teachers' active involvement in technology-enhanced lessons or courses is the major strategy to develop their future teaching of mathematics with technology. However, as knowledge and beliefs are highly intertwined (Crompton, 2015), teacher education should also develop positive dispositions for using technology (Huang and Zbiek, 2017). Therefore, to encourage effective use of smart technology, it is essential that ITE addresses both prospective teachers' lack of mathematics knowledge and beliefs concerning the pedagogical value of technology.

According to Price (2015), transforming the traditional classroom to an innovative, engaging SLE with technology playing a key role in personalized, student-centred teaching practices is a demanding task which requires holistic multidimensional approaches and combined efforts from ministries, education administrators, researchers and teachers. However, it is our belief that teacher education is the building block in this necessary conversation. Therefore, teacher education programmes should be adapted to prepare teachers for technology-enhanced teaching (Daniela and Lytras, 2018) so that technology in general and smart technology in particular become tools for mathematics learning as well as motives to learn about how to teach mathematics with technology.

5 TEMPCK in Action: A Few Examples Using Potential Smart Technological Tools

Some Portuguese teacher education programmes include a content-neutral course on information and communication technologies. However, our ITE experience and the literature suggest that this type of courses is not enough for prospective mathematics teachers to integrate technology in their future teaching practice properly. Therefore, technology issues are integrated in some mathematics and mathematics education courses as well as in supervisioned teaching practice of a secondary school initial mathematics teacher education programme, in order to promote prospective teachers' TEMPCK. This section describes three examples of prospective mathematics teachers' integration of technology in their teaching practice, which aim at leading school students to deepen mathematics content knowledge through technology. The proposals show different degrees of consistency with SLE. Their design and implementation were monitored by one of the authors (who was the university teacher trainees' supervisor) to support prospective teachers and to ensure that their plans to teach mathematics through technology could be expected to lead school students to learn mathematics knowledge and develop teacher trainees' competences to use technology to teach mathematics, that is, their own TEMPCK.

5.1 Web-Based Teaching of Quadratic Functions

According to the Portuguese mathematics syllabuses, school students are supposed to learn about quadratic functions at 10th grade. In addition, the 10th grade syllabus states that the study of functions should start from the analysis of the effect that changes on a parameter have upon the shape of the graphs of a family of functions. Even though this topic has to do with daily life situations, research has shown that it may be hard for students to learn about it (Vaiyavutjamai and Clements, 2006). In this first example (Larsen, 2012), the prospective teacher wanted students to do cooperative work to uncover mathematics concepts and ideas by exploring web applications or searching information in the web. Thus, she organized a technologically enhanced environment to foster students' active learning through web-based teamwork.

Activities based on web applications include the analysis of video clips (retrieved from YouTube) and the exploration of applets dealing with quadratic function-related issues. Video clips show diverse parabolas in everyday situations (e.g. up and down water in fountains, shapes of some bridges, paths of a basketball ball, etc.). In teams of three, students were asked to find out what the curves they could observe in the different situations had in common. Answering this question would require them to identify the type of curve (parabola) and to relate it with issues studied in other school subjects. Afterwards, students were asked to use three applets, which would help them to model the curve and to find out its mathematical equation and characteristics. Thus, one of the applets would enable students to relate the values of a selector representing the parameter a in the family of functions ($y = a\ x^2$) with the characteristics of a parabola, namely, signal of a with orientation of the concavity of the parabola and order of magnitude of a with the amplitude of the parabola. Another applet would enable the exploration of the effect of changing the values of a selector related with parameter h in the family of functions $y = a(x - h)^2$, which originates a horizontal displacement of the previous parabola. Finally, the third applet would enable students to explore the effect of changing the k parameter in the family of functions $y = a(x - h)^2 + k$. Changing this parameter would originate a vertical displacement of the previous parabola. The members of each team had to cooperate, among others, to collect data, take notes, make conjectures about quadratic functions and generalize about parabolas. For each family of quadratic functions representing a type of parabola, they should focus on the zero, the vertex coordinates, the symmetry axis, the monotony intervals and the contra-domain. They could get face-to-face support from their teacher (i.e. the teacher trainee).

On the case of web information search-based activities, students were asked to choose a new topic within the scope of functions to be studied in teams. The following topics were chosen: parity of functions, cubic function and polynomial interpolator. Then, each team of students was asked to look for information on the chosen topic and to prepare a presentation to the class. The latter should include a definition of the concept, a synthesis of its characteristics and everyday instances of the concept. In each team, students should share tasks according to their interests and preferences and get quick face-to-face and electronic (through e-mail and Facebook) feedback from the teacher. The two teams that chose the cubic function had a harder job because of a mismatch between their background and the complexity of the material available in the web. Therefore, they needed more emotional support and more feedback from the teacher (i.e. the prospective teacher) than their counterparts did.

Comparing this first example with the SLE requirements mentioned above, it could be stated that this prospective teacher showed some abilities to create a technologically enhanced environment that may match different students' profiles. However, the environments created are neither context-aware nor able to adapt themselves to different students' characteristics, that is, they do not possess the key features of a SLE. Nevertheless, they offer students the possibility to choose resources that fit best their interests and needs, to use them and to get instantaneous face-to-face feedback. Even though these are not the key SLE features, together with cooperation and the possibility of crossing between real (present through images) and virtual settings, they introduced some level of smartness in the learning environment. However, more profit could be taken from smart technology for teaching and learning about the quadratic function. For example, sensors could be used to collect data from falling bodies or projectile motion that could afterwards be used to model the motion of those moving bodies and to obtain the mathematics equations that describe it, which is also a quadratic equation.

5.2 GeoGebra and Mathematical Proof

The 9th grade Portuguese mathematics syllabus requires school students to deepen their knowledge about angles and to learn about mathematical proof. Stylianides (2007) states that a mathematical proof is a social construct which relies on a sequence of assertions for a mathematical result that is convincing for the mathematical community, which accepts as valid the rules and reasoning mechanisms in which the proving process relies. Therefore, an argument that could count as proof in a classroom community should be accepted as proof by the community and thus should be convincing to the students because of socially accepted mathematical rules.

In this second example (Capa, 2015), a prospective teacher wanted her 9th grade students to engage into proving processes in association with angles in a circumference. Thus, she organized a technologically enhanced environment to foster students' active learning through GeoGebra, which is a geometry web interactive application. First, students were required to make a conjecture on the relationship between the amplitude of an inscribed angle and the amplitude of its intercepted arc. Afterwards, students were required to prove the relationship conjectured, that is, to show that its generalization is valid. This proving process is necessary because reaching a conjecture about the relationship that is at stake based on a few instances does not mean that the conjecture applies to a new instance.

To make the conjecture, students (in pairs) carried out a first task focused on inscribed angles that have the vertex on the circumference. They used GeoGebra to calculate the amplitude of the inscribed angle but had to find a way to have GeoGebra computing the amplitude of the arc because GeoGebra does not have a tool to measure the amplitude of arcs of a circumference. The computation was based on the relationship between the length and the amplitude of the circumference (which they were already familiar with) and the length of the intercepted arc of the inscribed angle. Thus, students explored a few angles, and GeoGebra drew a table with pairs of values of 'amplitude of inscribed angle/amplitude of intercepted arc'. Then, students compared the diverse pairs of values and reached a conjecture that says that the amplitude of an inscribed angle may be half the amplitude of its intercepted arc. Afterwards, they were asked to prove that the conjecture was true and valid. They needed a clue to start the proving process. Hence, the teacher suggested them to compare the internal angles and the sides of a triangle whose sides belong to the inscribed angle. This clue was enough for them to prove the conjecture. In the process of conjecturing, the added value of GeoGebra was that it enabled students to

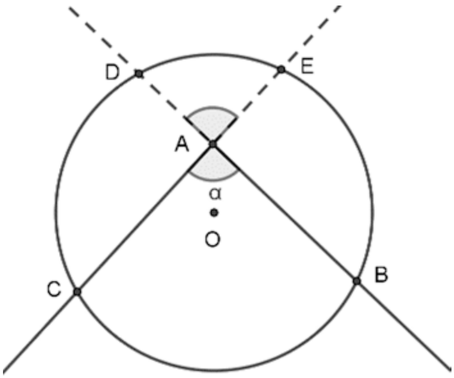

Fig. 1 Angle CAB is an interior angle

collect large amounts of precise data which would not be possible to get by 'hand and protractor' measures and calculations. In the proving process, GeoGebra made enabled students to easily visualize and explore the relationships between a triangle sides and its internal and external angles.

A second task concentrated on interior (but not central) angles in which the vertex is inside the circumference (see example in Fig. 1). This time, students were asked to make conjectures about the amplitude of this type of angles. The benefit of GeoGebra is that it permits dragging a side of the angle (from points C or B) over the circumference to make a new angle. Besides, in addition to providing a visualization of the new angles, GeoGebra provides immediate information on them. This facility enabled students to get a table with values on amplitudes of angles and arcs. After collecting data for a few interior angles and analysing them with regard to their amplitude, students made a conjecture on the amplitude of this type of angles. The different pairs conjectured that the amplitude of an interior angle is half of the sum of the amplitude of the arcs CB and ED. Then, they had to prove their conjecture, working in pairs. Students needed some scaffold information to do this task. Therefore, they were advised to draw triangle [BAE], as in Fig. 2, and they were given the amplitude of their acute internal angles.

Visual information provided by GeoGebra led students to perceive that they could use information about the triangle angles to prove their conjecture. To accomplish this proving task, students had to make arguments based on mathematical processes, properties and concepts.

To perform the conjecturing and proving tasks, students had to play a key role as learners because they themselves had to uncover the relationships and to prove them as valid relationships. To do so, they had to interact with GeoGebra and could get immediate visual feedback from it. Besides, they could discuss with their peers and get face-to-face support from their mathematics teacher, that is, the teacher trainee. Thus, she succeeded partly on aligning the use of GeoGebra with the smart pedagogy principles. However, she could have a learning environment fitting better those principles if she could include activities that promote the crossing between real and digital world. These could have to do with applications of angles inscribed angles in

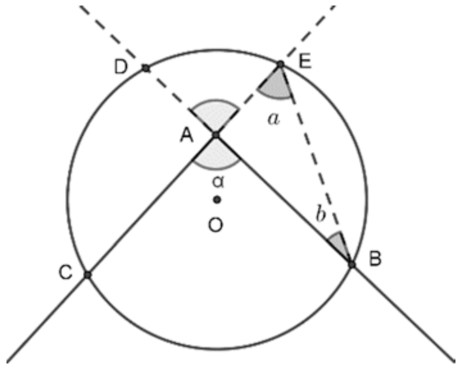

Fig. 2 Triangle [BAE], added to Fig. 1

daily life situations, to find the best place in a movie theatre or to describe the relative position of two chairs in a Ferris wheel or of the wheel spokes of a bicycle.

5.3 Applets and Graphic Calculator-Based Modelling of Exponential, Logarithmic and Logistic Functions

Modelling is a problem-solving process that enables people to find mathematics-based answers to everyday questions (Kaiser and Maaβ, 2007). It requires the analysis of the situation to be modelled in order to uncover its key elements and their relationships, to find a possible solution for the question and to compare it with everyday situations to check whether it is a good solution or not. According to the Portuguese mathematics syllabuses, the exponential, logarithmic and logistic functions should be taught at the 12th grade. The 12th grade syllabus stated that teaching about these functions could show how mathematics is present in everyday settings. Besides, it suggested the pedagogical use of technological devices including the graphical calculator so that students could cooperatively perform research tasks to get knowledge on those functions. Hence, a teacher trainee (Marques, 2013) planned to use a student-centred approach drawing heavily on technology for his 12th grade students to model the aforementioned functions from daily life situations.

Starting with the exponential function, students were given the possibility of using a simulator to study the braking distance of a car (distance travelled between the instant the car starts braking and the instant it comes to a complete stop) with different initial traveling speed values, road conditions (e.g. dry, wet, icy, try or clay) and driver's reaction time. Thus, in triads, students were asked to simulate the car braking movement in several conditions and to record the values obtained. Afterwards, they should work with these values to uncover the model that fits better the relationship between the braking distance and the speed of the car. They could do it by using the graphic calculator, which enables them to try different models easily and to select the one that could fit the data collected from the simulation best.

They concluded that the best model was $y = 16{,}861 \times e^{0.0345x}$, with x standing for the car speed and y for the braking distance. Moreover, they could compare the growth of this function (which was meanwhile named as exponential function) with the growth of other families of functions to conclude that it grows slowly for small x values but grows faster and faster as x values increase (as the $e > 1$).

With regard to the logarithmic function, students were given annual data on the rate of US citizens with own house. They were asked to uncover a model to predict the rate of citizens with own house 10 years after the last known value. The students did not collect data but rather used data that had to do with a real social issue. Students used a graphic calculator to try to find the best-fit curve and to uncover the mathematical model that lies behind it. This was a challenge for the students that were not used to do this type of task or to use the graphic calculator or both. They could get face-to-face feedback from the teacher (i.e. the teacher trainee) who tried to reply to their questions with other thoughtful questions. The idea was to avoid students' frustrating blocking but to promote student-student interaction and to provide them with clues on how to proceed. After reaching the mathematical model $y = -36{,}75 + 22{,}99 \ln x$, the function that it describes was named as logarithmic function. Afterwards, students compared its characteristics (e.g. shape, rate of growth) with other functions and with real-life situations (e.g. pH of chemical solutions, amplitude of an earthquake, growth rate of a population and rate of bacterial reproduction).

As far as the modelling the logistic function is concerned, students were given data on an experiment to study mice's behaviour using a Skinner box with a lever that enables access to water drops. Data were collected for the number of times that a thirsty mouse pushes the lever (to get a water drop) per minute. However, students were given only data for the minutes of an hour in which a different number of pushes were recorded and for 3 (final and non-consecutive) minutes in which the number of pushes was the same. Then, they were asked to analyse and interpret the set of data provided and, afterwards, to model the mouse's rate of pushing the lever. Again, students could use the graphic calculator and work in triads. Triads had a lot of discussion to interpret the data-set and required some scaffold questions from the teacher trainee. Anyway, they reached the qualitative conclusion that, as time elapses, the number of times that the mouse pushes the lever per minute decreases and finally it becomes constant. However, they still needed to get a mathematical model of the function. This was a challenging task for students. They needed help from the teacher to model the function as $y = \dfrac{13{,}0818}{1 + 22{,}6702e^{-0.23x}}$ named as logistic function.

The teacher trainee became aware that students' lack of technological knowledge about the graphic calculator interfered with the modelling process, which may explain students' need of support and clues. Even though the first task used shows a few smart characteristics like data collection on simulated daily life situations, the second and the third could be reasonably improved with regard to their smartness by using digital devices to collect or control real situations.

6 Concluding Remarks

As it was argued above, smart technology provides conditions to use real-world simulators that cross real and formal conditions and may make mathematics more meaningful for students. The examples of technology-based mathematics teaching put into practice by three mathematics prospective teachers (in the condition of teacher trainees), which were described in the previous section, showed some characteristics of a SLE but would need to be further improved for their smartness.

As stated before, the success of using smart technology depends on the pedagogical approach it is integrated in, and the latter depends on teachers' practices, which in turn depend on teachers' knowledge and beliefs about mathematics teaching and learning and the role of technology in these processes. Hence, ITE should prepare teachers to take educational advantages of smart technology in their classes. However, to succeed in doing so, it would need to acknowledge the development of prospective teachers' TEMPCK as a key goal of teacher education and to give digital and smart technologies an appropriate place and time in ITE programmes. Moreover, rather than being integrated within content-neutral courses on technology, they should be integrated within content-dependent courses, directed by qualified teacher educators, able to teach with them and about them.

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Virtual Reality as a Learning Tool: How and Where to Start with Immersive Teaching

Ivan Stojšić, Anđelija Ivkov-Džigurski, and Olja Maričić

Abstract Innovations in the field of educational technology are very prominent. The application of immersive virtual reality (VR) in teaching and learning is currently in the focus of interest of researchers dealing with education. Numerous studies indicated that there are significant potential benefits of using this technology to improve learning outcomes and students' motivation, overcome school-based and test anxiety, influence empathy, and ensure students focus on teaching content. However, there is still an issue of economic justification of investment in head-mounted displays (HMDs) and VR software for school use. Additionally, the key questions that arise from using VR in the classroom are on what theoretical basis to build immersive teaching and how to choose relevant content. The purpose of this chapter is to present a literature review of VR applications in education (with emphasis on both technological and pedagogical aspects, integration, and evaluation criteria), as well as to show the results of a small qualitative study conducted with teachers and an educational media specialist (all familiar with using VR as a teaching tool) in the Republic of Serbia.

Keywords Educational technology · Head-mounted display · Immersive learning · Immersive technologies · Technology-enhanced learning · Virtual learning environment · Virtual reality

I. Stojšić (✉) · A. Ivkov-Džigurski
University of Novi Sad, Faculty of Sciences, Novi Sad, Republic of Serbia
e-mail: ivan.stojsic@uns.ac.rs

O. Maričić
University of Novi Sad, Faculty of Education in Sombor, Sombor, Republic of Serbia
e-mail: olja.maricic@pef.uns.ac.rs

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1 Introduction

The use of information and communication technologies (ICT) in educational contexts modified the learning environments dramatically, providing a significant challenge and continuous changes in learning approaches and instruction (Spector, 2014). Recent innovations in the field of virtual technologies have facilitated the access to VR and augmented reality (AR) to everyone, which opened up numerous opportunities for using these technologies in educational sector in order to improve the efficacy of learning (Martín-Gutiérrez, Mora, Añorbe-Díaz, & González-Marrero, 2017). However, Spector (2014) pointed out that the simple use of a new technology to replace prior practice may not be beneficial and described a smart educational technology as one that accomplishes effective, efficient, and engaging use, often in an innovative, flexible, and adaptive manner.

According to Gros (2016, p. 6), "smart education encourages a 'high-level' use of technology, utilizing it as a 'mind tool' or 'intellectual partner' for creativity, collaboration and multimedia productivity." Also, the same author emphasized that a concept of smart learning is broader but highly related to the term "technology-enhanced learning" (TEL), which is more familiar and more frequently used in Europe. The term TEL is often described only as the usage of the ICT in teaching and learning (Kirkwood & Price, 2014), and in recent years the focus was on the application of mobile devices (Zhu, Yu, & Riezebos, 2016). However, the wider conceptualization of the TEL as the intersection of technology and pedagogy would be more appropriate (Bälter, 2017). Changes in teaching methodologies and learning strategies are also required since the effective use of technological advancements goes beyond the simple application of new educational technologies in a learning environment (Kinshuk, Chen, Cheng, & Chew, 2016).

Teaching using technologies is often considered innovative per se, and usually, the success of technology integration has been based only on the extent of use (Moyle, 2010). However, Daniela, Kalniņa, and Strods (2017) asked: "Can all technologies be considered innovative?" (p. 89), and Spector (2016) emphasized that innovative and adaptive technologies have the potential to support, facilitate, and enhance learning, but only if there is evidence of those benefits that innovative technology can be considered as an innovative learning technology, as well.

Modern immersive technologies created new opportunities to turn learning into an exciting endeavor (Kovács, Murray, Rozinaj, Sulema, & Rybárová, 2015). Kinshuk et al. (2016) indicated AR and VR as examples of innovative technologies that can be used in smart learning environments to enable learning opportunities that have been very difficult (or impossible) in traditional settings. Both technologies are different but related in some characteristics and usage (Liu, Bhagat, Gao, Chang, & Huang, 2017). AR supplements the real world with virtual objects, while VR simulates a whole reality and is usually defined as a three-dimensional computer-generated environment, available in real time, which allows user interaction through different input/output devices (Boud, Haniff, Baber, & Steiner, 1999). In the educational context, VR can be defined as a collection of various technologies (hardware and software) that could be used to deliver an immersive learning experience (Hussein & Nätterdal, 2015; Liu et al., 2017).

The term VR has been used to describe a lot of different technologies, such as online virtual worlds, massive multiplayer online games (MMOs), simulations, flight or surgery simulators, Cave Automatic Virtual Environment (CAVE) systems, as well as a wide range of HMDs (Jensen & Konradsen, 2018). Usually, VR involves full immersion by using the HMD and a six-degree-of-freedom (6-DOF) input controller to manipulate the environment (Robertson, Card, & Mackinlay, 1993). In the literature, immersion is related to the sense of presence (or to the experience of "being there") which should be the main goal of virtual environments design, as well (Cummings & Bailenson, 2016). However, Robertson et al. (1993) conceptualized nonimmersive VR (3D environments on a computer screen that can be directly manipulated using a keyboard or a mouse) as an alternative form of VR. Nowadays, the term "desktop VR" is more frequently used instead of "nonimmersive VR" since immersion also refers to an intellectual or emotional involvement, not only to the sense of presence in a specific space/environment or location (Freina & Canessa, 2015).

Currently, the use of VR in education is far from mature, and the main question still is what is appropriate and beneficial to teach with this educational technology and how to teach it (Liu et al., 2017). In this chapter, we argue that the immersive teaching and learning can be potentially considered innovative and effective, as well as that VR should be one of the various technologies included in a smart learning environment.

2 Literature Review

For more than half a century, technologies related to VR have been under development (Olmos, Cavalcanti, Soler, Contero, & Alcañiz, 2018).

Merchant, Goetz, Cifuentes, Keeney-Kennicutt, and Davis (2014) emphasized that immersive VR was beyond the reach of schools, and there were a lot of problems that disabled the mass use of this technology in education (e.g., the high cost of HMDs, many users experienced discomfort and motion sickness, and the instructional design of virtual learning environments was poor). However, desktop-based VR found its use in K-12 and higher education settings, and many educators have integrated those technologies (such as simulations, games, and virtual worlds) into their instruction practice. The same authors conducted a meta-analysis and examined a total of 13 studies in the category of games, 29 studies in the category of simulations, and 27 studies in the category of virtual worlds. The results showed that games, simulations, and virtual worlds were effective and had a positive influence on learning outcome. Still, games showed higher learning gains than simulations and virtual worlds.

Graziano (2017) pointed out Second Life as the most mature and popular virtual world used in education, and the TLE TeachLivE™ lab as one of the best-known simulations of classroom experiences for training pre- and in-service teachers. Nebel, Schneider, and Rey (2016) indicated that there is a growing interest of researchers and teachers for software (especially for educational videogames and serious games), and they emphasized that commercial videogames could be utilized as educational tools, as well. Also, the same authors analyzed the educational use of Minecraft and concluded that this game offers tremendous qualities regarding creation, collaboration, and distribution as well as that it has already been in worldwide use on various educational topics. Currently, a teacher-friendly platform Minecraft: Education Edition and virtual lab simulations Labster are more and more in use for learning in formal educational settings.

According to Freina and Canessa (2015), two main types of immersive VR are CAVE systems and HMDs.

The CAVE is a room-based fully immersive VR system invented in 1992. The side walls (as well as the floor and ceiling) of a cubic room are made of projection screens. The participant is wearing a special pair of goggles to obtain a stereoscopic view of the virtual environment. Different input devices can be used to provide interaction between participants and the system (the user can point out, select, or drag and drop virtual objects). The potential use of CAVE has been explored in various domains including education, but the actual application was often limited to research projects (Muhanna, 2015).

Ivan Sutherland created the first HMD and head tracking system in 1968, and since then (thought continuous development), this technology emerged from limited use in specialized fields and research laboratories to a low-price commercial device (Liu et al., 2017). The argument that immersive VR can be used for simulation-based learning (where students can learn and practice new skills in a secure and interactive environment) with the potential to revolutionize education has been discussed for decades (Jensen & Konradsen, 2018). However, the HMDs had no significant and large-scale application in educational settings until now (Stojšić, Ivkov Džigurski, Maričić, Ivanović Bibić, & Đukičin Vučković, 2017). Nowadays, the situation has changed due to success of the first developer version of Oculus Rift in 2013 which led to a new generation of better-quality and consumer-priced VR goggles (Jensen & Konradsen, 2018). The Oculus Rift was the first affordable and comfortable computer-assisted HMD with a wide field of view. The development of Google Cardboard (which uses a smartphone and a cheap cardboard/plastic VR headset) in 2014 enabled massive commercial use of immersive VR for the first time in history, and through Google Expeditions Pioneer Program (that started in 2015), millions of students worldwide began to use this technology for learning in their classrooms (Stojšić et al., 2017).

The new HMDs can be grouped into three categories: 1. PC/console-based (or desktop-driven VR) headsets (such as Oculus Rift, HTC Vive, Windows Mixed Reality devices, and PlayStation VR); 2. mobile-based (MVR or smartphone-driven VR) headsets (such as Google Cardboard-type devices [including View-Master VR, Nearpod VR, and Merge], Daydream View, Samsung Gear VR, etc.); and 3. standalone VR devices (such as Oculus Go, Lenovo Mirage Solo, VIVE Focus, ClassVR, and similar).

Freina and Ott (2015) conducted a systematic review of papers published during 2013 and 2014 related to the potentials of use of immersive VR for educational purposes. Most of the analyzed articles focused on pre-university (high school) and university learning settings (particularly in the field of teaching science and medical subjects), as well as adult education and training. The results showed that immersive VR has some advantages: it could give an opportunity to experiment with the situations and objects that have some limitations in real life (e.g., different time periods, physical inaccessibility, lack of access, or it is highly dangerous to access, ethic problems, etc.), could offer practice and training in a safe environment, could increase the learner's involvement and motivation, could support different learning styles, and could facilitate content understanding and memorization.

In a comprehensive review of the literature, Jensen and Konradsen (2018) analyzed 21 articles reporting on experimental studies of the use of new HMD devices in education and training published since 2013. All of included studies were based on the idea that immersion has a positive impact on the learning outcomes. The findings showed various situations where HMDs can be useful for skills acquisition (including cognitive skills, psychomotor skills, and affective skills) and that learners generally had a positive attitude toward the use of immersive VR technology. Reported drawbacks and barriers included cybersickness symptoms, lack of appropriate software, technological challenges, and the possibility that the immersive experience could distract students from a learning task. Also, the authors emphasized the need for further research on the use of HMDs but in an authentic educational context (not laboratory-style experiments).

According to Cochrane (2016) and Stojšić et al. (2017), the most suitable and affordable option for implementing immersive VR in educational settings is MVR since schools computers in most cases do not meet the Oculus Rift or the HTC Vive demands. The VR headsets based on a smartphone are suitable for classroom use and investing in such HMDs is economic (Olmos et al., 2018). Moro, Stromberga, and Stirling (2017) compared performances between two HMDs (desktop-based Oculus Rift and mobile-based Samsung Gear VR) in a study where 20 participants were allocated to one of two headsets in order to complete a lesson and test (which evaluated the transfer of knowledge) on spine anatomy. The results showed that the test scores in both groups were the same, but participants in the mobile-based VR group experienced more cybersickness symptoms (especially disorientation and blurred vision). The authors concluded that all participants perceived the VR lesson as more engaging and fun and that the affordable MVR could be just as suitable as the more expensive desktop-based VR for teaching medical and health science (since cybersickness symptoms did not drastically influence the perceived usefulness of this learning tool and students' enjoyment).

In the past, the high price of HMDs was one of the biggest entry barriers for using immersive VR in educational settings. Today with low-cost MVR HMDs that issue seems solved, especially in schools in which BYOD (bring your own device) model is allowed (Olmos et al., 2018). Vishwanath, Kam, and Kumar (2017) demonstrated that MVR (with the Google Cardboard-type viewers) could be successfully integrated in low-resource educational settings with positive impact (deeper level of students' engagement with the learning materials).

The use of pre-made (off-the-shelf) VR apps and content is prominent in research studies dealing with the educational use of MVR. For example, Minocha, Tudor, and Tilling (2017) pointed out the potential application of 360° photospheres and videos for educational purposes. They also investigated the use of Google Expeditions app in primary and secondary school science and geography (the research included both students and teachers). As a result, the authors identified 10 affordances of using this app: 1. 360-degree visual authenticity (accurate physical representation of the space, spatial relationships, sense of spatial presence, etc.), 2. 360-degree navigation, 3. 3D view, 4. emphasis (teachers can highlight certain aspects of a scene), 5. first-person perspective, 6. in situ contextual information, 7. simulations (perceived benefits such as realism, image detail, and ability to see the connection between elements), 8. single-user handling (not being conscious of others, sense of control, and sense of immersion), 9. synthesis (educators can use more than one expedition, as well as other resources), and 10. visualization (perceived benefits such as authenticity, sense of scale, sense of space, etc.).

The possibility that users (e.g., researchers, teachers, and students) can create their own VR content has become a reality (Martín-Gutiérrez et al., 2017; Stojšić et al., 2017). The game engine Unity was often used for creating immersive educational environments in research studies (see Freina & Canessa, 2015; Hussein & Nätterdal, 2015; Moro et al., 2017; Vega, Rose, Eckhardt, Tahai, Humer, & Pietroszek, 2017). Also, the popular VR creation tool CoSpaces Edu, commercial 360° cameras, as well as apps for making 360° panoramas (such as Street View, Cardboard Camera, and similar) were often mentioned in the literature (Stojšić et al., 2017). Cochrane et al. (2017) proposed a framework for designing MVR learning environments and described two projects (Mesh360 and Augmenting the Classroom) that aimed to enhance learning in higher education. The idea and concept of WebVR (instead of downloading and using apps, the VR content is available in a web browser) could be potentially useful to facilitate creation and distribution of educational VR experiences. A-Frame is an easy-to-use framework for creating WebVR apps without diving into technical details, and it supports embedding HTML elements (such as videos and images) inside a VR environment (Prins, Gunkel, & Niamut, 2017).

Virtual learning environments can be created using the VR technology, but a clear pedagogical model (or framework) is required to inform the design and use of the systems (Fowler, 2015). The questions covering relevant pedagogical frameworks (that could support the implementation of VR in the classroom) and integration and evaluation models need to be addressed as well.

Liu et al. (2017) suggested three key theoretical bases for applying VR in education:

1. *Constructivism* – puts students at the center of the learning environment and the activities and interactions keep challenging learners' prior experience, as well as promoting the construction of new knowledge. Instructional strategies (extended

from this theory) such as situated learning, experiential learning, and collaborative learning are appropriate for teaching and learning with VR.
2. *Autonomous learning theory* – refers to self-directed learning where learners pick their learning targets and choose how to achieve them. However, students' self-control and an ability to use the feedback from a teacher or the environment are required. The VR technology can provide a suitable learning environment for autonomous learning and practice, since students can check their learning outcomes and receive real-time feedback from the environment.
3. *Cognitive load theory* (CLT) – refers to limitations in human working memory during mental activities (e.g., thinking, problem-solving, etc.). The VR learning environments can be highly realistic with multiple modalities of information, but the rich simulation may induce split-attention effect (students ignore the real learning objective, focusing only on a specific stimulator) and overload (when mental load exceeds the capacity thus negatively affecting learning outcomes).

Pantelidis (2009) pointed out that it is not appropriate to use VR with every teaching material and instructional objective and proposed a ten-step model to determine when to use VR in education. This model emphasized the importance of considering the specific characteristics of objectives (steps 1 and 3), determining the reasons to use VR for selected objectives (type of immersion and interaction needed, as well as what are the main advantages of application) (steps 2 and 4), choosing appropriate VR equipment and the virtual environment design (steps 5 and 6), and using the evaluation cycle (steps 7, 8, 9, and 10).

According to Vishwanath et al. (2017), MVR could be integrated in the curriculum in four different ways: 1. to demonstrate actual real-world phenomenon (this is applicable when there is or can be made VR content exactly on the selected topic), 2. to illustrate abstract concepts, 3. to compare and contrast (e.g., students can be asked to compare different ecosystems, climates, landscapes, cultures, systems of government, etc.), and 4. to arouse interest. There is also a need for an evaluation framework appropriate for learning activities with VR, and the SAMR model (see Puentedura, 2013, 2015) is often recommended (Graziano & Daley, 2017; Romrell, Kidder, & Wood, 2014). This model includes four levels of technology integration (substitution, augmentation, modification, and redefinition), and for each level, explanation, examples, and questions are provided to support teachers in implementing educational technologies (Puentedura, 2013, 2015). Lessons and activities created using VR technology should be above the substitution level of the SAMR in order to be recognized as potentially innovative.

In the literature, health issues (such as cybersickness) are often related to the use of immersive VR. However, in the context of mental health treatment, VR is a powerful tool well suited for exposure therapy (Maples-Keller, Bunnell, Kim, & Rothbaum, 2017). VR exposure therapy (VRET) is a relatively effective treatment that can reduce anxiety and phobia symptoms (Parsons & Rizzo, 2008). School phobia is related to diverse events associated to school (such as to be bullied or criticized in front of the class, having to speak in public or do exams, etc.), and the use of VRET is an important tool to reduce the intensity of school-related fears

(Gutiérrez-Maldonado, Magallón-Neri, Rus-Calafell, & Peñaloza-Salazar, 2009). Examination-related anxiety is a serious problem in education and can affect students' academic results. The VRET offers several advantages over in vivo exposure and permits the design of various exam situations (such as adjusting the difficulty of the test or adapting the virtual environment more closely to the learner's situation in real life) (Alsina-Jurnet, Carvallo-Beciu, & Gutiérrez-Maldonado, 2007). Also, the VRET can be helpful for reducing public speaking anxiety of students, and VR smartphone apps for mobile HMDs provide the possibility of treatment in a home environment (which could be relevant for students who do not seek treatment) (Stupar-Rutenfrans, Ketelaars, & van Gisbergen, 2017).

3 Method

To capture authentic and in-depth information, we conducted a small exploratory qualitative study regarding teachers' experience and reflections on their use of immersive technologies in the classroom.

3.1 Participants

We used purposeful sampling and invited 12 teachers (whom we had previously established collaboration with) to participate in this research. The selected teachers met two required criteria: (a) demonstrated a passion for innovative teaching and (b) already used VR as a teaching tool in the classroom. For the first criterion, participants provided us with their lesson plans and online links to their materials (such as presentations of eTwinning projects they participated in, blog posts about their teaching innovations, video and photo materials from their classrooms, etc.). The second criterion assured us that teachers could provide a useful data about the integration and usage of VR in schools. However, only six teachers (from six different public schools in the Republic of Serbia) agreed to participate. Due to such low response rate, we invited an educational media specialist (responsible for the integration of VR and teacher training in a private school), and he responded positively.

The participants were given pseudonym names to protect their privacy. Toni (the educational media specialist) had 2 years of working experience with the educational use of VR. He had trained and supervised more than ten humanities and science teachers (in a private school where he works) on the use of different VR devices (HTC Vive, Samsung Gear VR, ClassVR, and Google Cardboard). For a summary of the teachers' demographic information, see Table 1.

Table 1 Teachers' profiles

Teacher's name	Gender	Years of teaching	Type of school	Subject	Immersive teaching experience
Sanja	Female	3	Primary	Geography	1 year (MVR)
Marko	Male	14	Primary	Geography	1.5 year (MVR)
Jagoda	Female	28	High	Mathematics	6 years (desktop VR and recently MVR)
Ana	Female	24	Primary	Mathematics	4 years (desktop VR)
Maja	Female	16	Primary	Chemistry	6 months (mobile AR/VR)
Mira	Female	10	Primary	1–4 grade teacher	2 years (mobile AR/VR)

3.2 *Data Collection and Analysis*

This study was carried out in the first term of the 2017–2018 school year. We used reflective writing as a method (see Chretien, Goldman, & Faselis, 2008; Jasper, 2005; Schön, 1983; Yesilbursa, 2011) to collect data from the selected teachers. A Microsoft Word template was created and sent via e-mail to all potential participants. The participants were asked to write reflections on their prior teaching with VR, as well as to provide their prepared lessons plans and other related materials. Also, we created an online questionnaire (through Google Forms) to obtain demographic data.

Miles and Huberman (1994) pointed out that "Qualitative data can be reduced and transformed in many ways: through selection, through summary or paraphrase, through being subsumed in a larger pattern, and so on." (p. 11). We used pattern coding to find common themes in the data. The identified related segments in participants' statements were used to demonstrate the particular theme.

4 Findings

The participants' statements were categorized into four themes: support, integration, perceived impact and benefits, and barriers and limitations.

4.1 *Theme I: Support*

All the participants dedicated special attention to the question of support (or the lack of it). The initiative and students' support (who through BYOD approach provided and used their own mobile and/or VR devices) were crucial for Sanja, Marko, and Mira to start using immersive technologies in teaching. Jagoda, Ana, and Maja saw themselves as the main factor in introducing new technologies into the teaching process. Sanja also emphasized the support of her school colleagues (with whom she organized exemplary classes using VR viewers), as well as the support of the principal who provided additional ten Google Cardboard headsets (she bought the first ones at her expense). Maja pointed out the significant support of her international colleagues (whom she cooperated through eTwinning and similar international projects), and a complete lack of support from the colleagues and managers in her school, and emphasized that she did everything "in a makeshift manner and at her expense." Marko and Ana indicated that they did not have any support of their schools for buying HMDs, while Ana stated that she tried (but in vain) to find help for creating her own educative VR contents. Jagoda (who saw herself as an innovative teacher with extensive experience with using ICT for educational purposes) pointed out the lack of society support for innovative teachers and the lack of parent support (because many of them oppose the use of modern technology in classes).

Toni emphasized that he was always the available support for teachers in his private high school. He indicated that the teachers were most frequently very reserved at the beginning of the training and without previous personal experience with VR/AR technologies. However, in the end, the majority of them started applying those educational technologies in their teaching. He described the process this way:

> Upon completing their training, the teachers have the opportunity to use all available VR/AR technology in school. Since there are a limited number of VR devices, there is a table where the teacher can reserve the HMDs (ClassVR or HTC Vive) for his or her class. Every teacher also received a short manual for each of the headsets and concrete examples for his or her subject. I always helped them in preparing their initial classes.

4.2 Theme II: Integration

Only Jagoda and Maja stated that they had technical and organizational problems in the process of integration, while Mira emphasized that the implementation of mobile AR (MAR) and MVR into the teaching process was easy.

Geography teachers described different ways they used MVR. Sanja wrote that she used 360° panoramas and video materials for covering regional geographic contents (grades 6 and 7) but always combining them with other mobile apps and online tools (e.g., QR codes, associations games, online blank maps, formative quizzes, or writing a blog post about a particular country or city). Marko wrote that he used pre-made apps (such as Titans of Space® Cardboard VR and similar) for covering mathematical geography and astronomical contents (grade 5) as an additional activity in classes along with his presentation and quiz. Sanja also emphasized what novelties the VR technology enabled in her teaching:

> Thanks to VR, children have the opportunity to learn in an interesting manner about distant places of the world (that they would probably never have a chance to visit). In this way, they can individually explore those remote spaces and analyse them together in the end. The entire class is directed towards students exploring.

Mathematics teachers Jagoda and Ana reported using desktop VR and mainly 3D mathematics simulations. Ana pointed out that VR helped her when she wanted to show real life mathematics examples (such as volume and surface calculations of actual objects and buildings). Jagoda wrote about her experience with SLOODLE (Second Life + Moodle), which was not always positive, so she started using Minecraft: Education Edition while she began using MVR through BYOD concept.

Maja and Mira reported using BYOD concept. Maja wrote that she used available mobile, AR, and VR apps and integrated them based on the examples of good practice from her international colleagues. Mira stated that she used MAR more, particularly with group projects where her students created posters and used the HP Reveal app and platform to make them interactive. She indicated that she used MVR apps occasionally in order to present the abstract concepts in a simpler manner.

Reviewing the written reflections (as well as provided lesson plans), we found that teachers reported the limited use of immersive technologies (only with certain teaching contents, through group work activities or as a part of project-based learning) and together with other teaching tools.

Toni indicated that it could be hard for teachers to cope with using VR headsets in classes. However, he emphasized that the Avantis, a company that produces ClassVR, made the process of classroom integration easy. Also, he pointed out that other (public) schools could relatively easily introduce the VR technology if they have a stable Internet connection (since students could use their own appropriate mobile devices).

4.3 Theme III: Perceived Impact and Benefits

In sum, all the teachers stated that every single activity is important for making the class successful and that VR/AR is just one of many tools they use. Due to that, Mira emphasized that she could not really evaluate to what extent VR (individually) contributed to the educational results but that her students were enjoyed by it. Similarly, Sanja indicated that "each time the students saw VR glasses on the desk the thrill was immense since they knew what was coming." Sanja and Ana noted that when using the immersive technology, an oral analysis and a systematization of the covered material are desired (and necessary) at the end of the class.

The teachers' perceived benefits of introducing immersive technologies in teaching were better students' motivation (Sanja, Marko, Ana, and Maja), the classes became more interesting (Sanja, Maja, and Mira), the students acquired the matter easier (Sanja, Marko, and Ana), better learning outcomes (Marko and Jagoda), the feeling of thrill (Sanja and Mira), longer memorization of the acquired knowledge (Sanja), and better attention in class (Jagoda).

Sanja and Mira emphasized that VR has great potential when different subject contents need to be correlated or for the STEM (science, technology, engineering, and mathematics) learning concept. Toni concluded:

> When teachers master the use of VR HMDs, they organize their application more frequently and creatively. After a while of training, they usually told me that their students were more motivated to learn and more focused on the contents being taught in class.

4.4 Theme IV: Barriers and Limitations

All of seven participants pointed out certain limitations, as well. They mostly wrote about those they were facing personally in their schools, while some wrote about general limitations that could be related to the entire educational system of the Republic of Serbia.

Reported personal perspective limitations were the availability of school-owned devices and the lack of investments in educational VR/AR content and apps (Marko, Ana, and Maja), the stability of the Internet connection in school (Sanja and Toni), the lack of easy-to-use authoring tools for creating VR experiences (Marko and Maja), and increased time needed for class preparation (Sanja indicated that it takes 4 h, on average).

General perspective barriers included the poor knowledge of teachers about immersive educational technologies, as well as the prevailing lack of motivation of teachers to introduce innovations and improve the teaching process (Maja, Mira, and Toni), and the teachers' fear of other teachers and parents (who oppose the use of new technologies and mobile devices in classes) (Jagoda).

Marko emphasized that "The main obstacle is the equipment because we do not have enough Google Cardboard viewers and smartphones in my schools. Luckily, my students always bring their own (whenever needed)," while Toni indicated: "In my opinion, the main obstacle is the teachers' lack of familiarity with the VR technology. It is necessary to train the teachers and motivate them to apply immersive technologies in classes."

Sanja concluded that it is possible to overcome all limitations since "if you have a motive and will to bring the world to your students (in the classroom) and make them love your subject then no obstacles truly exist."

5 Discussion and Conclusion

Smart education describes a concept of personalized and seamless learning in a digital age (Zhu et al., 2016), and since VR extends the learning experience, it could be one of many technologies integrated into a smart learning environment (Hoel & Mason, 2018). However, integration will require educators' time and effort to learn how to use VR as tool for teaching, and school leaders will need to navigate the purchasing decisions (the current offer of HMDs and VR educational apps creates an overwhelming choice), training sessions for teachers and students, as well as to monitor curricular implications (Johnston, Olivas, Steele, Smith, & Bailey, 2018).

The HMDs can be used as a medium to access virtual environments and simulations, but learning might occur only if particular VR content (or experience) is efficient and effective (Jensen & Konradsen, 2018). Olmos et al. (2018) emphasized that the VR technology is not a limiting factor anymore but rather the quality of experiences, and if we find a way to design and develop useful immersive educational content supported by the adequate teaching methodologies, “a new stage in educational history will be given birth” (p. 103). According to Johnston et al. (2018), “Adapting the VR technology means that educators will need to decide where and how the VR applications fit.” (p. 416).

Our study has several limitations. The number of participants was very small, and generalizability of the results is limited. Only six public school teachers and an educational media specialist (employed in a private school) took part. Also, the teachers reported their subjective perceptions of benefits of using VR, which were not objectively measured. Still, these limitations are often associated with the educational qualitative research.

We used reflective writing as a method since this approach could be helpful in triggering teachers’ in-depth thinking about their teaching practice (Yesilbursa, 2011). Four main themes in the participants’ statements were support, integration, perceived impact and benefits, and barriers and limitations.

Support was one of the key factors related to the use of immersive technologies in educational settings. All dimensions of support (student-teacher, teacher-teacher, teacher-media specialist, teacher-principal, teacher-parent, and teacher-community) were indicated. Also, the teachers reported the lack of formal training opportunities in the area of the use of VR in education. Therefore, proper preparation and training for pre- and in-service teachers should be organized (Graziano, 2017; Liu et al., 2017; Olmos et al., 2018; Stojšić et al., 2017).

The teachers included in this research reported using MVR (and MAR) based on the BYOD model of integration for specific learning targets, usually through group learning activities or in project work context. Our participants indicated that the off-the-shelf VR experiences have to be matched with the curriculum and lesson goals, as well as well combined with other tools. Similarly, Minocha et al. (2017) stated: “the most effective use of VR will be when it is combined with other technologies such as videos, podcasts, wikis, blogs or forums, and mobile apps” (p. 10). We believe that the new low-cost stand-alone HMDs (together with MVR), WebVR-based approaches (for designing and delivering VR educational content), and new easy-to-use authoring tools (such as Google’s Tour Creator) will greatly facilitate the integration process. Prins et al. (2017) pointed out that social WebVR could be utilized for remote participation in the classroom, as well. The new VR technology seems well suited to the context of constructivism theory and active and simulation-based learning (Jensen & Konradsen, 2018). Learning objectives and constructivist instructional strategies should be the starting point for teachers, and the evaluation framework such as the SAMR model (see Puentedura, 2013, 2015) could be also used for designing (innovative) lessons with the VR technology. Liu et al. (2017) divided the use of VR in education into four (not mutually exclusive) types: observational learning (immersive experiences could enable a deeper understanding of learning content, as well as various time and spatial perspectives), operational learning (VR environments could be used as a safer training platform for tactile and kinetic learning), social learning (VR offers the potential for interaction and cooperation in the simulated environment and could overcome the limits of physical distance which is suitable for distance and blended/hybrid education), and academic research (the VR technology is able to simulate different science and engineering experiments and could decrease the risk and cost burden).

According to the participants, the immersive technologies are useful and have potential to bring innovations in the teaching process. The teachers reported using VR combined with other teaching tools, and they did not measure the effects of this technology alone on learning results. Consequently, they indicated benefits mostly in motivational aspects of learning.

Half of the teachers stated the lack of school-owned mobile and VR devices as an important limiting factor, and two teachers reported the lack of easy-to-use authoring tools. Olmos et al. (2018) emphasized limited available educational VR contents (both provided by publishers and created by teachers) as the main bottleneck for the real implementation of this technology in school settings. Also, the problems with the Internet connection in the classrooms, restrictive school regulations, and health and safety issues (like cybersickness), among others, are still present disadvantages and limitations (Stojšić et al., 2017).

VR differs from other ICTs, but it can be connected with various educational technologies and linked to teaching and learning with computers and mobile devices. Easy integration is necessary since in a smart learning environment, heterogeneous devices have to be successfully interconnected and combined to support adaptation and personalization (Gros, 2016). The VR technology enables unique benefits and access to immersive visual and kinesthetic experiences previously not possible in traditional classroom and lecture hall settings (Johnston et al., 2018). However, utilization of VR as a teaching tool is strongly associated with educators' ability to integrate immersive technologies into their pedagogical toolkit and instruction practice (Graziano, 2017; Graziano & Daley, 2017).

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Flipped Learning and Online Discussion in Higher Education Teaching

Branko Bognar, Marija Sablić, and Alma Škugor

Abstract In education, smart technology supports constructivist and student-centred learning. Various teaching approaches can be adopted in higher education context to provide smart learning pointing out adaptive teaching, learning analytics, collaborative learning, context-based learning, game-based learning and flipped learning. This study focuses on flipped learning and online discussions initiated in the online learning system Moodle. In the previous action research, we had determined benefits of online discussions such as freedom of expressing thoughts and feelings and possibility of participating at any suitable time in a friendly atmosphere. However, some problems were detected such as insufficient preparedness of students for selected topics. In this action research project, flipped learning preceded online discussions that were organized at the end of the course. The aim was to improve students' preparedness for a discussion topic and engage them in active learning. We were aware that there was no new teaching method and no instant solutions. It is a way of thinking which includes teachers' critical reflection. Therefore, we established a Moodle forum for a critical reflective discussion about teaching. This approach seems to be the key precondition for improving the quality of smart learning we tried to establish in our higher education context.

Keywords Flipped learning · Smart learning · Higher education · Online discussion · Critical friendship

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B. Bognar
Faculty of Humanities and Social Sciences, Josip Juraj Strossmayer University of Osijek, Osijek, Croatia

M. Sablić (✉) · A. Škugor
Faculty of Education, Josip Juraj Strossmayer University of Osijek, Osijek, Croatia
e-mail: msablic@foozos.hr; askugor@foozos.hr

L. Daniela (ed.), *Didactics of Smart Pedagogy*,
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1 Introduction

Although we can use advanced information and communication technology, and particularly learning management systems, they are still rarely used in Croatian higher education (Dukić, 2011). Moreover, even in cases when it is used, it is often used with lack of layout that would contribute to improvement of learning quality for students (Dukić & Mađarić, 2012). Zhu, Yu, and Riezebos (2016) point out the importance of smart learning which although using modern technology tends to combine the constructivist and ubiquitous learning. Such learning is student-centred in trying to adapt the technology usage to their educational interests. Personal and smart technologies engage students to be independent, more open and better connected in their learning making use of their personally richer contexts. Smart learning is an acronym for self-directed, motivated, adaptive, resource-enriched, and technology-embedded learning (Kim, Cho, & Lee 2013). It is particularly important that such learning is used in higher education. Uskov, Bakken, Penumatsa, Heinemann, and Rachakonda (2018) identify the following innovative approaches that can contribute to realization of smart learning concept: adaptive teaching, learning analytics, collaborative learning, context-based learning and game-based learning. The starting point (postulate) of the constructivist theory that learning is an outcome of social interaction can be well added to this (Pritchard & Woollard, 2010).

The mere introduction of technology in teaching did not have a discernible impact on learning outcomes (Morgan, Morgan, Johansson, & Ruud, 2016). Based on the analysis of a number of meta-analytical studies, Hattie (2012) determined that different factors have an impact on learning outcomes. Many interventions have a positive but very modest impact. Such measures, especially if they are associated with high costs and efforts invested in their implementation, Hattie (2015b) calls politics of distraction. This includes, among other things, the use of technology in teaching. It is important to find solutions for the effective implementation of modern technology in teaching that will improve the quality of teaching and thus the learning outcomes. Therefore, this study focusses on flipped learning and online discussions initiated in the online learning system Moodle with the aim of improving student preparedness for the topic of discussion and engaging them in active and deep learning.

2 Smart Learning as a New Paradigm of Teaching

As a new paradigm of teaching, smart learning environment is based on smart devices and intelligent technologies. Due to the intensive research into technology application in teaching that has been done for the last 10 years, technology can be implemented in teaching and help learners in learning. It is described as technology-enhanced learning (TEL). TEL is used to facilitate more effective, efficient and enjoyable learning (Goodyear & Retalis, 2010). Technology can be used as a medium or as a tool for accessing learning content, inquiry, communication and collaboration, knowledge construction, expression and evaluation in TEL (Zhu, Yu, and Riezebos 2016). The development of mobile technologies made TEL accessible and ubiquitous way of learning. However, it should not be reduced to the use of smart devices (Durán-Sánchez, García, Rama, & Sarango-Lalangui, 2018). Learning should become smart too. Kim, Cho, and Lee (2013, 172) suggest the concept of smart learning that has the two main features: 'first, it is focused on humans and content more than on devices; second, it is effective, intelligent tailored-learning based on advanced IT infrastructure'. Therefore, smart learning is not focused on utilizing devices, 'it is more ubiquitous, effective and humanistic with adequate and adaptive use of devices so that' learners 'can open, share and collaborate with each other' (Sung, 2015, 120).

Middleton (2015) also confirms the learner-centric aspects of smart learning and the benefits of using smart technologies. Zhu, Yu, and Riezebos (2016, 3) point out that 'the personal and smart technologies make learners engage in their learning and increase their independence in more open, connected and augmented ways by personally richer contexts'. The smart learning environment should provide opportunities for improving smart learning for different people by using different learning methods. In a smart learning environment, learners can learn anytime, anywhere and in any way (Liu, Huang, & Wosinski, 2017). This type of learning environment can also encourage learners to engage and support effective learning. Smart learning environment integrates formal and informal learning (Leino, Tanhua-Piiroinen, & Sommers-Piiroinen, 2013) with the purpose of creating an autonomous, adaptive learning environment for supporting each individual student by providing appropriate learning methods (Kinshuk, Chen, Cheng, & Chew, 2016). One of the ways of smart learning is the flipped learning (Uskov et al., 2018; Zhu et al., 2016).

3 Flipped Learning in Higher Education

Flipped learning is one of the most popular contemporary approaches to education originating from the Socrates' maieutic, according to which the teacher helps students discover the truth and knowledge by guiding them through issues and debates and not providing complete solutions. Today's flipped learning was developed in 2007 by Colorado high school teachers Jonathan Bergmann and Aaron Sams when they began to record lectures, demonstrations and slide presentations which they then posted on YouTube for students who often missed classes (Bergmann & Sams, 2012).

According to Bishop and Verleger (2013, 2) flipped learning is:

> …a new pedagogical method, which employs asynchronous video lectures and practice problems as homework, and active, group-based problem solving activities in the classroom. It represents a unique combination of learning theories once thought to be incompatible – active, problem-based learning activities founded upon a constructivist ideology and instructional lectures derived from direct instruction methods founded upon behaviorist principles.

By its very definition, the flipped learning is 'constructivist: we require students to become actively involved in their learning rather than passive recipients of information' (Kavanagh, Reidsema, McCredden, & Smith, 2017, 17). Bergmann and Sams (2012) point out the advantages of flipped learning in which learners can access learning content anytime and anywhere and also by creating a problem-based learning environment during face-to-face teaching time. Fautch (2015) describes the flipped learning as a pedagogical approach that moves course content from the classroom to homework and uses class time for engaging activities and instructor-guided problem solving. Reidsema, Hadgraft, and Kavanagh (2017) point to the importance of deep learning that learners achieve by flipped learning since they are expected to find information on their own and then to share it with their team, which is an important skill for future workplaces. Students acquire knowledge and skills online and use them to solve or address a real problem or opportunity. The flipped approach focuses on moving content that fits in the lower levels of Bloom's taxonomy, such as understanding and remembering outside class and reserving in-class time for the higher-order levels, such as creating, evaluating, analysing and applying (Krathwohl, 2002; Srivastava, 2014; See & Conry, 2014). According to Larrington and Lihosit (2013), a small number of learners develop higher levels of learning in traditional education, and the overall learning outcome is low. In flipped learning, the lower-order learning activities happen outside of classroom when students view the video lectures, and the freed-up classroom time allows teachers to engage in higher-order learning. Wolff and Chan (2016, 23) see particular advantages of flipped classrooms 'in the possibility to promote active learning, to increase interaction between faculty and students, to improve the collaboration among students, to allow flexible learning just in time and to foster critical thinking'.

The issue of using time differently in this model is associated with many potential improvements: more time to interact and clarify material, more time to explore concepts deeply and more time for additional learning objectives or practice with active learning (Boucher, Robertson, Wainner, & Sanders, 2013). There are two more features of flipped learning – student's responsibility and autonomy. Students in this model generally have more autonomy and ultimate responsibility for their learning (Danker, 2015), so they must engage during class through a variety of ways. The teacher's role is to act as a 'guide on the side' rather than the 'sage on the stage' (King, 1993). An autonomy means that students' learning diversity can be supported with asynchronous access to lecture material; students who need time to review information or to pause and process can do so, while students who are ready to move on to the next concept can do so right away. By varying the examples provided in lecture content from those in class activities, instructors can support transfer of learning to new situations (Enfield, 2013). Students in class:

> …may reflect on the lecture material through questions and discussion with their teacher, by working with their peers to solve problems based on lecture content, by demonstrating or arguing their own solutions to classmates and the teacher, by checking their understandings through in class experimentation and lab work, and by peer tutoring or creation of learning objects. (Arnold-Garza, 2014, 10)

Roehling (2018, 132) points out that student engaged in active learning in flipped classroom can teach them 'about themselves, others and the world around them, outcomes that cannot be learned by lecture alone'.

4 Methodology

The results of our previous research studies and practices in higher education show that online discussions are a suitable approach for realization of e-learning based on constructivist principles (Bognar, Gajger, & Ivić, 2016) and for encouraging reflectivity in students by impelling them to become mutual critical friends in the online discussion forums (Bognar & Krumes, 2017). In order to be prepared for discussions on Moodle forums (http://pedagogija.net), the students should read the topic-related reading assignments. The results of the discussions have been analysed in the course of 4 years, and a negative trend in evaluation of reading assignments has been noticed, which also resulted in lower grades in online discussions (Fig. 1). Additionally, the analysis of student online discussions shows that students' comprehension of the discussed issues was quite superficial particularly in the academic year 2016/2017.

In this regard, we have decided to encourage students to reading assignments and only then involve them in an independent discussion on the agreed topics. Besides, our aim was to improve their deep learning. We also believed that in this context, the flipped classrooms could facilitate higher cognitive levels (Krathwohl, 2002) in class. Thus, the basic objective of this action research was to encourage students to deep learning and to be satisfied with their participation in flipped classrooms and online discussions (Table 1).

Norton (2009, 16) points out that 'pedagogical action research is to systematically investigate one's own teaching/learning facilitation practice with the dual aim of modifying practice and contributing to theoretical knowledge'. Since our intention was to improve students' learning by introducing changes in teaching and to

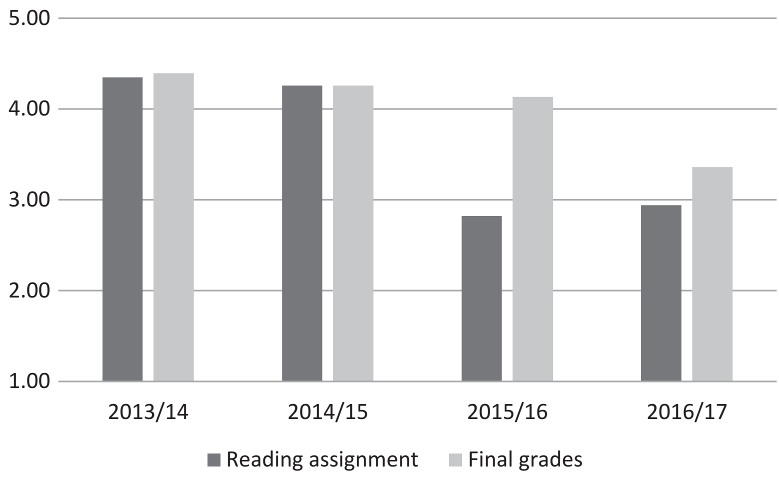

Fig. 1 Evaluation of reading assignment and online discussion. (The results represent average grades in reading assignment and final grades that students got for their participation in online discussions within the course pedagogy. The first author taught this course at the first year of the university study programme for teacher education. The following number of students participated in online discussions: 43 (2013/14), 31 (2014/15), 45 (2015/16), 50 (2016/17))

Table 1 Objectives and criteria for action research

Objectives	Criteria
Engaging students in deep learning through flipped classrooms and online discussions	Students use a greater number of sources in the discussion Students learn at higher levels of Bloom's taxonomy by applying, analysing, evaluating and creating new knowledge and understanding
Students' satisfaction with participation in smart learning activities (flipped classroom and online discussion)	Students determine their satisfaction level of participation in smart learning activities on a five-point scale Students indicate advantages and/or disadvantages of the activities

contribute to theoretical understanding of smart learning activities, we considered the choice of action-research design appropriate.

This action research was conducted within the course on the theories of education systems, which was attended by 39 students of the second year of undergraduate study programme of pedagogy in winter semester of the academic year 2017/2018. The first author was responsible for the realization of classes. The classes lasted for two periods (90 min) and took place every Monday in a classroom designed for collaborative learning. At the beginning of the semester, the students were divided into three six-member and three seven-member teams, and every team was given a name. The teams participated both in class and Moodle activities (http://pedagogia.net). The students interacted with the members of their team in pre-set forums. We planned to carry out three flipped classrooms that consisted of tasks at Moodle and teaching activities. At the end of the course, we anticipated an online discussion in which the students were to participate in previously formed teams.

At the first meeting with the students, an agreement was reached on the manner of realization of classes and the required consent for participation in the action research. Prior to this, students were informed of the research objectives, and they all gave their consent to participation in the research and for recording and publishing their photos and videos. Moreover, six students agreed to be critical friends. Critical friendship represents a form of systematic reflection in which friends, colleagues or students whom we trust may participate (Bilić Meštrić, Đurić, & Ivančić, 2014; Bognar & Krumes, 2017; Costa Kallick, 1993; Kember et al., 1997; Lomax, Woodward, & Parker, 1996; Reed & Stoll, 2000). In our case, critical friendship was established by allowing students to comment on the curricular activities created in the flipped classrooms on the Moodle system forum. The teacher prepared a written review on the lectures and set up a short video recording. The co-authors of this paper were also involved in critical friendship.

As action research implies systematic 'documenting and monitoring what happens' (Kemmis, McTaggart, & Nixon, 2014, 68), we used different sources of data. For documenting the process of flipped classroom and online discussion, we used video recordings of classes and students' correspondence by means of the Moodle system. We used logs to monitor the intensity of students' activities on Moodle. Logs allow to 'see what pages the student accessed, the time and date they accessed it, the IP address they came from and their actions (view, add, update, delete)' (https://docs.moodle.org/34/en/Logs). The logs were saved in Excel format for the purpose of additional log analysis. At the end of the course, we conducted an online questionnaire that comprised questions related to the use of the Internet, participation experiences in flipped classroom and online discussions. In addition, students were required to respond to closed-ended questions about engaging in cognitive processes in preparatory and teaching activities in flipped classrooms, how they learned and how satisfied they were with participating in flipped classrooms and online discussions. The answers to the questions were offered on the five-point Likert scale (1 – I am not satisfied, 5 – I am completely satisfied). We also asked open-ended questions to find out what students consider the benefits, disadvantages and improvement of teaching in flipped classroom and online discussions. Open-ended questions were encoded by using QDA Miner Lite v2.0.2. software. The questions asked in the online questionnaire were answered by 35 of 39 students.

The answers to the online questionnaires conducted at the end of the course indicate that all students use the Internet on a daily basis. They use it most frequently at home (48%) and at the faculty (26%), while others use the Internet at the cafe (12%), at their friends' (10%) and in the library (4%). The Internet is most commonly used for communication in social networking (4.8), text messaging communication as well as in audio and video calls (4.6); it is used also for playing games and for entertainment (4.1), learning (4.0) and informing (3.8); it is used the least for work (2.2) and digital creativity (2.5). Most students (about 90%) have not participated in flipped classrooms yet. There are ten students (25%), who had a prior experience in online discussions.

Winter and Munn-Giddings (2001) believe that strict application of data analysis found in traditional research is not appropriate for action research because it only becomes a task for a person who has an overview over the structure of the whole research. In addition, categorization resulting from the research framework cannot include the participants' ideas stepping outside this framework or data contradicting the findings of the researcher. That is why they suggest the use of critical reflection in action research, in which our students were involved. In our research this was accomplished in the course methodology of pedagogical research that students could attend the following (summer) semester. The first author was entrusted with conducting this course. We prepared the students for the draft report and asked them to comment on a previously conducted analysis. Moreover, in groups the students engaged with critical reflection of certain data (e.g. summaries of sociological theories and critical commentaries of the read assignments sources published by students on the forums in the first and third flipped classrooms).

5 Teaching Intervention and the Results of the Achieved Changes

There are seven different activities that were performed on Moodle and they are listed in Table 2. Firstly, the students met the members of their team at the forum. Then, their task was to read the text Human Being and Education (Bognar, 2015),

Table 2 Schedule of the activities on Moodle within the course on the theory of educational systems

	Activities	Beginning	End
1.	Introducing the members of the teams	9.10.2017	22.10.2017
2.	Creating and commenting the comics based on the previously read text *Human Being and Education*	23.10.2017	29.10.2017
3.	The first flipped classroom: *Sociological education theories*	31.10.2017	6.11.2017
4.	The second flipped classroom: *Quality education system features*	28.11.2017	4.12.2017
5.	The third flipped classroom: A critical commentary on the *Meeting the Changes in the Education System*	7.12.2017	16.12.2017
6.	Discussion *Curricular Reform: For and Against*	8.1.2018	25.1.2018
7.	Written exam and course evaluation	27.1.2018	30.1.2018

draw and comment the comics related to the read text using one of the programmes available on the Internet (e.g. ToonDoo or Cartoon Playground). The tasks in three flipped classrooms followed.

The first flipped classroom included the task of reading a chapter on sociological theories of education (Haralambos & Holborn, 2002) and writing a summary on their team forum and putting one question on three major sociological approaches. In addition, students should watch the film Freedom Writers (https://en.wikipedia.org/wiki/Freedom_Writers). The students were given a week for the task completion. Out of 39 students, 38 accomplished the task.

In their critical reflection, the students considered an advantage that they all read the text that they were familiar with key concepts and had the opportunity to ask questions. They mention disadvantages such as the lack of communication among team members, retelling the text without a critical review. Although the results of self-assessment in the online questionnaire (Fig. 5) show the students' creativity, they believe that in this activity it was:

> … traceable only in the part where the students themselves should put questions about the issues they are particularly interested in. By comparing student summaries, we recognized that they were quite superficial. The students did not get engrossed in the article and did not express their opinions anywhere. (The group of the second year students of pedagogy, personal communication, 27 April 2018)

At the beginning of the lesson in this flipped classroom, the teacher[1] praised students' activity and then gave them a list of questions that they wrote on the forum. Each team should choose three questions to be discussed and presented in front of the entire group. They should put one question to the teacher. In addition to answering questions, the students had to link sociological theories with examples from life and based on the film that they watched at home.

The second flipped classroom was devoted to the features of a quality education system. Similar to the first flipped classroom, the students had a week to prepare for the class. They had to solve a quiz consisting of six questions. Most of the questions included a text and a video footage posted on the YouTube service or on the TED website (www.ted.com). The texts were taken from two of teacher's previously published articles (Bognar, 2009, 2016). To make the watching of the video easier for

[1] First author.

the students who have difficulties understanding the texts in English, the teacher translated the original subtitles in one of the YouTube videos (https://youtu.be/NNgp1_B-6c8) into the Croatian language.[2] The other two videos could not be translated since they were not available for community contribution (https://youtu.be/ERvh0hZ6uP8 and https://youtu.be/I3LctIAh9-E), whereas the Croatian subtitles for Ken Robinson's TED presentation How to escape education's death valley (https://goo.gl/YPVGve) were already available. At the end of each unit, the students' task was to comment on the text and video or answer the question. The answers to the questions were not graded, but their purpose was to motivate students to active participation and as a feedback on the level of students' preparation for the classes. Finally, the students had to ask at least one question related to the topic of the flipped classroom. All students participated in this activity.

During the classes the students had the opportunity to comment on a few questions they put at the end of the quiz. The main part of the class (60 min) was dedicated to poster designing. The teacher told students to imagine that they arrived as part of the expedition at a habitable planet that has not been inhabited by intelligent creatures to create a new civilization. Their task was to create a quality education system on that planet and to revise the features of a quality education system by browsing the content of the Moodle quiz by means of mobile devices (Fig. 2).

Fig. 2 Collaborative poster designing in the class. (https://youtu.be/sOBtK_ds_lk)

[2] 'Some channels let you contribute titles, descriptions, subtitles and closed captions to their videos. They are viewable on the video watch page and by clicking on the [CC] icon in the player. Approved content is owned by the video owner, but you can get credit for your contributions on the video'. (https://support.google.com/youtube/answer/6054623?hl=en).

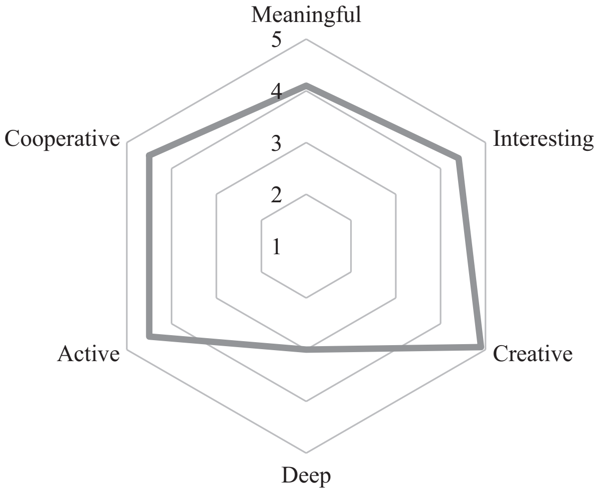

Fig. 3 Results of students' assessment of learning in the second flipped classroom (N = 28). (Some students were absent during the course, and some did not participate in the evaluation so that the number of students in a particular case and all subsequent cases differs slightly from the total number of students attending the course (N = 39))

Finally, by applying the Mentimeter application (https://www.mentimeter.com), the students evaluated on the scale of 1 to 5 how meaningful, interesting, creative, profound, active and collaborative their learning was (Fig. 3). Creativity ranked the highest (4.9), while learning depth ranked the lowest (3).

After the class, critical friends wrote their comments on the forum. One of the students commented on the students' assessment of the depth of learning:

> The results indicate that the students did not understand their work deep enough, but they found it sensible… During their work, the colleagues expressed how satisfied they were with their team's way of thinking and how proud they were of their systems because they managed to avoid the shortcomings of some other educational systems that they had learned about, and additionally introduced a number of more advanced solutions. This way of thinking suggests that the students considered their work meaningful and productive, which also indicates depth in their work. I think the students graded the depth parameter the lowest because this concept was too abstract and unnecessary in the context of assessment. (J.M., personal communication, 6 December 2017)

All critical friends point out the advantage of the possibility to cooperate and the creativity of students in the class:

> In my opinion, classes were conceived and performed in a very creative way. I think that group work is excellent because, besides getting to know each other better, we learn how to cooperate and accept other opinions, and do the task in the best possible way by compromise. I believe that other students will also agree with the view that working in groups is more interesting and useful than working individually. In other words, by working on the task of education system development, the students aimed at eliminating as many disadvantages as possible of the present system, and thus they had to think critically, which is certainly desirable. (A.E., personal communication, 7 December 2017)

In the third flipped classroom, the students were required to read the text Meeting the Changes of the Education System and write a critical review on their team forum. This text had not been published then, though it was filed for a review in a scientific journal. The teacher asked the students to be his unofficial reviewers. In order to help them to write a critical review, he instructed them to watch the video How to Summarize & Critically Respond to an Article (https://youtu.be/1gZsmNGScH8) and/or read a pdf document under the same title (https://goo.gl/BsD1pG). They had 2 weeks to complete this task. This time again all students did their tasks. Students were involved in reflecting on the critical comments published on the forum. They found that there were very few critical comments. Most students only summarized the article without stating their opinion:

> The critical feedback of that small number of students was very superficially explaining their opinions. We also noticed that the students did not make a critical review of the article itself but of the article topic. We related this to the instructions for writing seminars because these are always limited to quoting and citation of references whereas expressing own opinion is considered inadequate. The topic should have been more controversial so that students would have more to say thereto, unlike the topics that most of us mainly agree. (The second year students of pedagogy study programme, personal communication, 27 April 2018)

Petra Kolesarić,[3] who was a critical friend, wrote the following about the critical comments of students:

> The task itself did not take too much time, and it sufficed to prepare for the class. However, you said that you noticed most of the students were giving the summary of the text with a lacking critical review. I think this may be partly due to the lack of understanding of the critical review and its concept, and on the other hand, a certain “fear” of making a mistake in a critical review. For the future preparation of the class, I suggest a method of comparative analysis of two or more texts, so that, based on the comparison of different theories and views, the students can see the differences and similarities of different authors’ views on the same or similar topic and thus critically reflect. The students had almost two weeks to do the task, which greatly facilitated time organization and this is certainly one of the reasons for a hundred percent student activity. (P. Kolesarić, personal communication, 2 January 2018)

Reading and critical commentary of the text served as an introduction to the topic How to make changes in the education system? dealt with in the class held on 18 December. Class was accomplished in three units. In the first unit, the students answered the questions they asked in their preparation for the previous flipped classroom. The teacher prepared in advance for one of the questions they put. The question was about the dimension of knowledge and cognitive processes according to revised Bloom’s taxonomy (Krathwohl, 2002). As an answer to that question, he explained what the category of ‘deep learning’ in evaluation means since some critical friends stated that some students found it incomprehensible.

Finally, the teams should organize the process of education system change. A part of each team should carry out a SWOT analysis of the existing education system using the attached form, and the other part of the team should design the changes.

[3] In accordance with the idea of conducting research with people rather than on people (Reason, 1994), we asked the students whether they wished their names or their initials to be included in the reports.

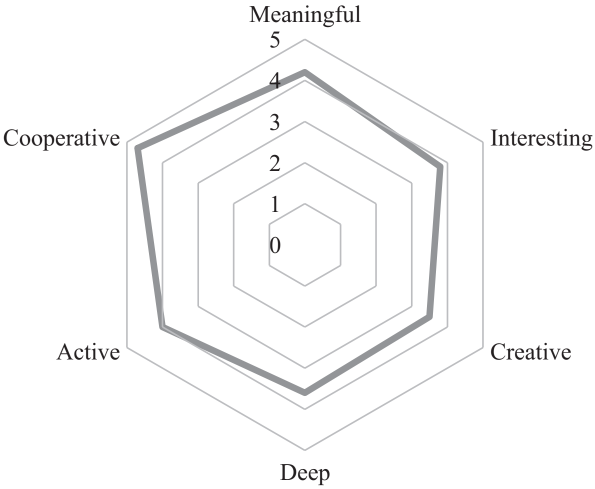

Fig. 4 Results of students' assessment of learning in the third flipped classroom (N = 28)

Based on the class video footage analysis (https://youtu.be/Sbc-D0GodmA), we established that creativity was not as much expressed as it was the case in the second flipped classroom. The results of the evaluation carried out by mobile devices and the Mentimeter application (Fig. 4) confirm this as well. Students seem to have repeated the ideas they designed in previous meetings. However, we managed to elaborate some of the previous creative ideas. For example, the idea of introducing Pilates balls into the classroom was expanded with the idea of the classrooms arrangement so that they more or less satisfy children's needs.

In the final questionnaire, the students noted the presence of all cognitive learning processes at home and in the classroom. Understanding and analysis were the most present in learning at home, while application, analysis, remembering, understanding and creation were equally represented in the class (Fig. 5).

The answers given in the online questionnaire showed that students learned the most in the second (4.8) and at least in the first (4.3) flipped classroom. However, in all three flipped classrooms, the assessment of the learning level was very high. According to the level of learning, students are very pleased with their participation in flipped classrooms. They were satisfied the most with the second (4.8) and the least satisfied with the first (4.3) flipped classroom.

The open-ended question related to the advantages of flipped classroom was answered by 27 students.[4] They gave the same number of different responses (Fig. 6). The advantage was for most students the preparation for classes (14), the more active participation in the class (13), motivation to critical thinking (9), the ability to express their own opinions (6) and better understanding (5).

[4] The students put forward several advantages, some of which were repeated. In this regard, we conducted a qualitative analysis of their responses using the QDA Miner Lite software. It resulted in categories related to the advantages of flipped classrooms and the frequency of their occurrence.

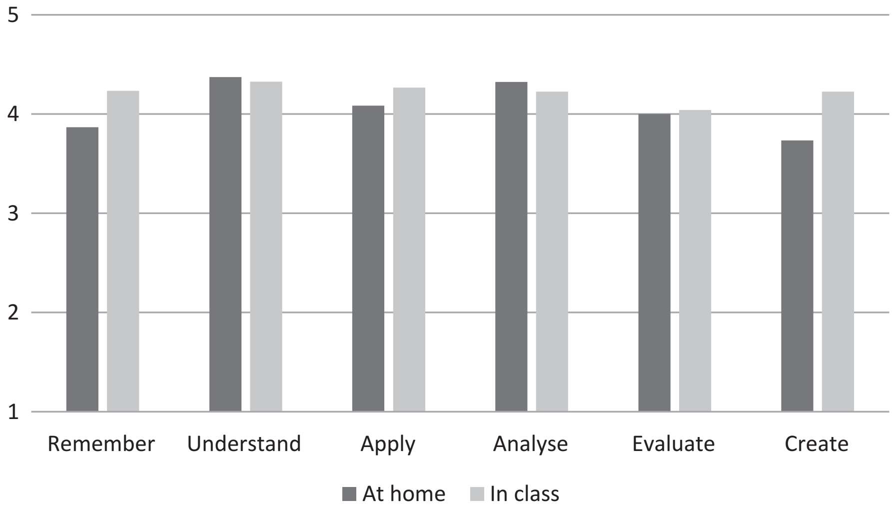

Fig. 5 Results of students' self-assessment of engagement of cognitive processes by revised Bloom's taxonomy in flipped classrooms (N = 35)

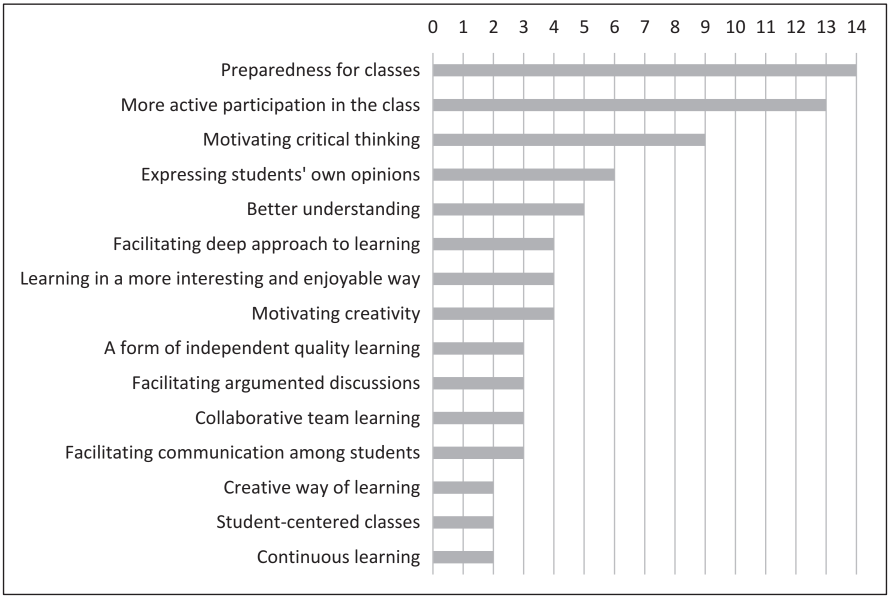

Fig. 6 Advantages of flipped classroom stated by two or more students

There were 18 students, who answered the question about the disadvantages of the flipped classrooms. Only four disadvantages were indicated: they are time-consuming (16), require a lot of tasks and work (2), lack content understanding (1) and it was not always easy to actively participate (1).

Twelve students made suggestions for the flipped classroom improvement, and these refer to less tasks (6), introducing breaks between flipped classrooms (1), more collaborative learning (1) and a wider range of activities in the class (1), creative assignments in the class (1), shorter texts (1) and better instructions (1).

At the end of the course, there was an online discussion on the topic Curricular Reform: For and Against. For several years now, this topic has been a very current social issue, and it has opened debates among various social actors in Croatia. In the class, the teacher explained to students how they could participate in the online discussion, and they agreed on the evaluation criteria. Discussions were conducted within previously established teams on forums set up for that purpose. Each team was divided into an affirmative and a negative side. In order to be acquainted with the specifics of an online discussion, the students were offered the article the teacher had previously published on this subject (Bognar, Gajger, & Ivić., 2016). The discussion was divided into two parts, each of which took a week. In the course of the first week, the students discussed whether curricular reform should be carried out. At the beginning of the second week, a new topic was introduced in which students agreed on measures to improve the quality of the education system in Croatia. During the discussion, students could read the literature available to them in the Moodle repository, as well as the sources they chose. Furthermore, in the course of discussion, they should refer to the read literature and eventually make a list of references. All 39 students were actively involved in the discussion.

The students assessed their learning in online discussions with an average grade of 4.5, while the average teacher grade was 4.6. Excellent grades in the discussion relate to the number of sources the students read and used in the discussion. By comparing the number of references with the achievement of the best study group whose results we have been observing for 4 years, we found that this year the students read two more resources on average, that is 6.5, compared to the 4.5 resources that they used in the academic year 2013/2014 (N = 43).

The students were generally satisfied with their participation in the online discussion. The average grade in the online questionnaire (4.5) confirms this as well as most of their reviews at the end of online discussion:

> I am proud of every member of our group, the way we all worked and participated. I consider this to be a new way of learning yet to gain ground. I think we can all learn a lot from this discussion. We have learned to deal independently with literature sources, to recommend the sources to each other, to discuss, to appreciate opinions, to try to represent the views that we might not represent in our everyday lives. And in the end, we could really express everything we think and strive for. I hope that one day we will really succeed in putting some of these activities to practice. (S. M., personal communication, 24 January 2018)

> This method of teaching has been an interesting way of giving us insight into the education systems of other countries, but we also found out more about our education system, which I think (and we all agree) needs a change. We have learned to cooperate, to respect other opinions, but also to represent our own opinions. I think this was a wonderful experience, and I hope we will have the chance to repeat this type of work in future. (A.E., personal communication, 24 January 2018)

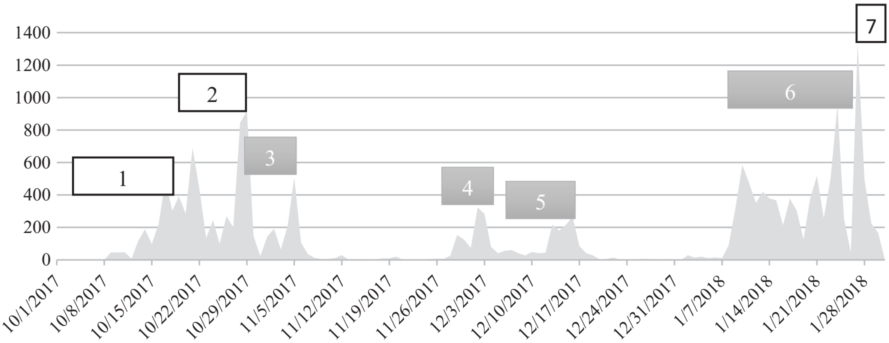

Fig. 7 Intensity of the activities on Moodle (Table 2) based on log analysis in the course on theory of education systems

Figure 7 shows the intensity of activities on Moodle. The intensity of activity is expressed by the number of logs of all students for each day in the course of the semester. Numbers 3, 4 and 5 are activities related to flipped classrooms, and number 6 is the activity of students during online discussions. It shows that in the course of introduction, publishing and commenting the comics, the activity was more intensive on Moodle than in flipped classrooms. The students had 2 weeks (5) to carry out the third flipped classroom. However, very little activity was observed in the first week. This indicates that the students were dealing with the task in the second week.

6 Interpretation

Teaching within the course theory of education systems was organized according to the didactic approach enabling student-centred learning (Bognar & Matijević, 2002). This approach considers teaching as a common activity of all participants. In order to do this, activities within the course were carried out in three stages: agreement, realization and evaluation. In this regard at the beginning of the semester, we agreed with the students on what and how to learn. The students actively attended all teaching activities and activities at home; during and at the end of the course, the students were involved in evaluation of the achieved results. In addition, we involved the students in reflection and data analysis, which we sought to contribute to overcoming:

> …the dogma that the researcher is in some way a quite different animal from the subjects studied…This separation of roles carries with it the implication that only the researcher is able to exercise free will and creative judgement (in being able to discover 'new knowledge'), while those being studied are subject to deterministic laws which it is the researcher's job to discover. A participative methodology in which we conduct research with people rather than on people attempts to heal this division, proposing that people of all kinds can inquire together into their experience and their practice. (Reason, 1994, 11)

The main idea of flipped classroom is to deliver 'direct instruction (lecture) at home via videos that teachers either create or curate and that which has traditionally been done as home is done in a class' (Bergmann & Sams, 2013/2014, 24). In our case, the flipped classrooms were not so much based on video footage, but we mostly instructed the students to read the sources from the list of compulsory reading. In this sense, the students were reading the assignments during the semester and not in the end to prepare for the exam, which is a common practice in other courses. Students' written questions and comments in preparing for the class were a form of communication with the author of the texts they were supposed to read. However, the reading assignments were set in a way that would not allow (the first and third flipped classrooms) or enable communication among the students (the second flipped classroom).This has also contributed to the lower level of students' activity in the Moodle system in the flipped classroom compared to the activities that involved interaction (Fig. 7). We discussed this problem with the students. They suggested that we should not insist on their interaction when preparing the flipped classroom, as this is more appropriate for classroom activities. Besides, they suggested that additional tasks would expand the time required for preparation, which they pointed out as the main disadvantage of flipped classroom.

Since flipped classrooms are time-intensive, it is good to allocate them with the time interval, which was one of the students' suggestions for improvement. Based on the log analysis, we have determined that the optimal time for task completion at home was a week. When in the third flipped classroom the time for preparation was extended to 2 weeks, we noticed the activity on Moodle only in 1 week (the second week) (Fig. 7).

The log analysis gave us insight into students' activities at Moodle. However, Moodle is still not a developed adaptive learning environment.

> A learning environment is considered adaptive if it is capable of: monitoring the activities of its users; interpreting these on the basis of domain-specific models; inferring user requirements and preferences out of the interpreted activities, appropriately representing these in associated models; and, finally, acting upon the available knowledge on its users and the subject matter at hand, to dynamically facilitate the learning process. (Paramythis & Loidl-Reisinger, 2004)

However, there are studies in which Moodle's adaptivity has been achieved by dividing students into groups according to their learning styles (Radenković, Despotović, Bogdanović, & Barać, 2009; Despotović-Zrakić, Marković, Bogdanović, Barać, & Krčo, 2012). Along with using the existing options as well as activity completion and restricted access or lesson activity in which it is possible to adjust the questions in accordance with previous responses, it is possible to additionally improve adaptive learning in Moodle. However, adaptive learning in Moodle depends on development of automatic routines for monitoring students' activities, which could be its next evolution stage.

The videos were included in the second flipped classroom where the students learned the most from their assessment and in which they were most satisfied with it. Video recordings of presentations by top experts (e.g. Pasi Sahlberg and Ken Robinson) and examples of quality education systems (Singapore) were an excellent supplement to the scientific text. On services such as YouTube and TED, there are many high-quality video recordings that can be used in higher education. Most of them are published in English, which can be an obstacle for those students who are less familiar with the language. However, this can be an incentive to develop their foreign language skills if they listen to native speakers' presentations.

In our research, nearly all students participated in the preparation for all three flipped classrooms. Without their preparation at home, classroom activities would have no meaning. Namely, teaching activities involving problem-based, inquiry-based, collaborative learning as well as other types of active learning have relatively little impact on educational outcomes (Hattie, 2012). Hattie points out that it would not be correct to conclude that problem-based and similar types of active learning generally fail. He considers 'it is likely that this failure is more a function of introducing PBL before students have sufficient surface knowledge' (Hattie, 2015a, 85). The fact that the students themselves noticed in analysing their online activity in the first and third flipped classrooms that their summaries and critical reviews were superficial and lacking cognitive levels such as creativity should not be understood as a problem in flipped classrooms but as part of the process of shifting from surface to deep learning. Biggs and Tang (2011) suggest that, as a consequence of treating the subject matter meaningfully, a student uses a deep learning and thus uses the appropriate higher cognitive activity, which is what is required to work with the material. They relate the deep learning, the motivations and intrinsic desires of the student, claiming that 'when students feel this need-to-know, they automatically try to focus on underlying meanings, on main ideas, themes, principles or successful applications' (Biggs & Tang, 2011, 26).

The problem arises if deep learning generally fails in teaching. The results of the evaluation conducted at the end of the first and second flipped classroom (Figs. 3 and 4) may lead to the conclusion that we were unable to achieve a deeper level of learning in flipped classrooms. However, the commentaries by students – critical friends suggest that the former is a misunderstanding of the notion of deep learning. This fact points to the need to explain the key terms used in the research. Additionally, students' self-assessment should not be the only indicator for determining the engagement of cognitive levels. Other indicators used in our research were video recordings and students' correspondence on Moodle. Video recording analysis shows that higher levels of cognitive processes among students were engaged in the classroom (e.g. discussions and answering questions asked by students themselves, SWOT analysis of Croatian education system, designing a quality education system on the imaginary planet). The results of self-assessment of the engagement of cognitive processes indicate this as well. Figure 6 shows that on the scale from 1 to 5, all cognitive processes engaged in the class were evaluated with the lowest grade from 4 (evaluation) to 4.3 (understanding). Creativity as the highest cognitive level was evaluated with the average grade 4.2. This is also supported by the commentaries by critical friends who consider that they were creative in the class, especially in the second flipped classroom.

Deeper learning was contributed by online discussions where students could critically discuss the issue of the current curricular reform in Croatia. In addition, they offered their suggestions for education system changes based on what they learned in the flipped classroom and in the class. Reading into various sources was quite helpful in this respect. The results also show that in combination with flipped classrooms, the students read more resources than their colleagues who in previous years only participated in classes and in online discussions. With the use of higher levels of cognitive processes, this result indicates that the first goal was achieved, which implied the engagement of students in deep learning.

To facilitate students' deeper understanding, it will be necessary to design other teaching activities in which higher levels of cognitive processes, in particular creativity, emerge. This can be achieved by applying students' ideas to practice.

The questionnaire results, the comments of critical friends and comments at the end of the discussion lead to the conclusion that the students were satisfied with the participation in the activities of smart learning, which was one of the set goals. Reasons for students' satisfaction are reflected in the fact that flipped classroom and online discussions make a meaningful unit that has enabled a deeper understanding of the content of the course. Satisfaction is an important prerequisite for achieving activities that require a high degree of independence and students' activity. If the students had not been satisfied with the course, it would have been difficult to achieve their almost 100 percent participation in the flipped classroom and in online discussions. The students were the most satisfied with the second flipped classroom, where, besides reading the text, they could watch quality videos at home. In the classes, they had a task that inspired their creativity. We believe that all this has contributed to students' satisfaction. Other research findings also show that students are generally satisfied with flipped learning and consider it an effective technique (Roehling, 2018).

7 Conclusion

Although advanced digital technologies are available to students and they use the Internet on a daily basis, they are still rarely used in higher education. Introducing modern technology in teaching does not necessarily contribute to the quality of students' learning (Hattie, 2015b). It is therefore important to take into account the organization of the learning process that should allow shifting from surface to deep learning. The importance of surface learning should not be ignored since without it active learning activities often fail to contribute to students' learning outcomes. One of the possibilities of linking surface and deep learning is flipped classroom. The results of our research show that flipped classroom can be included in higher education. The key assumption for flipped classrooms is student's activity in the learning process, especially at home. We have shown that this can be achieved by involving students in all teaching stages: agreement, implementation and evaluation.

The assumption for active task completion at home is its relevance, actuality and the ability to communicate with the author of the text. We offered students the texts written and published by the first author. They could ask him questions and thus receive first-hand information about the issues that interested them. High-quality videos available on the Internet can contribute to the curiosity and current relevance of learning at home. Students do not only read texts and watch videos; they should also complete the related tasks at home. This encourages them to activity and at the same time gives feedback on their preparation for teaching. We established the optimal time for preparation to a week. In addition, the breaks between flipped classrooms are important, and in a one-semester course, it is optimal to have three to four flipped classrooms.

After independent learning at home, teaching should be organized so that students use multiple cognitive processes (applying, analysing, evaluating and creating). It is especially important to encourage students' creativity, which we largely managed to do in the second flipped classroom. Students think that they have learned the most in the classroom and are most pleased with it. For a future action research, it can be a challenge to find ways to foster students' creativity in flipped classrooms.

Smart learning is defined as being self-directed, motivated, adaptive, resource-enriched and technology-embedded (Kim, Cho, & Lee., 2013). In our case, most of the features of smart learning were present. During the course, the students took over the responsibility for their learning. Their self-instructed learning developed gradually: from less autonomy while they were preparing for flipped classrooms to high level of autonomy in online discussions. The evidence of students' motivation for learning is the fact that almost all students took part in all activities at Moodle. Adaptive learning was the smart learning feature that was at least apparent.

In future research, we should pay more attention to this. This, however, depends not only on our efforts but also on the development of an adaptive learning environment in Moodle. The availability of different digital sources, and above all the quality educational videos, has enabled resource-enriched learning. Finally, technology-embedded feature makes it possible for the students to learn whenever and wherever they want (Kim & Oh, 2014).

In our action research, the students had an opportunity to actively participate not only in teaching activities but also in research. We gave them an opportunity to be critical friends and involved them in critical review and data analysis when drafting the report. This has given us an important feedback for improving the ongoing activities. Moreover, we can approach further changes in higher education based on the results of this research more confidently.

In the end, we believe that scientists who research into the possibilities of improving higher education should take care of the quality of their teaching and not just lead theoretical discussions and research into someone else's practice, as the first author pointed out in his response to a critical friend:

> At the beginning of the course, I said that we would learn at two levels: the first is the theoretical, the other the methodical level. In this context, my intention was not only to talk about education systems, since I believe that the features of quality education systems should also distinguish our classes. Certainly, in this process we all need to take the role of a student. There is an important reason for which I like this profession and that is the ability to learn continuously i.e. to improve my practice. The comments made by you as my critical friends are a great help to me therewith. (B. Bognar, personal communication, 11 January 2018)

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The Power of EMPs: Educational Multimedia Projects

Rab Paterson

Abstract This chapter highlights the pedagogical approach taken by the author in his teaching, both at secondary school and university undergraduate level. It begins with an overview of how a variety of digital approaches to teaching such as technology, pedagogy, and content knowledge (TPACK) were developed. Next, this section then explores these approaches such as flipped learning and blog journaling in detail by examining their strengths and weaknesses and which apps the author suggests they be used with. The apps used are also briefly explained along with an explanation of the Substitution Augmentation Modification Redefinition (SAMR) process used to evaluate the apps in the first place. With this background finished, the chapter then highlights the actual Educational Multimedia Projects work done by the author by looking at the specific projects undertaken by liberal arts undergraduate university students in Japan and the reactions of the students. This chapter concludes with the lessons learned from this action research approach taken by the author as the student reactions to this type of approach were overwhelmingly positive.

Keywords Twenty-first-century learning · Challenge-based learning · Digital literacy and pedagogy · Multimedia learning · Project-based learning

1 Introduction: Educational e-Volution

Technological change is one of the constants in the modern world as almost every device ever made has been continually improved over time. As these technological creations have improved, the way society interacts with them in daily use has also correspondingly changed. The field of learning is no exception, and there are many teachers making the maximum use of these advances in technology for educational purposes. Educationally speaking, these trailblazing teachers can be seen as being on the cutting-edge/bleeding-edge area of the technology diffusion of innovation

R. Paterson (✉)
Toyo University, Tokyo, Japan
e-mail: Paterson@toyo.jp

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scale (Rogers & Rogers, 2003) as they are doing innovative work in their blending of the discipline of teaching with the advances in technology, whether it be direct educational technology (e.g., like writing apps) or of taking some other types of technology not usually seen as educational (like video editing and website building) and repurposing it for educational use. This chapter will illustrate how one teacher has approached this blending of the traditional and the modern and will hopefully provide a template for other teachers to follow to whatever extent they desire.

The rise to prominence of the Internet, and more specifically the Web 2.0 revolution that enabled users to be creators as well as consumers of media, has created a number of divisions in society. One of these was the so-called digital immigrants/digital natives divide theory (Prensky, 2001) which named older people who were adults before the dawn of the Internet Age as digital immigrants, while those younger people who grew up in the Internet Age were called digital natives. However, more controversially, this theory also posited that the immigrants were less tech savvy than the natives. This was a problematic assertion in many ways as many of those older people were those who worked to create the Internet and its many apps, while many younger people, especially those from poorer socioeconomic groups with low levels of access to Internet-connected devices at home or school, were and are far from being competent users of technology. So teachers approaching the idea of using digital technology in their classrooms need to be aware that although many of the students are from the same generation (or even around the same age if they are school pupils), they will not all be at the same starting level of ability in terms of their digital technology skill sets. Therefore when planning course/class content, teachers will have to be able to differentiate their lessons to account for these differences.

1.1 Projects

When looking at pedagogical approaches in general, the actual class lessons and lectures should be structured to maximize the learning that takes place. Here, the use of projects has been used before as the idea of having students complete projects is not really a new idea as it has been around for a long time in many forms and indeed, was even discussed by Dewey around 80 years ago (Dewey, 1997). However, the idea of having projects that included multimedia creation content, and which were cross-disciplinary in nature, is a much more modern approach that leverages what is possible technologically speaking.

1.2 The Power of Projects

Project-Based Learning In the early 1990s, research showed the power of projects to motivate students (Blumenfeld et al., 1991), and this was before the advent of the Internet in a widespread way in schools, colleges, and universities.

Much more recently, Brookhouser has tried to mirror the famous Google 20 time approach in his work on projects with high school students (Brookhouser, 2015) where he sets his projects up as an extracurricular activity. However, many other teachers have tried to keep their projects within their school curriculum ("Project-Based Learning," n.d.). The only criticism is that for in-group project works, some students may try to avoid doing work by letting more motivated students do the majority of the work. By assigning different tasks to different students with each being responsible for their segment, this problem can be mitigated. This was the approach used by this author in the Educational Multimedia Projects approach, and in addition, the projects used are cross-disciplinary in nature (and conducted within the parameters of the "normal" university curriculum which had no specified multimedia content), while the author's approach was heavily involved with multimedia content as the EMP name implies.

Challenge-Based Learning This is an approach that had its roots in the original Apple Classrooms of Tomorrow (Dwyer, Ringstaff, Haymore, & Sandholtz, 1994) and its 2008 follow-up research by Apple as it attempted to propose educators design projects that have real-world challenges for students to grapple with. Researchers are positive that such challenges better prepare students for the modern world and the type of work they will probably end up doing (Johnson, Smith, Smythe, & Varon, 2009). Indeed the World Economic Forum's latest list of skill sets it suggests are necessary for success in the modern world are the type of skills that can be developed by challenge-based learning (Gray, n.d.). Therefore, these suggested skill sets helped inform the way the EMP approach was structured.

The Technology Pedagogy and Content Knowledge Approach The current best practice for project classes should be based on the lessons gleaned from the work done by cognitive scientists ("Educational Psychology & Instructional Technology," n.d.; Mayer, 2001, 2005; Medina, 2011) on how best to deliver digital content to learners. These researchers also discuss the use of technology to amplify the class content and teaching pedagogy, the so-called technology, pedagogy, and content knowledge (TPACK) approach (Marino, Sameshima, & Beecher, 2009; Mishra, Koehler, & Zhao, 2007). The TPACK approach posits that as appropriate pedagogies improve teaching practice by improving the delivery of appropriate content, appropriate use of educational technology can alter pedagogy as it makes previously impossible approaches very possible via the technologies available now. This enables teachers to better engage and grab the attention of the so-called "digital native" learners, and therefore teaching is also improved. So to achieve this beneficial outcome, a modern set of pedagogies, and the appropriate learning technology apps and tools for these pedagogies, need to be adopted and implemented by teachers.

2 Digital Pedagogies

With the advent of digital technology and Web 2.0, a number of SMART or digital pedagogies have been developed to leverage this technology in the classroom. This section will explore some of these approaches, the ones that make up this author's Educational Multimedia Projects approach. However, the technology is not a passive partner. Knowledge of technology informs and changes the pedagogy, as previously unavailable teaching methods have now become available, especially via the use of Web 2.0 technologies as this section will show. An example of this is online tutoring services like the Khan Academy ("Khan Academy," n.d.). Also of note are the ideas of Creanor and Trinder (Sharpe, Beetham, & Freitas, 2010, pp. 43–55) on how the tools are presented and used digitally. This leads directly to the digital approaches.

2.1 The Digital Pedagogy Approaches

Flipped Learning One teaching approach that has become popular in recent years is flipped learning. This takes the traditional in-class activities such as reading of books and articles and watching of videos and "flips" them to be done by students as pre-class homework. These are usually time-consuming activities, so by having them done outside class, it frees up in-class time for teachers to focus on the more active tasks such as writing of papers, creating presentation slideshows, and making videos that were more traditionally assigned as homework. The idea here is that these creation-based tasks need more teacher guidance, so it is more beneficial to have them done in class when the teacher is present. Other more consumption-type tasks can be more easily done without the teacher so are better suited as homework tasks. Eric Mazur has written about his students' positive experiences when he incorporated a flipped learning approach into his curriculum at Harvard (Lambert, 2012).

The approach itself is a very efficient one as it leverages teachers' ability to make and share digital copies of readings, audio files, and video files with students very easily using any one of a number of services such as Dropbox, Google Drive, Apple's iCloud, and Microsoft's One Drive. This sharing can be done as far in advance of the class as teachers desire with longer lead time given for longer readings/viewings to be completed by students. The only issue here is how teachers check that these readings/viewings have been completed to a satisfactory level.

Concept Questions Many university teachers including Mazur use a clicker approach combined with concept questions at the beginning of the class where the readings/viewings are scheduled to be discussed. Teachers ask an appropriately designed question to divide student opinion, and students answer by either a show of hands or pre-disturbed cultured cards or even electronic clickers if they are available to teachers. Students are then partnered with those who gave a different answer to their answer and are then set the task of convincing the other students why their answer was the correct one. Obviously, this cannot be done well if the reading/viewing has not been done properly, and so students can lose face in front of their peers if they cannot provide evidence from the homework assignments to support their answers. This then can act as a motivational tool for completing the flipped assignments.

The downside to this approach is that it can take up a lot of precious in-class time if done in every class for every flipped assignment. Therefore, alternative approaches are also needed. If the schools/colleges/universities have electronic clickers, these can instantly capture the data from the students' answers for teachers to analyze later. However, these electronic clickers and the data collecting apps that accompany them are relatively expensive when compared with free alternative approaches that are also available.

Blog Journaling Traditional journaling is a teaching technique where teachers have their students keep a learning log, usually in a paper notebook. The entries in these logs are designed for students to reflect on what they have learned in each class and how this can impact their future learning going forward. More recently, alternatives to paper notebooks have been used, and after a detailed examination of learning logs, Moon found 18 purposes (Moon, 2003, pp. 8–9):

- To record experience
- To facilitate learning from experience
- To support understanding and the representation of that understanding
- To develop critical thinking or the development of a questioning attitude
- To encourage metacognition
- To increase active involvement in, and ownership of, learning
- To increase ability in reflection and thinking
- To enhance problem-solving skills
- As a means of assessment in formal education
- To enhance reflective practice
- For reasons of personal development and self-empowerment
- For therapeutic purposes or as means of supporting behavior change
- To enhance creativity
- To improve writing
- To improve or give "voice," as means of self-expression
- To foster communication. In particular reflective and creative interaction within a group
- To support planning and progress in research or a project
- As a means of communication between one learner and another
- Of course not all purposes will be utilized by all teachers, but the list gives an idea of what is possible.

The approach taken by this author was to use learning logs but with blogs. Blog journaling offered a number of advantages over paper-based learning logs. The first benefit is timing. Reflective blogging by students (if done well and done regularly) can enable teachers to see the visible learning taking place in students' thinking processes (Hattie, 2012) and enable more timely corrective measures if any errors are spotted using the just-in-time teaching methodology described below. Medina has written about time and its effect on memory (Medina, 2011), so having students write blogs within 3 days of each class creates the ideal conditions for reflection as after this period, the students are drawing more on longer-term memory rather than the more immediate reflection needed. Furthermore, with blogs being date-stamped, teachers can check when they have been written and with a Really Simple Syndication (RSS) reader can regularly monitor multiple blogs in class-by-class folders on mobile or desktop devices. Depending on the actual RSS reader, many of these RSS apps also allow for searching blog collections by keyword, another useful bonus for teachers in checking on student learning.

Learning Communities Students are also encouraged to make their blogs semi-public (open to other students in the same class) as this promotes what this author calls a "writing for 'we' rather than writing for me" approach. Having blogs open allows students to read and comment on each others' posts and can also promote dialogue on lessons outside the classroom, the so-called expanded classroom (Shaw, 2013). Related to this, all students are added to an online group (in this author's case, a Google Group), and this group's discussion board along with the students' comments made in their peer-reviewed documents (in Google Docs/Slides/Sheets) creates a community of learners (Lave & Wenger, 1991; Lewis & Allan, 2004) for them to learn with and from. In addition, it has been argued that this is necessary in the facilitation of twenty-first-century learning (Nicosia, 2013, pp. 29–30).

Just-in-Time Teaching This pedagogical approach was popularized by science teaching staff at Indiana-Purdue University, and their system has students completing online questionnaires a few hours before classes start. Teaching staff then base their teaching plans according to the results of the questionnaires to address issues arising from the results. This approach has borne fruit as students have shown improved results in a range of fields such as grasp of concepts and problem-solving skills when compared with their peers, who took a more traditionally taught course (Handelsman et al., 2004, p. 522). Therefore this approach can also be done with blogs as this author's approach uses blog journaling instead of online questionnaires to help prepare lessons. If only a few students have issues (as shown by blog entries), they can be addressed privately; if many have the same issue, then a corrective mini-lecture can be given in the next class after their blog post due dates, i.e., correcting errors "just in time."

2.2 *Digital Toolkits for Students' Projects*

Personal Learning Environments Students need to be provided with a set of useful apps for academic work as although students can be very comfortable with online work and using online apps, the apps they are most familiar with are often not those best suited for academic purposes. The list of apps (and guides to using them) in the Educational Multimedia Projects (EMPs) approach were provided to students via shared documents (in this case Google Docs shared via the Google Groups) and in-class instruction in how, why, and when to use them were also provided as part of the personal learning environment (PLE) approach. The specific apps used can vary according to the different aims of the EMPs selected and the age range of the students. For example, if the EMPs involve video work, then video editing apps need to be covered; if website hosting of project work is a part of the project, then web building apps should be covered. Teachers can choose whatever range of apps they need for the aims of the EMPs. The overall range of apps covered becomes the student's personal learning environment (PLE), and they learn the skill sets required for using all these apps.

The Substitution Augmentation Modification Redefinition Model The Substitution Augmentation Modification Redefinition (SAMR) model developed by Ruben Puentedura (Puentedura, 2013) is a conceptual approach to help teachers select which apps and approaches to use in their EMPs and other teaching. It is used cognitively to evaluate the pedagogical potential of apps as opposed to the more normal functional or cost-based evaluations. A number of different educational technology advocates have championed its use at their events including Apple and Google's educational divisions. At its heart is the idea that not all apps are equally useful for promoting learning as some so-called "new" apps merely replicate what has been done before in a slightly different way so there is little utility in substituting an app of this kind. For example, switching to a new word processor from an old one is still just using a word processor. However, if the word processor had some new fucntion that the older one did not (e.g., when Google Docs first came, it offered cloud syncing and simultaneous editing, some very useful functions that Microsoft Word did not initially have), then it could be seen as an augmentation to the functions of the older app, and there would be a stronger case to be made for the adoption of the newer app. The next step is modification, and if the newer app (in this case Google Docs) allowed for the modification of the tasks (e.g., by using collaborative writing assignments in real time) given to students, then there would be an even stronger case for its adoption. Lastly, if the app is so radically different from its predecessors that it allows for a redefinition of tasks or of what learning is, then those types of apps would have the strongest rationale for adoption into a teaching workflow. In this conceptual model, the adoption of Google Apps for Education was exactly the type of app set that checked all the boxes of the SAMR model for adoption into this author's EMP approach.

3 Educational Multimedia Projects

A number of researchers have looked at the important role of digital literacy in modern educational settings (Jones & Hafner, 2012; Knobel & Lankshear, 2007; Kress, 2003; Lankshear & Knobel, 2008). Other studies have looked at the way different aspects of new media and technology can be combined with language learning in a "bridging approach" (Thorne & Reinhardt, 2008). So this author's approach attempted to do exactly that as the students in the school and university classes were high-level language learners in Japan, in an International Baccalaureate school in the Middle Years Program, and at a Super Global University with freshmen undergraduates. Research has been conducted on digital literacy levels of students in Japan which showed a high level of smartphone capability (the social aspects of some of the apps enabled the students to contact each other and this author at any time, and given the ubiquity of smartphones, they could be reasonably sure of a quick response) but much less with actual computers (Lockley, 2011; Murray & Blyth, 2011, p. 313). So while the EMP approach did have a mobile component to it, the projects were heavily skewed toward actual computer usage and apps to address this imbalance.

3.1 The EMP Approach

Initially freshmen university students were randomly assigned to groups of three or four students per group (depending on class size), and they created a smaller Google Group for these members while still being part of the larger class umbrella Google Group. These groups were then given a challenging task related to their educational setting. For these university students, it was how to create a set of multimedia materials highlighting their views on how their own university education could be improved, with the idea of "improve" being defined in whatever area or way they felt best. Student groups then brainstormed a set of ideas and then narrowed these down to the specific set of ideas they would work on, and they produced individual peer-reviewed essays, a multimedia presentation slideshow which they delivered live in class, a team video, and all these materials were hosted on a team-made website; see below for details.

3.2 EMP Specifics

Search Students were shown effective Google search techniques from the many lesson plans Google has online to teach search techniques ("Lesson Plans – Search Education – Google," n.d.), and this covered the use of Boolean operators and other options for more efficient searching and narrowing of search results. The students then conducted their own research using what they learned. They were also given academic writing instruction, which included a number of online writing apps for checking and evaluating specific aspects of their writing, and they wrote individual (but peer-reviewed) five-paragraph essays using Google Docs on their section of the group topics.

Slideshows Then they designed, created, and video screencast recorded/narrated a slideshow presentation. For the slideshow presentation, students learned about modern slideshow design current best practices and presenting theories like picture superiority effect (PSE) and the contrast, repetition, alignment, and proximity (CRAP) theories (Duarte, 2008, 2010; Reynolds, 2008, 2009, 2010) and used these in making their own slideshows.

Videos These were then converted into slideshow videos using a combination of Google Slides, QuickTime X, and iMovie and uploaded all the above materials to a website their group collectively designed and made using Google Sites. The presentation videos and site intro videos were also uploaded to their YouTube channels, and the videos were also embedded into their respective teams' Google Sites.

Websites These Google websites also hosted a links page to show the depth of their research. Key parts of each group members' written work were also combined into a more visual style project brochure, and the key parts of the data were incorporated into info graphics. The full set of online class materials then became part of each student's e-portfolio as it not only highlighted the work they had done but also showcased their skill sets used to produce that work and the potential range of things they could now do as a result of these projects. The URLs of these final group project websites were then shared with everyone in the class for group constructive feedback purposes on each groups' sites.

Presentations Lastly this course also covered a variety of presentation delivery techniques (Duarte, 2010; Reynolds, 2010) and covered how to deal with audience questions, so students could deliver these presentations to a very high standard.

3.3 EMP Learning Outcomes

The course had a set of learning outcomes (LOs) for students:

1. Be able to find appropriate copyright free images/multimedia materials and incorporate them into suitable essay work, presentation slideshows, videos, and website designs for academic work
2. Be able to record and upload/share a self-narrated video of their presentations
3. Be able to create and share a website that hosts their presentation slide show, self-narrated video presentation, essay, and links page
4. Be able to deliver their presentations live to an audience and deal with questions in a competent manner

3.4 Learning Outcome Indicators

These LOs were accompanied by a set of learning outcome indicators (LOIs) to show that these skills were mastered. These were:

1. In-class student demonstrations of their search techniques for their essays and presentations showing techniques previously covered in class

2. In-class and/or outside viewing of student's self-narrated video presentations for project work showing techniques previously covered in class
3. In-class and/or online viewing of students' websites showing techniques previously covered in class
4. In-class practicing of student presentations showing techniques previously covered in class

In terms of tools, the course fully utilized the Google Apps suite as well as covering reference management of sources in essays via Zotero, and the sharing of files via Dropbox, Google Drive, and iCloud. Therefore, by the end of this course, students were able to demonstrate their ability to find a range of good academic sources for their papers and presentations and to store, organize, and share these with others, and also reference these sources properly in their academic work.

3.5 Student Profiles

The students taking part in these EMP classes were freshmen students in their first semester at the university, and almost all came straight from international high schools. All but one of them had experience of studying overseas (i.e., outside Japan) for periods ranging from 1 year to, in one case, their whole life. Only one student had their whole educational experience in Japan, but even this student attended international schools in Japan for the most part. So they were a very diverse group in terms of their international experience. The students themselves were at the very top of the English language ability range for Japanese universities as they all had to score 650 or higher on their TOEFL entrance test to be put into the academic reading and writing (ARW) classes this author was teaching. For gender makeup the class was roughly two thirds female and one third male in the 3 years this author conducted this EMP work at that university as that was the average for liberal arts students in the wider university population at that time. In addition, the students ranged from 18 to 21 at the time of the class used in this chapter.

3.6 Data Gathering

In addition to the reflective blogging mentioned above for this one specific class, this author also conducted end-of-term interviews and five surveys (S.1 on the overall class, S.2 on Apple apps and tools, S.3 on Google apps and tools, S.4 on all other non-Apple/non-Google apps and tools, and S.5 general follow-up survey 6 months after the course). For the interviews, four females and two males signed up on a voluntary basis via private online signup, and these all had overseas educational experience in a range of countries outside Japan, some in more than one country. One of the male students and one of the female students interviewed had English as their dominant language and were actually studying Japanese as they were far weaker in that language. The other four students interviewed were effectively bilingual and in two cases were studying a third language; however, their ability level in the third language was low to intermediate. In terms of technological ability, none of them were particularly heavy users. As expected, they all had Facebook accounts and had all used MS Word and PowerPoint, although they freely admitted they were not power users, so most of what was covered in class was new to those interviewed.

The surveys were collected and collated online using SurveyMonkey, and this tool provided the average scores for those questions that included sliding scales in the answer. In these responses, the codes and themes that developed were closely related to the tools and techniques covered and their value in the eyes of the students in terms of the bridging activities the class focused on. In the class feedback survey, these topic themes were “usefulness,” “community” (both positive and negative aspects), the pedagogical approaches taken, the project work, “wikis” and “remixing,” and their overall feelings regarding the course in terms of the other bridging activities. This author also conducted specific thematic surveying of all the different apps and tools covered in surveys 2–4, but the detailed results of these for each app are outwith the scope of this chapter. Survey 5 was a follow-up survey (conducted 6 months after the initial class ended), and again the themes were mainly based on usefulness and applied to everything from the previous class as by then the students were in a position to judge the usefulness of what they learned in this course, in terms of preparing them for their follow-on classes at the university.

The actual results were looked at from an interpretive *Applied Thematic Analysis* type viewpoint as advocated by Guest (Guest, MacQueen, & Namey, 2012, pp. 15–16), and the surveys mainly cover their satisfaction with the classes and include their evaluations of the classes in terms of usefulness of their other academic studies at university. Their interviews were all transcribed, and as with the surveys, all text was kept as it was originally written for authenticity (including grammar/spelling errors) and to provide an indication of the English language fluency levels these students possess.

3.7 Results and Discussion

Usefulness

In terms of being useful and enjoyable, the classes were rated very highly indeed, scoring 9.45 out of 10 on a simple scale with 0 as totally boring and not useful at all and 10 as incredibly interesting and useful (Fig. 1).

A selection of the comments illustrates just how happy they were with this style of class and educational technology content:

S.1, Q9

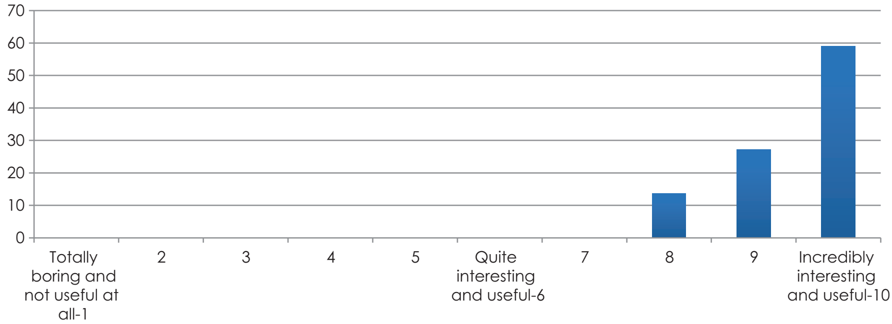

Fig. 1 S.1 Q9 – How useful and enjoyable did you find the ARW classes?

2 – The tech-tools are something we can use for a lifetime; thus, I think the classes were relevant for our education.
6 – Enjoyed every bit of it, it was so stimulating to be with many bright, talented, classmates, the content of the class was always pushing me which was great!
11 – ARW classes were the only classes this term where I did not feel the urge to sleep during class.
15 – Best classes I've taken in my life. Amazing quality, new insight, integrating technology, just fantastic classes.

When asked for particular highlights, the following also speak volumes about how much of an impact these classes made.

S.1, Q.10
4 – I found everything very useful and enjoyable! And Funky Fridays[1] *were fantastic!*
9 – The collaborative learning using Google and other technological tools was very useful and enjoyable. I think that Rab should hold an independent class just on those things.
21 – These days, it should be NORMAL to have classes in rooms filled with computers. Technology plays a huge role in our lives today, and I don't see why it should be the same in classrooms.

So based on that, it is clear the classes were very successful in this regard, as the only negatives tended to be on the workload mentioned above, although one student complained that if they had known she would be using Apple computers so much, she would have bought one rather than a Windows computer. Based on this feedback, this author would recommend a push for more of these digital bridging activity classes given the feedback this course received.

[1] The class nickname for the Friday afternoon classes held in an iMac lab.

Community

When looking at the collaborative- /community-type aspects of the course, a few more positive themes emerged:

S.1, Q.10

8 – The discussions with everybody, it was great to see people my age vocalizing their thoughts in Japan, and to be a part of that was amazing.

This was no doubt in response to the all too real stereotype of Japanese students who only passively listen in class at schools. From the follow -on survey, another student mentioned collaboration:

S.5, Q.3

2 – Google Docs Most students have a busy schedule, so there is limited time for all of us to get together to prepare for a group presentation. In those times, sharing a document that all of us can edit online was extremely useful.

Another student said:

S.5, Q.13

4 – That was awesome!!!! There are times I think back on our classes and it's a major relief to know that I can actually contact anyone whenever I come up with a cool idea or sth (something). It's like class is still presuming in your phone.

On the actual Google Group for the course, it was given a score of 8.41 out of 10, another very high score (Fig. 2).

So this seemed to be a popular community-building tool. Overall though from the class survey, it seems clear that the students had positive reactions to the community aspects of the ARW course based on their feedback and the levels of engagement observed in these classes with this tool.

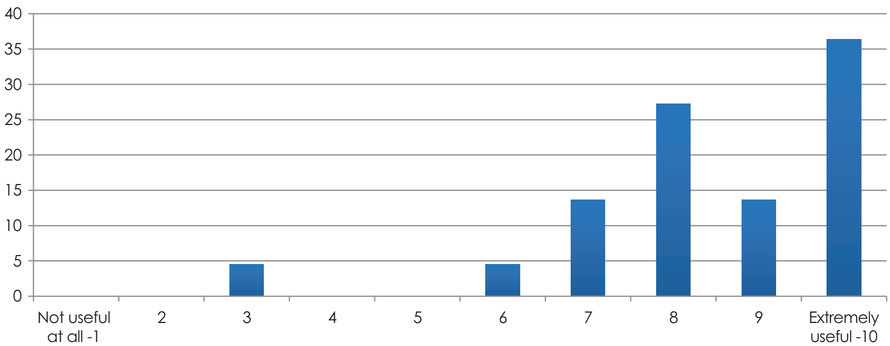

Fig. 2 S. Q10 – How useful overall did you find the Google Groups this year?

Values

Here the survey was concerned with the students' usage of Zotero for reference management and Grammarly, a grammar-checking app. Survey 4 dealt with non-Apple and Google tools, so the responses here are mainly drawn from that survey. When asked for their favorite Firefox Add-On, 13 students out of 22 mentioned Zotero, even though there is a stand-alone version for Chrome and Safari. On the actual Zotero question, it received 8.27 out of 10 for its usefulness (Fig. 3).

However, it did receive a few comments about being difficult to use at the beginning, probably as it was a type of software they were unfamiliar with.

In contrast Grammarly only received an average of 5.36 out of 10 (Fig. 4).

One of the comments said:

S.4, Q.13

A "Grammar Check" isn't necessary (most of the time). In addition to that, the plagiarism checker was worthless. It was not accurate at all.

However the student was probably referring to the fact that Grammarly searches the Internet for matching text and suggests a reference source based on the site it finds text matches, even if the site is also quoting from the same offline source. With Zotero being used, it seems that most students only used Grammarly for grammar

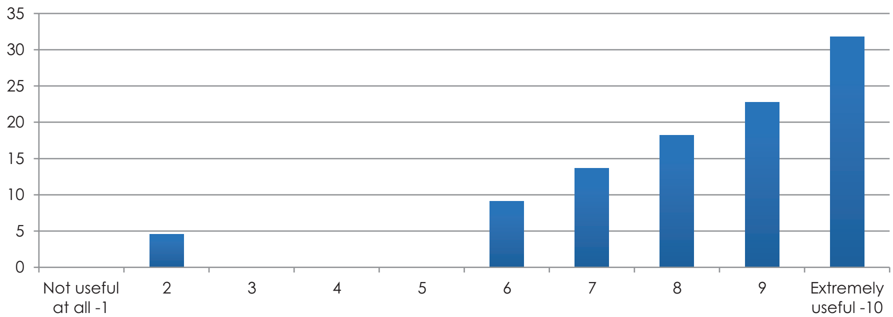

Fig. 3 S.4 Q9 – How useful overall did you find Zotero this year?

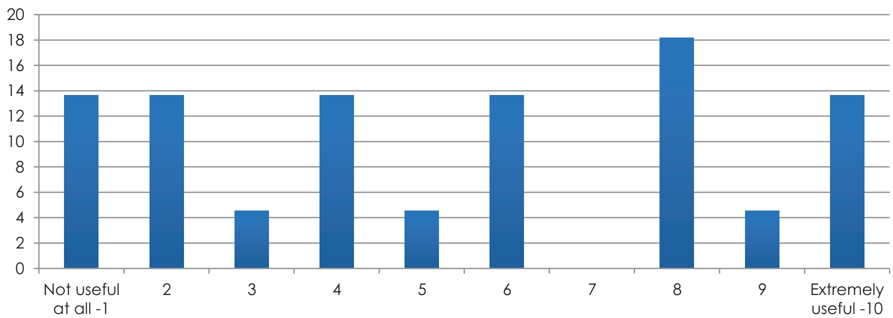

Fig. 4 S.4 Q13 – How useful overall did you find Grammarly this year?

checking, not plagiarism. However, from grading their essays, many students did make formatting mistakes in their referencing, probably due to errors in inputting data into Zotero. So more extensive training is needed in future classes, and this would go along with the students' comments regarding it being difficult to use at the beginning.

Bridging Activities: Messaging and Chat

There were no specific questions in any of the surveys related to Google Chat. The question on Gmail (which hosts Google Chat) resulted on a score of 9.45 out of 10 (Fig. 5).

However that was referring to Gmail as a whole, not chat specifically. Also there is a comment function in many of the tools that make up Google Apps, and more than a few students mentioned the utility of this.

S.4, Q.1
3 – Google docs, and its sharing system, made it much easier to work in groups. It was much more efficient time wise!

Again though this comment was not specific to the real-time comment, just the overall sharing capabilities. So more research could be done here on this aspect of the bridging activities. On the pedagogical side of chat, the expanded classroom idea was also highly rated, and most of the positive comments related to how they felt happy they could contact the teacher (this author) outside class at any time and get answers fairly quickly. Indeed the follow-on question on teacher response time drew an average of 9.27 with 10 being the maximum. This question also received some amusing statements like:

S.1, Q.13 and 14
1 – When do you sleep?
8 – Your replies were very fast; so fast I did not have the time to correct my mistakes when I realized them.

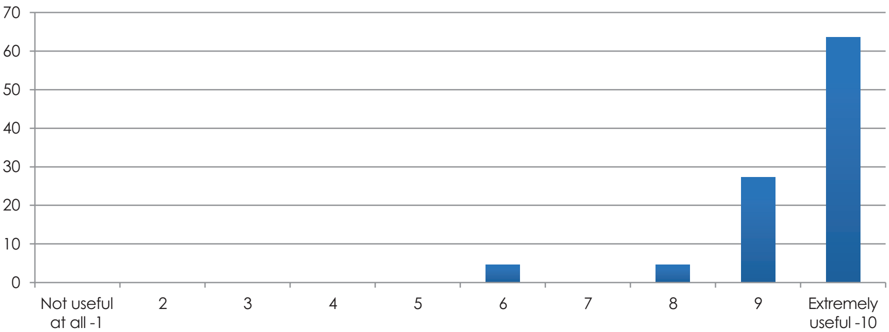

Fig. 5 S.3 Q4 – How useful overall did you find Gmail this year?

However, there were a couple of replies that mentioned replies were sometimes really slow, and it is likely these were in relation to emailed questions from early on in the course when some students' emails went into the email Spam folder for some unknown reasons. This is something to be aware of, and in the future, if teachers send the students an email first, their address will be in the teachers' address book, and this should take care of the Spam filter on Gmail.

Blogs and Wikis

Here there were a number of questions across the surveys that were relevant. On the pedagogical side of blogging, the just-in-time teaching received reasonably good feedback with a few respondents stating it was better than doing paper journals and praising the ability it gave to enable them to see the thoughts of their classmates.

S.1, Q.12
4 – Very useful! Much better than writing it down on paper and handing it into you every class!
6 – I thought it was great to get feed-back while you still remembered what you were thinking.
15 – I think it is a good idea for we are able to look at what our fellow classmates think and things we cannot say during class in limited time.

One of the few negatives was the fact that this author did not comment on all the blog posts; however, that would have been far too time-consuming. Overall though the blogs received a score of 8.05 out of 10, and the ease of use was mentioned a few times (Fig. 6).

Conversely the Google Sites were rated much lower, scoring 6.18 on the same scale. Students mentioned that it was fun (Fig. 7),

S.3, Q.8
4 – Fun, but wanted more timeeee

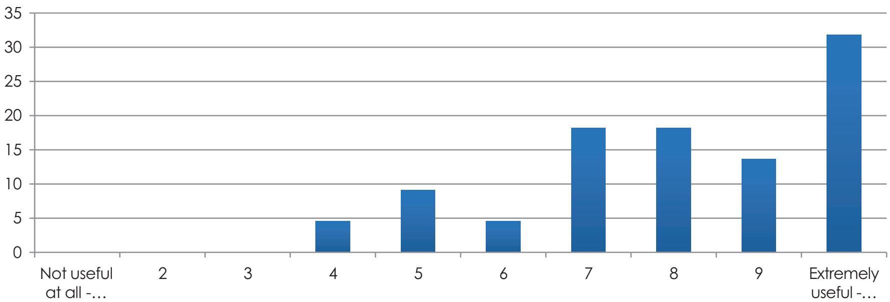

Fig. 6 S.4 Q15 – How useful overall did you find the Blogger Blog this year?

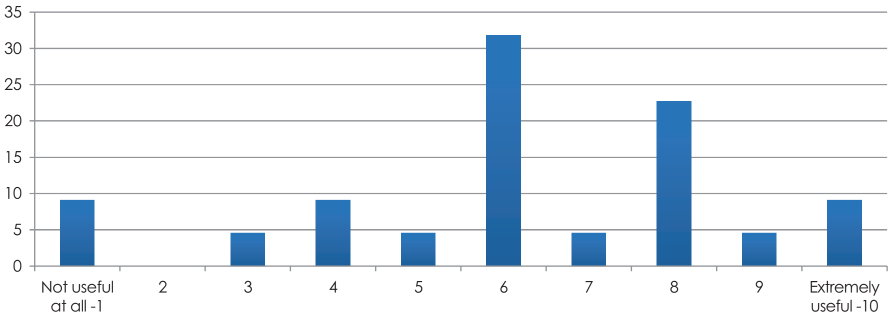

Fig. 7 S.4 Q8 – How enjoyable did you find making the Google Sites this year?

something that would go along with the comments on remixing (Thorne & Reinhardt, 2008), but negative points were the shortcoming of editing tools and the time frame for completion. So despite the students producing some very interesting remixes on the sites, in the future a longer project period should be used. Recent improvements in the GUI of Google Sites have addressed these problems in this author's current classes.

Remixing

The multimedia project drew mixed responses. On the one hand, the content and idea itself were rated very highly.

S.1, Q.19
15 – I am glad we are doing this even though there is a lot of stuff to do but because of this we were able to learn the many uses of the computer

However, the time frame and the fact that it had to be at the end of the semester after the tools were taught drew criticism as mentioned above:

S.1, Q.19
7 – It was very useful but too much work to do in such a short period.
8 – It was great to gain experience as cushioning before the RW (Research Writing – their follow on course taught by another teacher) class, but was very, very tight on time.

So here it would seem better to spread that work out over two semesters rather than cram everything into one, and indeed two students mentioned that in their comments. Overall though, the course seems to have been very popular with the students. The answers to the question "Did your overall spring class experience live up to your expectations?" on this satisfaction issue make this very clear:

S.1, Q.21

4 – YESSSSSSSS! I had expected something very different, but it was much better than what I had in mind.
9 – Yes. It was completely different from the lectures and more emphasis on read texts themselves, and became a very revolutionary experience.
19 – I never thought classes could be this fun interesting, and challenging.

Interviews

From the interviews, a number of similar themes also emerged. In terms of their holistic rating of the course, the term "useful" features prominently, as it is fairly ubiquitous across the interviews, although not always used to refer to the same aspects.

Student A mentioned Zotero as being the most useful item, and also the site making. However, this only came up when questions were asked about the sites directly, Zotero was mentioned without any prompting. This was the shortest of the interviews, and the least focused, as it was the first when interview style kinks were still being ironed out, so there was little else of note regarding the research questions from that interview.

Student B also mentioned Zotero in terms of being useful but also referred to difficulties in initial usage,

> *Zotero was really useful but it was hard at first, and difficult to use it at first, but when I learned how to use it in the right way then it was good.*

and student B also mentioned the usefulness of the communication tools outside the course and also stated that Blogger was useful in terms of connecting with the community:

> *I think the most interesting was Blogger because I got to see how other students were writing because I'm interested in looking at different writing styles. So I would say that Blogger helped in how I present what I put in my writing.*

In terms of values, they also cited Grammarly, but only for grammar checking, not as a plagiarism checking tool, which was interesting as this matched with the survey results on Grammarly. Message and chat did not come up, but blogs (mentioned above) and wikis did in a positive way:

> *Um it was a very new experience for me, I've never thought of myself as a media / computer type person, never created a website by myself, but now that I've done it I can say that I've made a website for, like in my future job interviews etc. And if I get a job that needs this then I can say that I can make a website.*

However remixing did not arise, probably as she admitted to not being a very creative computer user.

Student C also mentioned problems with Zotero usage and did not use Grammarly at all. He did mention that his essay work was improved a lot by group feedback:

> *Yes, my essay became a lot better and my many partners on the project helped me look over my report and pointed out many grammatical corrections a lot through Google docs.*

In terms of the utility of the blogs and wikis, he mentioned these points:

> *In all I've seen as I was doing it, I thought that it was very hard, that it took a lot of time and felt horrible, but looking back at it now I learnt the many uses of the internet and the computer, making your own website, making your own videos, posting your essays online and how to do it correctly without any copyright or plagiarism issues so in the end it was a very good project and I have learnt a lot, although I am not so good at computers yet. I have learned a lot and I do think it was a very good project.*

So it seems in retrospect he valued it but possibly not so much at the time. As to remixing, he was not an existing user of multimedia tools like iMovie but picked up the basics:

> *It took me a little of a while; first I listened to your classes, and to be honest I couldn't grasp at first; I had to ask my friends who already knew and then it took me at least an hour to figure it out. I'm still not that familiar with that software but I can get some simple things done with it.*

And this was reflected in the design and style of his multimedia content on his section of the group's site.

Student D initially had no major themes emerging but admitted to starting from almost zero in terms of digital literacy:

> *I didn't even have a Gmail, so I didn't know like anything pretty much. So I started off pretty much from scratch.*

However later she mentioned the blogs and community idea,

> *I like the blogs because like even though they were kind of like time consuming I still felt like allowed me to think twice about what we did in class. So, like it was a good time for me to like think back about the things we discussed and like how did everyone feel, it gave me, it allowed me time to think about it one more time plus, I got to read other peoples like notes, and since we normally got into groups we were closely sitting by certain people but when you read blogs you get to see other peoples' groups too it's like, oh this group, this is what they are talking about, so I will get to see their point also, since you get to see different viewpoints, you can see at lot of peoples' ideas all at once.*

which implied a certain level of facility with the digital tools that was not present pre-course. She also gave some positive comments regarding the remixing while admitting she was not fully proficient at this yet:

> *On the Mac thing that we did, I liked the video stuff that we did. I have a Mac at home, and I just bought a new MacBook Pro for other class, but I barely use like the video stuff, I never really edited with it. So well, I haven't done like all the intense, cool stuff like some of the other students can do but when we had to do like the PowerPoint and stuff, where we make the slides and then we put them onto like the video and putting our voices and stuff, I thought I could just do that as I got the gist of it, so I wanted to try that a little more and get used to it.*

So possibly for those starting from a lower base of technology familiarity, they need to be given extra instruction.

Student E said she had a Gmail and Blogger account before the course but did not notice it was Gmail, presumably as the names of the software were not important to her as was shown by her comments on a referencing tool she had used in high school:

I used um, what's it called, Bib, Biby, Bib.com or something. Easy Bib. Yeah I always used Easy Bib instead of Zotero.

However by this it was obvious she had some awareness of the concept of referencing before the course and had some ability to use software in a community:

Uh, Google I used just the other day for this presentation and for turning in this essay, and my friend, he actually didn't have time to turn in his essay, but he wrote it on Google Docs. So he shared it with me and I was able to print it out for him. So that's when I actually realized that I can use it not just for studies and everything like that, but it's so efficient for those everyday uses as well.

Interestingly despite being in the group that had the most creative remixing going on, she never raised this topic in the interview, as she was more interested in her language level and the segmentation between different types of students (Japanese and non-Japanese educated) at the university,

But it's just that after entering the university it wasn't as international as I thought it would be, because in all the classes like there is this wall between the September students (from overseas) and April students (mainly from Japan).

as her comment shows.

Student F was originally educated in the UK and did a GCSE in Information and Communication Technology and in addition had made a site with Google Sites before. So she was less than happy at the level of IT/ICT training at her high school, which was affiliated to the university these classes were taught at. However except for Google Sites, she had little experience with any of the other tools taught on the course, something that was surprising given her GCSE. She also missed a few classes as she had to take Japanese language classes as well, so she tried to make up for this by doing extra blog reading and commenting in the community, but ironically not writing many of her own blog posts. She did enjoy the remixing aspects and contributed to a few groups projects:

It was very easy for me. It wasn't really anything to do with the technological side of making websites at all and if you've seen used our site – I worked on that.

but this was more of a non-digital creativity as she is a talented artist.

4 Conclusions

From the research results on the EMP teaching approach given above, the satisfaction levels of students seem high in regard to this kind of teaching. In addition the specific education technology tools and techniques covered also seem to resonate with students, as the vast majority of the feedback was usually very positive. Students really appreciated learning this modern content, and based on the overwhelmingly positive comments, teaching this content is something that this author not only recommends but also feels it is something that schools and universities would be remiss in their responsibilities as educational establishments if they neglect this vitally important component of modern learning.

With technology playing a larger part of people's lives every day, especially in the younger generation's lives, education has to evolve with these changes to remain relevant to succeeding generations of learners, as teachers cannot teach students the way they were taught and expect engagement to happen. Therefore it is this author's recommendation that more universities in Japan and elsewhere implement these kinds of EMP courses, and sooner rather than later, given how long it takes to get teachers up to speed on these approaches and able to use the tools efficiently. It is this author's prediction that this is indeed what will happen and a few of the more forward thinking Japanese universities are already starting this approach. Warlick makes a pertinent comment, "We need technology in every classroom and in every student and teacher's hand, because it is the pen and paper of our time, and it is the lens through which we experience much of our world" (Warlick, 2006). Finally, it is this author's hope that this chapter will help inform other teachers in what is now possible, educationally and pedagogically speaking, with digital literacy and digital pedagogy in modern education, and help them seek out further resources on the very important issue of modern learning as the knowledge base in this area is expanding continually, and teachers need to keep up to date with the latest developments to avoid their teaching practices becoming outmoded.

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Classroom Education Using Animation and Virtual Reality of the Great Wall of China in Jinshanling: Human Subject Testing

Jin Rong Yang and Fabian Hadipriono Tan

Abstract Virtual reality (VR) was employed to create the Great Wall of China in Jinshanling using several software and hardware. Different techniques of displaying the construction methods, such as on-site photos, 3D static images and animations from SOLIDWORKS, and VR, were implemented, and a human subject testing of the VR using an Oculus Rift headset was performed on graduate students in the seminar led by the second author. The results were positive, and some suggestions included better rendering of the 3D models in VR. Therefore, the present chapter discusses different techniques of texture iterations to correct and improve the texture of the 3D models of the Great Wall. Overall, several pedagogical aspects, such as tools, value integrators, and interactions of VR, in the Smart learning environment are presented and discussed in this study. For future studies, the authors hope that this study will open up more research and generate more propositions and implementations of VR in classroom settings.

Keywords 3D visualization tools · Ancient engineering · Animation · Great Wall of China · Smart pedagogy of virtual reality survey · SOLIDWORKS · Virtual reality · Virtual reality value integrators

1 Introduction

The aim of this research is to create, test, and implement a highly interactive virtual reality program to be used in classrooms for Smart education. The objectives are to display different techniques for creating a VR program, the virtual construction of the Great Wall of China as a case study, that allow researchers to develop similar programs to meet their teaching objectives. The study also hopes to respond to students' ratings and feedback on the VR program to open up further discussion on the technological resources for teachers to use in their classroom setting. The research methodology to achieve the objectives including the use of VR hardware and

J. R. Yang (✉) · F. H. Tan
The Ohio State University, Columbus, OH, USA
e-mail: yang.1089@buckeyemail.osu.edu

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software, Oculus Rift, Xbox controller, SOLIDWORKS, Autodesk 3ds Max, Google SketchUp (with Google Earth Pro), Unity, and a human subject testing, graduate students, on the creation of the VR program. The virtual construction of the Great Wall was chosen as a case study because of the complexity of the construction method. The VR interactions and displays would simplify the complexity and allow students to comprehend the construction sequence more effectively and efficiently, compared to traditional on-site photos and 3D models. Therefore, the virtual construction of the Great Wall has been chosen as a case study for this research.

The creation of the Great Wall of China in Jinshanling in virtual reality (VR) was discussed in an earlier study (Yang, Tan, Tan, & Parke, 2017). The advantages and disadvantages of different teaching methodologies (such as on-site photos, 3D static images and animations from SOLIDWORKS, and VR) to explain the construction methods of the Great Wall were discussed as well. For instance, students perceive on-site photos as authentic and credible, such as the one shown in Fig. 1. However, on-site photos do not show any missing or hidden components of the structure. This is where 3D modeling using static images and animations created by SOLIDWORKS comes in, as such 3D modeling can show the missing and hidden components. However, there is the lack of dynamic interaction among the images, animations, and students. While technically SOLIDWORKS can provide dynamic interaction between the 3D modeling and the students, the students must have a working knowledge of the software to perform a walkthrough of the model, so the model is

Fig. 1 On-site photo of the structure

not user friendly. Furthermore, at the time of the research, SOLIDWORKS could not directly support VR glasses such as the Oculus Rift headset, and therefore the model could not provide a state-of-the-art display. Therefore, using various software and hardware described in the previous paper (Yang, Tan, et al., 2017), the authors created VR models to overcome the issues while providing a user-friendly control and sophisticated display.

For this chapter, the authors tested the feasibility of the VR models for classroom use in general as well as the realism of the models by performing a human subject testing. The results from the study were positive, and some comments recommended better rendering of the models. Therefore, two additional techniques are discussed to correct and improve the texture of the models, namely, the creation of individual thin parts from SOLIDWORKS to block the incorrect texture from Unity and rendering using *UVW Map* from Autodesk 3ds Max (a rendering software).

Several pedagogical aspects, such as tools, value integrators, and interactions of VR, in the Smart learning environment are presented and discussed in this study. First, the 3D visualization tools implemented to create and display the VR models are discussed. Next, the VR value integrators are presented alongside discussion of how the models encouraged engagement in the VR learning environment. Finally, the effectiveness of the VR interactions is shown via discussion of how the learning interactions promote the learning strategy (i.e., dynamic interaction with the construction method used for the Great Wall of China) in the VR learning environment. In the future, the authors hope that this study will allow students to immerse themselves in the virtual erection process of ancient structures in a classroom setting. Accordingly, the authors ultimately aim to conduct a test pilot through collaboration with administrators, instructors, and students.

2 Review of Literature on Virtual Reality in Classroom Settings

A literature review on the possible applications of VR can be found in earlier work by Stojšić, Ivkov-Dzigurski, Maričić, Ivanović Bibić, and Đukičin Vučković (2016). Furthermore, from the results of empirical studies (including those on the use of head-mounted display in VR) conducted by Bailenson et al. (2008), it is suggested that virtual environments in learning science have an exclusive capability to change the social elements of learning conditions by means of changed social communications (Bailenson et al., 2008). An empirical study conducted by Lau and Lee (2012) shows that VR could improve students' learning experiences with the use of the virtual environment. Furthermore, video games in teaching and training have already impacted many fields, such as the armed forces, firefighters, and healthcare practitioners, among others (Annetta, 2008). However, a study conducted by Vogel, Greenwood-Ericksen, Cannon-Bowers, and Bowers (2006) shows that there was no significant improvement in mathematical skills in a game-based experimental condition. The authors' work in this study does not contain game-like features, such as scores, rewards, and challenges. Instead, the research study is a dynamic interaction between the program and users that relies on the Xbox controller and an Oculus Rift headset. Because of the future potential advantages outlined by Annetta (2008), the authors' work is related to these categories (i.e., the use of Xbox controller of the dynamic interaction of the Great Wall in VR). A human subject testing has been performed to strengthen the positive impact of VR use on pedagogy learning, which is one of the objectives of the study.

3 Background Information on the Creation of the Model

From the authors' earlier research (Yang, Tan, Tan, Parke, & Yang, 2016; Yang, Tan, et al., 2017; Yang, Hadipriono Tan, & Tan, 2017), the model of the wall and towers were created using SOLIDWORKS, shown in Figs. 2, 3, and 4. Some SOLIDWORKS features include displaying the construction sequence using static images and animation (Fig. 4). The animation was produced using the hide/show feature, and the *.avi* file format was used to save it. A walkthrough of the structure on SOLIDWORKS can be achieved if the user has a working knowledge of SOLIDWORKS.

SOLIDWORKS animations and models may be appropriate for a classroom lecture using PowerPoint presentations or videos, but the user friendliness of virtual reality allows students to be immersed in a virtual environment. In VR, students are able to visualize the construction process from different angles using head movements. A walkthrough of the wall would allow students to examine the wall in a virtual environment. In this virtual environment, students are able to control the camera and directional movements using the Oculus Rift headset and an Xbox joystick game controller.

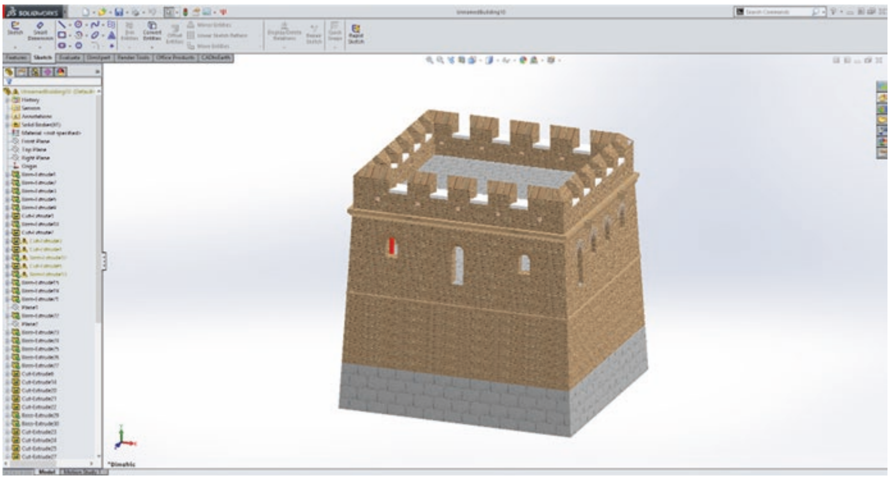

Fig. 2 Unnamed building 10 on SOLIDWORKS. (Yang, Tan, et al., 2017)

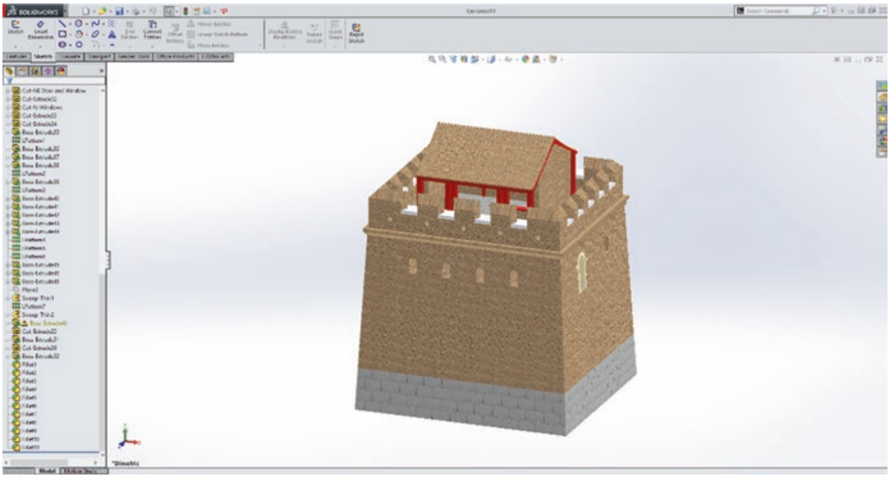

Fig. 3 Unnamed building 11 on SOLIDWORKS. (Yang, Tan, et al., 2017)

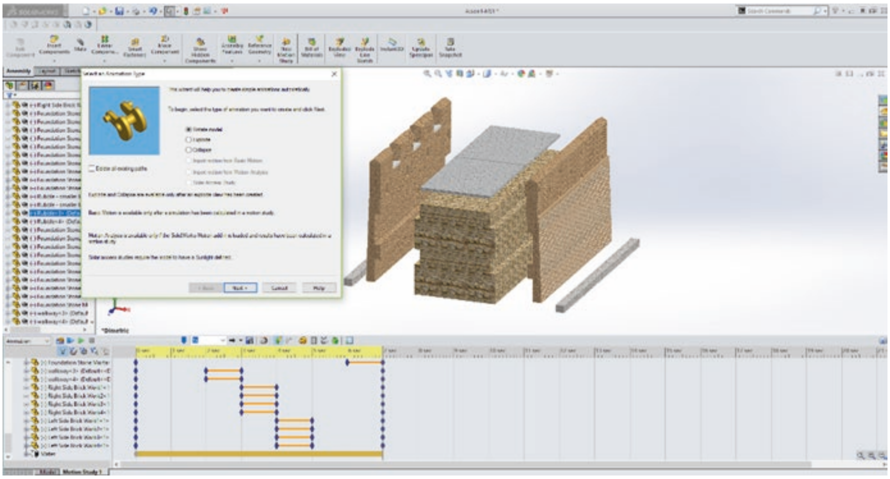

Fig. 4 Animation wizard on SOLIDWORKS. (Yang, Tan, et al., 2017)

The three software packages were necessary for completing the creation of VR on the Great Wall were SOLIDWORKS, Google SketchUp, and Unity. The hardware required for the VR creation comprised of Oculus Rift headset with a sensor and Xbox controller, as pictured in Fig. 5. SOLIDWORKS is a 3D computer-aided drafting (CAD) design software used to construct the 3D model of the Great Wall. SketchUp is a 3D CAD design software used for the extraction of the existing terrain of the Great Wall from Google Earth. Finally, Unity is a gaming engine compatible with the virtual reality hardware, particularly Oculus Rift, and its part in constructing the VR. Unity was used to load and apply textures to all objects

Fig. 5 Oculus Rift sensor, headset, and Xbox controller (from left to right)

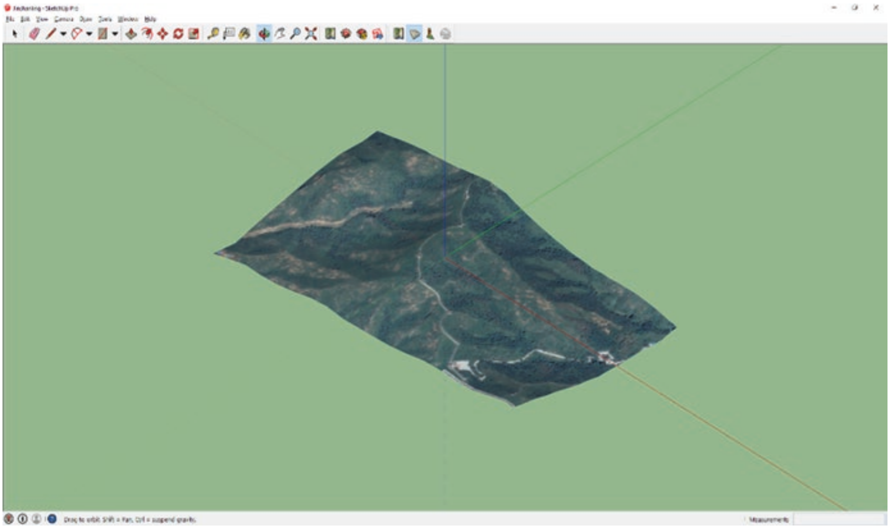

Fig. 6 3D model of the terrain in SketchUp (the satellite image was from 2015 CNES/Astrium DigitalGlobe) (Yang, Tan, et al., 2017)

(terrain, wall, and towers), program dynamic interaction of construction method, program camera views, and program the hardware.

The first step in completing the creation of the VR on the Great Wall is extracting the actual model of the terrain using Google Earth and Google SketchUp, as shown in Fig. 6. The satellite image was taken from Google (Imagery 2015 CNES/Astrium DigitalGlobe).

The model of the structures (wall and towers) was then produced using SOLIDWORKS. The structure was separated into parts and reassembled for animation, which was necessary in the creation of dynamic interaction on the Great Wall.

Following this process, the texture from on-site photos for terrain and the structure were applied in Unity. The first-person view was then programmed for the walkthrough of the wall and towers; the height of the camera was adjusted to 1.60 meters, assuming that this was the height of the average Chinese soldier in ancient times. In Unity, head movements were programmed so that it is controlled by the Oculus Rift headset, while the directional movement was programmed so that it is controlled by the right joystick of the Xbox controller in the VR model. Finally, the construction method's dynamic interaction was programmed in Unity. The dynamic interaction is comparable to the animation in SOLIDWORKS, but the end user is allowed to control the camera view, movements, and step-by-step constructions using the Oculus Rift and Xbox controller. The construction method is programmed so that the end user can visualize the construction sequence by pushing buttons A and B on the Xbox controller, as shown in Fig. 7. The end user is permitted to return to the preceding step by pushing the left bumper (LB) button on the Xbox controller. Parallel to the walkthrough, the directional movement of the camera is controlled by the right joystick. The Oculus Rift headset was required to control head movements.

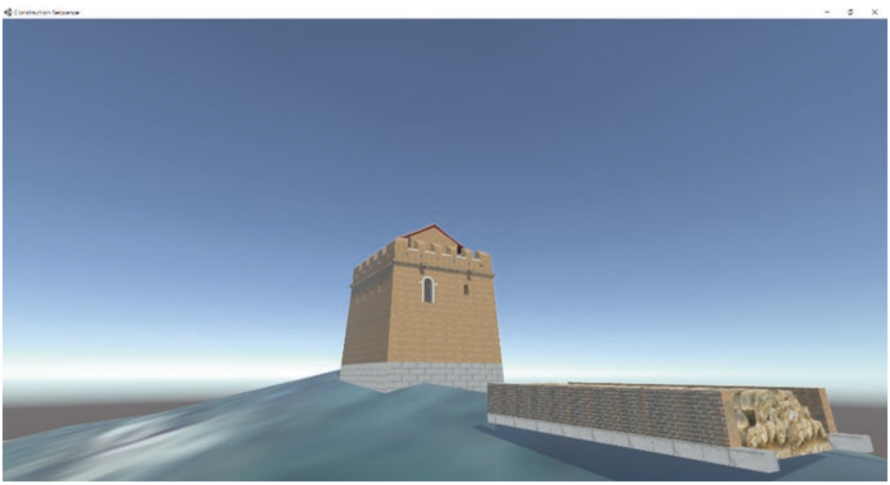

Fig. 7 Dynamic interaction of the construction sequence using the Xbox controller (the satellite image was from 2015 CNES/Astrium DigitalGlobe). (Yang, Tan, et al., 2017)

4 Human Subject Testing Methodology and Results

The purpose of the human subject testing on the VR of the Great Wall in Jinshanling using the Oculus Rift headset study was to determine whether the VR models created by the authors are realistic, i.e., if users could easily learn the construction method and if users prefer VR in a classroom setting over traditional on-site photographs. This study tested the VR program with seven graduate students from CE5880 (a seminar course run by the second author at The Ohio State University). All test subjects had prior knowledge of the construction sequence on the Great Wall from on-site photos, as well as 3D images and animations from SOLIDWORKS. A posttest survey was administered to rate the realism of the models, the ease of learning the construction method, the students' preference of VR in the classroom over on-site photographs, and the degree of cyber sickness (if any was experienced). Because the program is in VR, there was a small chance that some students would experience cyber sickness. There was only a minimal risk associated with student participation, because the authors programmed the walkthrough and dynamic interaction to be at a slow and normal walking pace; the authors also tested the program themselves and did not experience any cyber sickness. Participation was voluntary. No compensation or incentives were offered to any participant involved in this research project. The students were informed that if they experienced any discomfort, they could stop the simulation immediately. Before instructing the students to put on the Oculus Rift and start the program, the authors worked with the students to ensure that the instructions were clear and that the students felt comfortable with the walkthrough and construction dynamic interaction. This effort decreased the possibility that the students would experience cyber sickness.

To test the realism of the VR models, the seven students were given verbal instructions on how to use the VR, including warnings of potential side effects such as cyber sickness. The subjects put on the Oculus Rift headset and used an Xbox controller to perform a walkthrough and construction sequence. They completed the tutorial within 10 min. Throughout the walkthrough and construction method, the authors verbally asked the subjects if they felt any physical discomfort, assuring the students that if that was the case, the VR program would be stopped immediately. One student had to stop, potentially due to the prescription glasses he was wearing. After the completion of the walkthrough and construction method viewing, the subjects were given a survey to fill out anonymously; the students were instructed not to add their names or any personal information that could allow them to be identified. The first author provided all of the equipment necessary for the study (i.e., computer supporting the Oculus Rift). The questions and results are summarized in Table 1.

Table 1 Survey results

Questions	Results	Standard deviation
Being that this is a preliminary design (first iteration) of the structure, on a scale of 1 to 10, 1 being the least realistic and 10 being the most realistic, how realistic is the *walkthrough of the first floor of the wood column tower* on the virtual reality?	8.71/10	0.76
Being that this is a preliminary design (first iteration) of the structure, on a scale of 1 to 10, 1 being the least realistic and 10 being the most realistic, how realistic is the *walkthrough of the first floor of the bricks and arches tower* on the virtual reality?	8.71/10	1.11
How realistic is the *construction method* of the Wall? (1 being the least realistic and 10 being the most realistic)	7.86/10	1.46
What is the level of *difficulty* of learning the construction method using the dynamic interaction? (1 being the most difficult and 10 being the easiest)	9.43/10	0.79
What is your *preference* for learning about an ancient construction method such as that of the Great Wall of China via VR as opposed to the traditional PowerPoint slide presentations with on-site photographs? (1 being least *preferred* and 10 being most *preferred*)	9.71/10	0.76
Did you experience any cyber sickness? What is your *comfort level* after the completion of the program? (1 being least *comfortable* and 10 being most *comfortable*)	7.00/10	3.51
Was the walking pace (speed) acceptable on the VR walkthrough and dynamic interaction? (1 being least *acceptable* and 10 being most *acceptable*)	7.86/10	1.95

5 Discussion of the Results

The results shown in Table 1 indicate a high standard deviation in experiencing cyber discomfort (3.51). Indeed, one participant could not finish the program because he had motion sickness from the VR. During the experiment, this particular participant wore prescription glasses, which may have contributed to the symptoms.

The motion sickness may have derived from a vergence-accommodation conflict caused by the hardware itself. In the real world, the vergence distance and the focal distance are the same when a person focuses on an object; however, in 3D display, the focal distance is shorter than the vergence distance (Hoffman, Girshick, Akeley, & Banks, 2008). In the VR environment of this study, the focal distance is between the eyes and the display from the Oculus Rift's head-mounted unit. In a news article by LaMotte (2017), according to Walter Greenleaf, a behavioral neuroscientist who has studied VR in medical settings for more than 30 years, this phenomenon deceives the brain. Thus, the vergence-accommodation conflict may have contributed to a small degree of motion sickness experienced in some testing subjects and to the extremely large degree of motion sickness experienced in the subject who had to stop the program. Regarding this issue, Oculus Rift gives the nonscientific recommendation to take a 10- to 15-min break after 30 min of using the hardware, regardless of the presence of symptoms (LaMotte, 2017). However, in this study, all testing subjects finished the models well before the 30-min duration.

There are three recommendations, proposed by the authors, that may help to reduce cyber sickness: First, only the Xbox controller should be used. The Oculus Rift headset does not have to be used in VR; instead, one could just use the Xbox controller to control the camera and directional movement. These adjustments would have to be programmed in Unity before implementation. Second, the ability to control the walking speed should be granted. This ability could be programmed in Unity's *FPSController*, as shown in Fig. 8, to allow users to slow down the walking pace. Third, the Omni Treadmill should be employed. As stated in the previous paper, the Omni Treadmill may help with the cyber sickness, as it would permit the user to walk, run, sit, and perform other motions in the VR environment as they would naturally, during the walkthrough and dynamic interaction. These three recommendations will need to be tested to validate the results.

Table 1 shows that the students did not find the walking pace speed especially acceptable, as it had a somewhat low rating of 7.86 with a high standard deviation of 1.95. As just stated, the ability to adjust walking pace could be granted via Unity. The process of addressing this issue is shown in Fig. 8. The new speed was set to five in *FPSController*.

As shown in Table 1, the rating for the realism of the construction method (7.86) was low compared to the rating for the towers (8.71). This issue was solved by performing additional iterations on the texture of the model using the two different methods (SOLIDWORKS and 3ds Max) described in the next section.

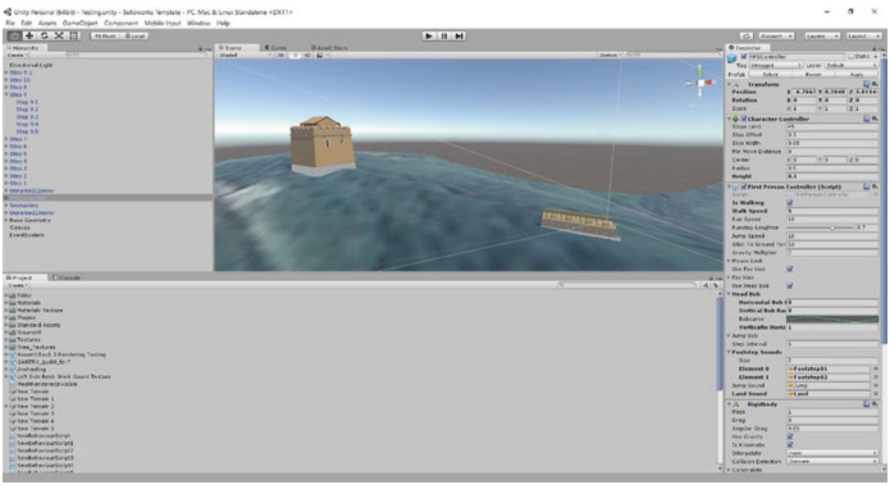

Fig. 8 FPSController in Unity

5.1 Discussion of SOLIDWORKS Individual Thin Part Replacement Method 1

During the transfer of the structure from SOLIDWORKS to Unity, different parts of the structure were linked together by sharing the same mesh in Unity. This process caused the incorrect configuration of bricks shown in Fig. 9. In other words, one side of the linked mesh is correct, but the other side is always rotated in an incorrect configuration. To solve this issue, a thin part of the structure was created in SOLIDWORKS as shown in Fig. 10, transferred to Unity (using the same technique

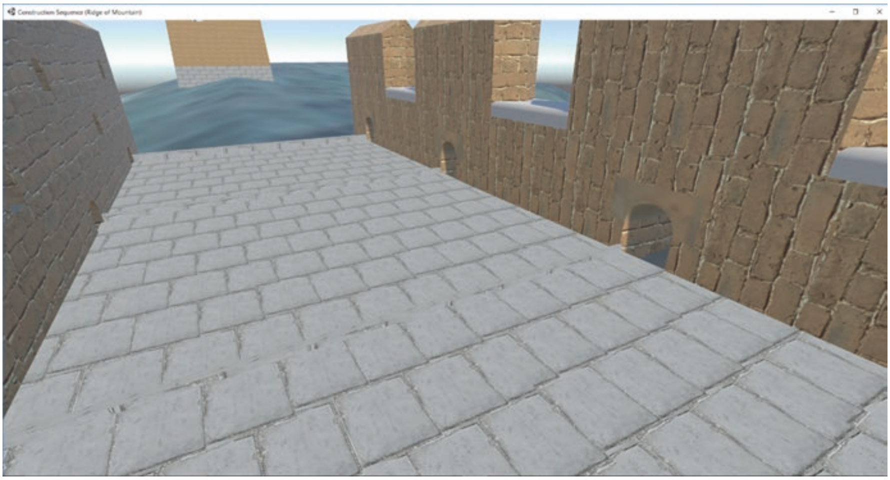

Fig. 9 Battlement with incorrect brickwork configuration

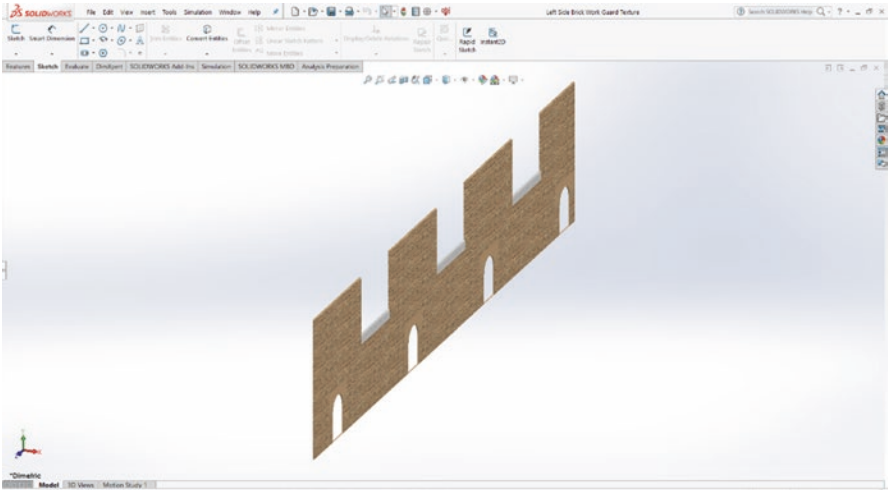

Fig. 10 Thin part creation from SOLIDWORKS

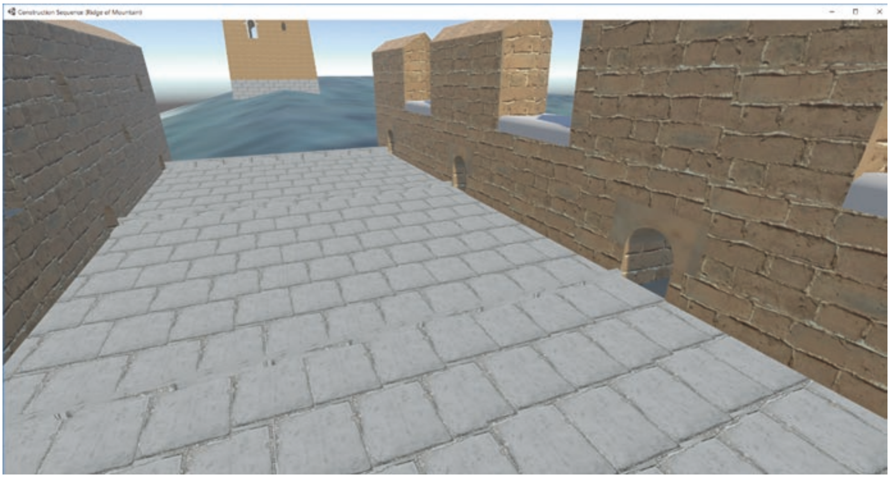

Fig. 11 Corrected brickwork texture in Unity

described in the previous paper (Yang, Tan, et al., 2017)), and used to cover the incorrect brickwork configuration side of the wall. Finally, the texture of the thin part was applied with the correct brick configuration in Unity as shown in Fig. 11.

5.2 Discussion of 3ds Max Rendering Method 2

While the SOLIDWORKS Thin Part Replacement method was suitable for large areas, it became tedious to perform in multiple small areas of the structure. 3ds Max, which is a rendering software, solved this issue. First, the 3D modeling was transferred to 3ds Max for application and rendering of the texture using features such as *UVW Map*, as shown in Fig. 12. Then the 3D models were transferred to Unity with all the texture by saving it into a *.fbx* or *.max* file, since 3ds Max is compatible with Unity. The knowledge of 3ds Max was acquired from *Kelly L. Murdocks 3ds Max 2016 complete reference guide* (Murdock, 2015).

6 Discussion of Smart Pedagogical Aspects

Pedagogy can be defined as “the interaction between teachers, students, and the learning environment and the learning tasks” (Murphy, 2008). Successful interaction, and hence pedagogy, should be based on constructive criticism and feedback. For instance, teachers often provide feedback to students by assigning a letter grade on assignments, and students, especially in higher-level institutions, in turn provide

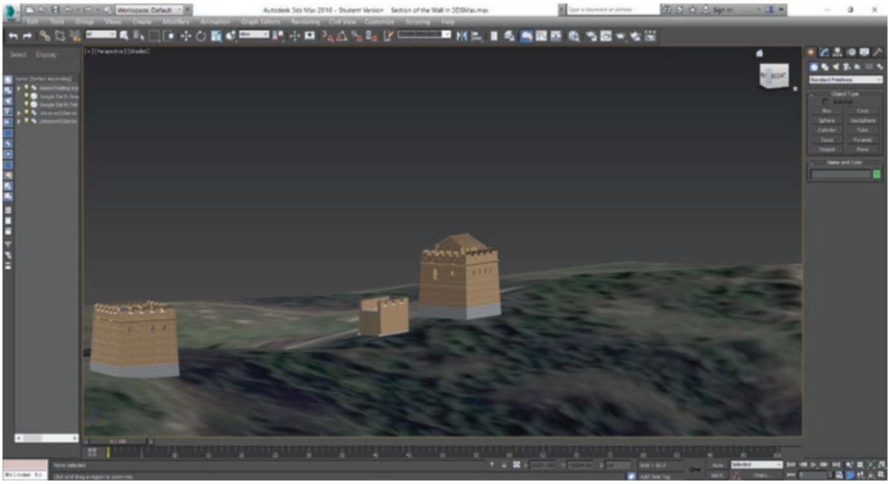

Fig. 12 Rendering in 3ds Max

an evaluation on the teaching methods of their instructor. The area of Smart pedagogy is no exception. In the field of Smart pedagogy, any new and innovative Smart teaching prototype, such as the VR on the Great Wall of China in this chapter, should be tested and receive feedback. After the feedback, solutions and corrections should then be implemented.

With this study, the teaching prototype has been implemented at the micro-level. The aim is now to implement the teaching prototype at the macro-level, namely, with students in academic courses such as *Sustainable Ancient Constructed Facilities* (CE 5860H from the Department of Civil, Environmental, and Geodetic Engineering) and *History of Ancient Engineering* (ENGR 2361 from the Department of Engineering Education) at The Ohio State University. In preparation for macro-level implementation, this procedure has ensured not only the effectiveness of the tool, but also the safety of the tool. The authors hope, with additional testing, that the VR models can be standardized in the classroom setting on a global scale.

As discussed in the earlier sections of this chapter, several pedagogical aspects, such as tools, value integrators, and interactions of VR, in the Smart learning environment were examined in this study. First, the 3D visualization tools implemented to create and display the VR models were discussed. These tools included the software SOLIDWORKS, Google SketchUp (with Google Earth), Unity, and 3ds Max and the hardware Oculus Rift with an Xbox controller.

Next, the VR value integrators for the VR program were presented. These value integrators concerned how the program avoids disengaging or discouraging the end users in the VR learning environment. The VR program is designed to have an appropriate time duration in the learning environment. Earlier research findings have suggested that students' concentration during lectures starts to decrease after

10–15 min (Stuart & Rutherford, 1978; Wankat, 2002). All human subjects tested were able to complete the dynamic interaction of the construction method and the walkthrough of the structure within 10 min in the VR environment. This duration is long enough to allow users to engage, but not so long that cyber sickness (in most cases) or boredom can develop. Because the dynamic interaction of the construction method and the walkthrough of the structure are not programmed with game-like features, such as keeping scores, discouragement was unlikely, because the end users could not make mistakes. If end users do not understand a concept, they can repeat the confusing step of the construction method as many times as needed without fearing any negative consequences, such as losing points in a game-like program. The preference for learning about an ancient construction method such as that of the Great Wall of China via VR as opposed to a traditional PowerPoint presentation with on-site photographs was very high, at 9.71 out of 10, as shown in Table 1.

Lastly, the survey indicated high effectiveness of the VR interactions, such as the learning interactions promoting the learning strategy (i.e., dynamic interaction of the construction method used for the Great Wall of China) in the VR learning environment. As shown in Table 1, the level of difficulty of learning the construction method using the dynamic interaction was rated at 9.43 out of 10, with 10 being the easiest. Therefore, the interactions of the VR allow the end users to acquire the knowledge effectively in a reasonable amount of time.

The Smart pedagogy of virtual reality is the future of learning. However, this technology can have some negative consequences. The main disadvantage of VR is the lack of human interaction. Furthermore, the VR program can be used in virtual learning environment. According to Fowler (2015), while high-fidelity 3D Virtual Learning Environments (VLEs) can create virtual classrooms, the use of VLEs may prevent the generation of innovative learning platforms. This risk is one of the main reasons that the authors of this research did not integrate multimedia features, such as voice response from the program, into the VR models. Instead, the setup of the models allows the instructors to give instruction on the simulation and receive feedback from the end users and, in turn, allows the end users to comprehend and meet the learning objective. Thus, via the dynamic interaction and walkthrough of the structure, the setup thus guides users in achieving knowledge acquisition regarding the construction materials and method used for the Great Wall in Jinshanling. This achievement is easily accomplished due to the advantages of the software and hardware implemented in this research. Instructors and teaching assistants can see exactly what end users are looking at on each Oculus Rift headset by looking at the computer monitor, as shown in Fig. 13. Therefore, in this case, verbal communication between the students and instructors is feasible in the VR environment. The authors believe this hybrid teaching technique, which integrates multiple teaching interaction strategies, may be the key to solving the disadvantage of limited human interaction in VR and Fowler's concern.

Fig. 13 Walkthrough of a timber column supported tower in VR

7 Conclusion and Future Studies

In conclusion, human subject testing was performed using seven graduate students in the seminar led by the second author. The results were overall positive, with some suggestions for improvements of cyber sickness and the realism of the structure. Three recommendations were proposed to solve the cyber sickness issues, namely, not using the Oculus Rift headset, slowing down the walking movement in VR, and using the Omni Treadmill. Next, two different methods were performed to improve the realism of the structure. The first was the creation and use of thin parts from SOLIDWORKS to cover up any imperfect areas of the Great Wall in Unity. The second was the use of 3ds Max rendering software to correct the texture of the structure before transferring it to Unity. A discussion of the Smart pedagogical aspects in the VR models then covered aspects such as tools, value integrators, and interactions of VR.

Future studies include performing a study with a larger sample size and different age groups (such as undergraduate students) on the new models and recommendations. If data is still limited for multivariate statistical analysis, the use of the fuzzy sets concept using a translational model and fuzzy logic may be appropriate, but more research is needed in this area. Furthermore, a study on the effectiveness of the learning outcomes, such as development of motivation using VR described in the Discussion of Smart Pedagogical Aspects section of the paper could be tested for future studies. Lastly, for future studies, a classroom setting design that takes VR into account can be proposed and implemented as a test pilot program. For instance, a researcher could design a VR-ready computer lab for teaching that offers swivel chairs to allow the user to rotate in the VR using the Oculus Rift headset. Additional VR-ready computers without Oculus Rift headsets could be implemented for individuals with light sensitivity (to reduce cyber sickness). However, such programs would obviously require collaboration with the university's administrators, instructors, and students. In the near future, the authors hope that this study will enable students to submerge themselves in the virtual erection process of ancient structures using state-of-the-art displays in a classroom setting.

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Technologies Facilitating Smart Pedagogy

Panagiotis Karkazis, Helen C. Leligou, Panagiotis Trakadas, Nicholas Vretos, Stylianos Asteriadis, Petros Daras, and Penny Standen

Abstract This chapter analyses the learning principles governing the learning theories of blended learning, personalized learning, adaptive learning, collaborative assisted learning and game-based learning towards capturing requirements of these theories that can be successfully met and aspects that can be significantly facilitated by technological solutions. We also present a generic learning process structure that can model the above learning theories along with a prototype implementation. The end goal is to showcase the beneficial use of technological solutions in pedagogy.

Keywords Personalized learning · Adaptive learning · Affect detection · Technology-enhanced learning

P. Karkazis (✉) · H. C. Leligou
Department of Informatics and Computer Engineering, University of West Attica, Athens, Greece
e-mail: p.karkazis@puas.gr; e.leligkou@puas.gr

P. Trakadas
University of Applied Sciences of Central Greece, Psachna, Greece
e-mail: ptrakadas@teiste.gr

N. Vretos · P. Daras
Centre for research and Technology Hellas, Thessaloniki, Greece
e-mail: vretos@iti.gr; daras@iti.gr

S. Asteriadis
Maastricht University, Maastricht, The Netherlands
e-mail: stelios.asteriadis@maastrichtuniversity.nl

P. Standen
Division of Rehabilitation and Ageing, University of Nottingham, Nottingham, UK
e-mail: p.standen@nottingham.ac.uk

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1 Introduction

The results of pedagogy, i.e. of the principles and practices of teaching, highly depend on the adopted learning approaches. While pedagogical principles change at a very slow pace mainly due to human nature, the available technologies do change very fast providing different tools to pedagogists. However, teachers do not necessarily follow technological evolution, and computer scientists are not necessarily aware of the benefits that specific developments could bring in education. For our society to make the most out of technology for pedagogy, pedagogists and technology experts have to be brought together. For example, for the learning process to be effective, in the direction from the teachers to the learners, the learning materials should be attractive and tailored to the needs and characteristics of the target student group; in the opposite direction, accelerating the reception of feedback in terms of performance and affect state would help teachers adapt the learning process accordingly.

Different classifications of learning approaches are possible depending on the selected classification factors such as the structure/environment (formal vs non-formal and informal education) and the dominant learning material means (e.g. electronic books/tools/games vs traditional hardcopy books). In all cases, the aim of technology providers is to assist the process and help teachers easily design pedagogical processes, quickly develop learning materials that are attractive to the targeted audience and offer an unprecedented experience as learning is nowadays a lifelong activity, and thus the relevant market is huge and growing.

In this chapter, we briefly discuss different learning approaches and explore the point where technology could bring an added value which ends up realizing that detecting the affect state of the learner is an important step in the learning process irrespective of the learning approach. A flexible learning experience model that can accelerate curricula building, learning material reuse and non-linearity implementation is then described followed by its implementation in a prototype which has been developed in the framework of the H2020 MaTHiSiS project (MaTHiSiS, 2018). The capability to detect affect using face recognition is showcased, and finally an example application use case is presented.

2 Technological Requirements of Diverse Learning Models

Despite the fact that there is no one strict definition of *blended learning*, the term is commonly used in order to describe teaching methodologies combining the traditional face-to-face learning activities with online learning experiences (Garrisson & Heather, 2004). In many cases, terms like hybrid, mixed or integrative are used to describe the same trend. Blended Learning is commonly defined as a combination of instruction from two historically separate models of teaching: the traditional face-to-face and the distributed learning systems. In the past, these two learning models have used different materials and methods, and they have focused on the needs of different target groups. On one hand, face-to-face learning uses teacher-centred environments based on synchronous interactions between persons. On the other hand, distributed computer-based systems emphasize a self-paced distant learning model operated in an asynchronous way. The evolution of technological innovations during the last decades had a huge impact on the possibilities for learning in a distributed environment. Nowadays, the available communication technologies allow us to have real-time synchronous distributed interactions similar to face-to-face environments. So, a blended learning system supports human interaction providing tools, such as real-time virtual collaboration software, self-paced web-based courses, electronic performance support systems (EPSS) embedded within job-task environment and knowledge management systems, but also aims to make machines and computers behave in a more human way. Consequently, the design of such a hybrid teaching activity is a highly challenging process, and it can't be simply addressed by just adding computers in a classroom. In fact, the most difficult part of the above process is that it requires reconsidering the way of thinking from the teacher's and also from the student's side. Blended learning approach is based on the idea that learning is not a onetime process but a continuous process.

Personalized learning refers to educational programs which intend to address special educational needs of specific student groups. In the traditional teaching model, within a classroom, the educator may provide to all students the same lecture, the same material, textbooks, assignments, etc. with little variation from student to student. On the contrary, personalized learning follows a student-centred approach, since the main goal is to make the individual learning needs the primary consideration during the learning process. So, the personalized learning approach aims to provide an optimal learning path to academic success of each student first by determining the learning needs, interests, prior background and aspirations of individual students and then by providing learning experiences that are customized for each student. Personalized learning models started from web-based tutoring applications providing a great quantity of learning material (Berghel 1997; Borchers, Herlocker, & Riedl, 1998). Next, in order to increase the efficiency of the learning process, personalized guidance mechanisms based on mechanisms for adaptive content navigation/presentation and also student's intelligent analysis have been proposed (Chen, Lee, & Chen, 2005; Tang & Mccalla, 2003; Weber & Specht, 1997). In our days, modern personalized systems consider the learner's preferences and interests and investigate the learner's behaviour in order to create a continuously adapting learning environment based on the interaction with each one of the learners (Lee, 2001; Papanikolaou & Grigoriadou, 2002; Tang & Mccalla, 2003). In general, a personalized learning environment can be considered to be any platform in which the learner expresses his/her learning requests and knowledge background, and the material is presented in a way that takes advantage of the learner's learning preferences (Steed, 2002).

Adaptive learning is based on the idea of designing learning methodologies to address student's specific learning preferences and needs. The concept is that an individualized method of teaching will help students to understand better and learn faster (Jones & Jo, 2004). The first development attempts of adaptive learning environments were targeting either small groups of learners or a very limited area of interest. This is due to the fact that these earlier implementations provided a very basic adaptivity model. In our days, adaptive learning platforms have evolved rapidly using innovative computer technologies, such as data mining, artificial intelligence, etc., in order to deliver customized material per student. The platform profiles each learner by monitoring his/her behaviour, tracking the level of his engagement and identifying his requirements, preferences and background in order to adapt the learning process to provide specific knowledge as and when it is required (Paramythis & Loidl-Reisinger, 2004). A modern adaptive learning platform is able not only to identify each learner's current knowledge level but also determines the activities, the sequence and the medium in order to maximize student's academic success. In fact, in a modern learning platform, both personalized and adaptive approach can be complementarily combined. The personalized-based techniques can be used in order to determine the main learning milestones that each individual learner needs to accomplish in order to succeed. But the "learning path" (content, activity types, sequence, etc.) that each learner is going to follow from milestone to milestone is different, and it can be modified dynamically during the learning process based on the adaptive learning techniques.

Collaborative learning assumes that the knowledge does not exist somewhere waiting to be discovered, but it is socially produced when a group of two or more parties interact with each other in the learning process. In general, the term collaborative learning refers to learning activities specially designed to be executed from pairs or small interactive groups. But, just assigning learners to groups does not guarantee that they will collaborate with each other (Brush, 1998; Soller, Lesgold, Linton, & Goodman, 1999). In this context, the instructor's responsibility is first to design the tasks of the learning activities in a way that promotes the interaction in the group and second to become a member of a team searching for the knowledge rather than the authority which provides it. This learning approach helps the learners to achieve a deeper level of learning as well as to develop their critical way of thinking (Garrison, Anderson, & Archer, 2001; Johnson & Johnson, 1999). Additionally, this approach provides an environment in which group members can improve their social and communication skills and build positive attitudes towards co-members and the learning process (Johnson & Johnson, 1989). However, parameters like group size, group composition, learning preferences, etc. have been identified as factors that have an impact on the effectiveness of collaborative learning, and they are summarized under the term of "social interaction" (Hooper & Hannafin, 1991). Many researchers believe that social interaction plays a very critical role in collaborative learning because any kind of collaboration is based on it (Johnson, Johnson, & Stanne, 1985). Researchers (Kreijns, Kirschner, & Jochems, 2003) discuss three approaches to stimulate the collaboration within groups: the cognitive approach of promoting "epistemic fluency", the direct approach of structuring task-specific learning activities and the conceptual approach of applying a set of conditions to stimulate/stress collaboration. Further discrimination of collaborative learning cases with respect to the competence level of each learner is also discussed in the next section.

In many cases the usage of technology (e.g. web-based learning materials) in the learning process is not enough to motivate students, especially the younger ones and those who had lived in the midst of technology all their lives. One approach to enhance their engagement is to introduce computer games in education (Norman, 1993; Martin & Reigeluth, 1999). A game-based learning application creates a virtual environment that looks and feels familiar, within which learners can make mistakes at no risk, practise through experimentation on things and learn to do things in the right way. This approach keeps learners highly engaged in practising through tasks that can be easily transferred from a virtual to real life. However, in order to maximize the effectiveness of an educational game-based platform, both dimensions of educational goals and gameplay experience must be carefully balanced. In Rollings and Adams (2003), authors discussed several types of challenges that can be applied to educational games. Designers of educational games should also pay attention to the appearance of the game, an engaging storyline and the appropriate game balance in order to involve players (Killi, 2005). There is no doubt that people do learn from games; the open issue is how to design games in a way that people learn what they need to learn. To achieve this goal, we need generally effective techniques, processes and procedures for designing games that reliably achieve the intended instructional objectives (Tobias, Fletcher, & Wind, 2014).

3 Affect Detection for Effective Learning

Research has shown that maintaining high levels of student engagement during the learning procedure can significantly determine successful learning (Iovannone et al., 2003) (Carpenter et al., 2015; Hargreaves, 2006). Effective personalized learning was shown to encourage participation and engagement, not only in the classroom but also in extracurricular clubs and work-related learning (Sebba, Brown, Steward, Galton, & James, 2007). As the tutor forms a better understanding of their pupils' strengths and challenges, they are in a better position to consciously plan their scaffolding objectives and choose the interaction media while preserving the pupils' interest and engagement (Dolan & Hall, 2001). Classroom-related affective states are linked to the students' goal structure and their adoption of specific achievement goal orientations. The goal to learn and understand is associated with an increase in positive emotions like enjoyment of learning as well as a decrease in negative emotions like boredom. The relation between goals and affect, however, is a reciprocal one as proposed in Linnenbrink and Pintrich's bidirectional model (Linnenbrink & Pintrich, 2002). In 2002, Linnenbrink and Pintrich described a model of affect in which performance is reciprocally related to the learner's mood (Pekrun & Linnenbrink-Garcia, 2014). In this model, the learners' personal goals are highly influenced by their perception of challenge. This perception in turn has a direct influence on their affect state. Based on the larger literature, positive moods like learner's interest and their active engagement are thought to support greater performance, while negative moods lead to performance degradation.

This relationship dictates the quality of learning where positive moods encourage a greater result and negative moods encourage less learning or learning abandonment. This relationship has also been described in more detail in the Mihaly Csikszentmihalyi theory of flow (Shernoff, Csikszentmihalyi, Schneider, & Shernoff, 2014), where skill and task challenge perception can launch someone in a variety of emotions. Importantly, it has been argued that not all emotions are relevant to educational context or when the learner requires scaffolding intervention. It was Sidney D'Mello and Rosalind Picard (D'Mello, Picard, & Graesser, 2007) who conducted a study on the relevance of emotions to learning in an e-learning tool and found that they could quantify the most relevant emotions to skill acquisition as "frustration", "boredom" and "flow". Only later in 2013, a study (Basawapatna, Repenning, Koh, & Nickerson, 2013) combined learner skill, independent learning limit and scaffolding in a state change diagram (Fig. 1). This diagram depicts the relationship between perception of challenge, the affect state of the learner and their performance. Greater performance happens where the task difficulty is just slightly above the learner's skill level, and it is where optimal learning occurs. Critically, this work provided the first state change diagram that shows the relationship between the learner's affect state and their learning potential and the relationship it has with the perception of difficulty or challenge.

The learner's performance or skill level is displayed as the X-axis, and the task challenge is displayed as the Y-axis. This diagram can be used to track the learner's progress in a learning activity. In this way, the diagram can represent any permutations of level of skill or task difficulty. Ideally, the optimal learning path must take the learner through what Vygotsky named the "zone of proximal development" (called hereafter ZPD) (Chaiklin, 2003). This is the optimal level of arousal and where learning challenge perception is just slightly more difficult than the learner's

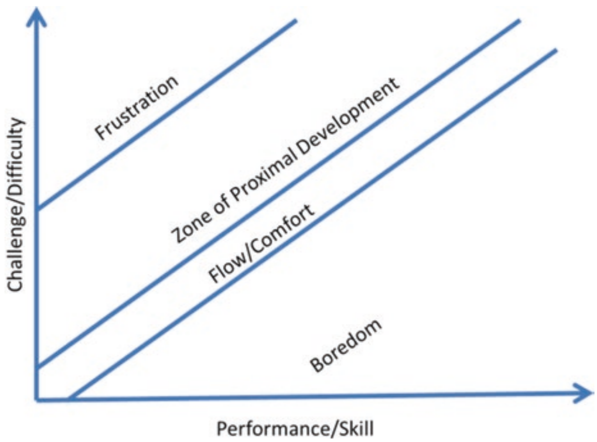

Fig. 1 Zones of proximal flow

current skill level. In this state the affective state would have the learner in an engaged and interested state of mind. In turn, this promotes greater learning opportunities and an affective state or mood that encourages higher aims and goals. It is important to note that the optimal learning experience would try to avoid both boredom (challenges that are too easy) and frustration (challenges that are too difficult) to maximize engagement.

3.1 Adaptive Learning

To achieve optimal learning, a dynamic learning approach must be adopted which considers both the learner's affect state and their performance – then in return *adjust the learning material challenge to maintain the positive mood of the learner* where the learner's ambitions for goal achievement and subsequently the learner's performance are maximized. The system will then lower or raise the difficulty of the learning material challenge to a level where the learner's affect state is engaged (in the ZPD) and their performance is always improving. The system would continuously monitor both *affect state and performance* to maintain this delicate balance. The learner state of affect must, however, be continuously monitored to avoid projecting the challenge too high and making the user "frustrated" or too low which would make the learner "bored" (as visualized in Fig. 1). Conclusively, the outcome of this process is the new concept of materialization in the learner's mind and learning which has been achieved, adding to the learner's skill base and progressing them on the graph higher and higher and further to the right.

3.2 Collaborative Learning

In educational research and developmental psychology, there has been a move away from seeing the learner as a lone individual to recognizing the importance of social interaction and seeing learning as a distributed process (Luckin, 2010). One of the theoretical underpinnings of MaTHiSiS is the sociocultural learning models of Vygotsky and his concept of the ZPD. Collaboration is key to the ZPD, and it is often interpreted as between a teacher or more experienced learner and a less experienced learner. However, such collaboration would also be possible between two learners of similar experience. Authors (Ghou, Chan, & Lin, 2003) describe this as the companion to an educational agent. Luckin (2010) goes on to explain that participants develop a shared understanding through the use of mediating tools. According to (Damon & Phelps, 1989), three types of peer-based instruction need to be distinguished: peer tutoring, cooperative learning and peer collaboration. A somewhat different categorization is described by Boyle, Arnedillo-Sanchez, and Zahid (2015) who designed a multi-user collaborative game using gestural interaction to provide autistic children with a means to build, practise and consolidate their joint attention skills. The authors describe three different collaboration patterns: passive sharing pattern, where users engage with their own objects; active sharing pattern, where users begin to select from shared resources; and active sharing and joint performance pattern where users must build on their turn-taking skills to assist each other. Similarly, collaborative learner approaches have been the focus of attention in many works, as well. Grasha-Reichmann has enumerated a learner's role in a collaborative learning experience (Oray, 2010; Ford, Robinson, & Wise, 2016) as "avoidant", "participant", "competitive", "collaborative", "dependent" and "independent". These roles can be recognized and used to coordinate compatible learning groups or learning pairs that best nurture successful peer-to-peer scaffolding opportunities.

However, successful cooperation is not always guaranteed. Although the first consideration here is that learners will automatically become more involved, thoughtful, tolerant or responsible when working with others, there is considerable and disturbing evidence that students often do not behave prosocially. If not handled correctly, dysfunctional interactions can occur between learners such that low achievers can feel stigmatized and differences in status can be exacerbated (Beaumont, 1999; Blumenfeld, Marx, Soloway, & Krajcik, 1996; O'Connor & Jenkins, 1996). A second consideration is that giving help is not straightforward and conventionally is the responsibility of the teacher. It may not come easily to a peer. Collaborative learning involves both giving and seeking help, and it is believed that help-giving can benefit not only those receiving it but also those giving it. However, help givers can feel frustrated. They may not know how to help effectively and may require special training to learn how to elaborate their thinking such that it benefits their partner. Their partner may not be aware that they need help nor seek it when needed because they believe that needing help indicates incompetence. Finally, the success of collaboration depends on the nature of the task and what the learners think the task is about. Learners who believe that the task is to develop mastery are more likely to engage in meaningful collaboration than those who have been led to believe that the goal of the task was performance (Luckin, 2010).

4 The Learning Graph Model

For the learning experience to automatically adapt to the personal preferences and skills of the learner as well as to their temporal affect state, a learning experience model capable of deciding the learning material (exercise or task) based on the learning goals, the context and the personal characteristics and temporal state of the learner has to be defined and adopted. Then, this learning model (decision mechanism) has to be implemented together with the subcomponents that allow for identifying the affect state, the personal characteristics, the performance and the context.

With respect to the learning experience modelling, a novel framework is presented in Tsastou, Vretos, and Daras (2017). It has been developed, comprising of

(a) a graph-based representation of the learning objectives (i.e. what to learn) and (b) a knowledge-based schema of the learning activities (i.e. what to do to learn). The graph-based modelling scheme provides educators with the means and method to define reusable, self-sustained and interoperable learning objectives, discretised into smaller learning goals, which represent competences, skills or knowledge that they aim for their learners to acquire. Goals are interconnected in directed learning graphs, with differences in the degree to which they contribute (edge weights). Complex goals comprise the central-most nodes, and atomic goals comprise leaf nodes that contribute to one or more complex goals. These atoms are competencies that cannot be further reduced to more primitive notions.

Generic learning activities are attached to the atomic goals, while different materializations for each activity can be defined based on contextual conditions (device used, etc.). A learning actions ontology has been engineered and presented in the same work, based on educators' and psychologists' feedback, to represent under a holistic schema such abstract activities, but also parameters that affect their materialization in the real world, such as the type of learner, the types of devices used during a learning session, the types of digital content, etc.

Based on this model, personalization and adaptation mechanisms can be summarized as follows in our work: Firstly, the personalization method allows the proposed platform to be initialized in order to maximize the knowledge acquisition of the learners. To that end, performance registered in previous interactions with the learning platform is utilized as the main parameter to establish the appropriate learning content to be deployed along with context information. "Context information" describes whether the learner is in a classroom or at home or on a train, the device available at each environment to select the appropriate learning material to deliver for interacting with and other similar parameters. This process enables the selection of the learning content (and the level of difficulty associated with it) to be used as the first interaction with the learning platform. As a second step, MaTHiSiS focuses its effort on the achievement of optimal affective state of the learners in order to maximize the knowledge acquisition. To that end, the affective state inferred by the platform (through sensorial components (SC) information as well as interaction parameters, e.g. score, time needed to accomplish a task) is utilized. By applying different methods, the values of the affective state, represented by using the theory of flow model, are taken into account for the proper update of the corresponding competences. This update occurs several times during a regular learning experience, adapting the content of the platform (in terms of level of difficulty) according to the affective state registered in real time.

For example, the learning graph may consist of a single learning goal, namely, "understanding numbers", which can be achieved through three distinct learning atoms: "counting", "association of numbers to quantities" and "distinguish greater than from less than", with different participation to the central goal and with "association of number to quantities" bearing the highest importance to the achievement of the goal. This means that mustering this atom will weigh more heavily towards the achievement of the ultimate objective, i.e. understanding numbers, than the achievement of counting, which will fulfil its purpose to this goal in a more suboptimal achievement state. Each skill denoted through a smart learning atom can be trained by one or more learning actions. The adaptation process will always seek to train the atom with the lowest achievement score out of all the atoms in the graph. For instance, considering the smart learning atom “distinguish greater than from less than” having the lowest weight out of all three in the example above, the system will proceed to train this skill in the next iteration of the learning process, by actuating one of the learning actions attached to it. In this case, “distinguish greater than from less than” can be achieved through a single activity, i.e. exercising with the generic learning action constituting a game (playing action) where one puts numbers in order. This action can be manifested in many ways and, in the particular example, through two related learning action materializations, each of which can be suitable for execution either through the same or different applications (materials) and through the same or different devices (e.g. smartphones, tablets, robots, interactive whiteboards). The system will proceed to present the appropriate materialization for this learning action, that being the materialization that matches the learner’s context at the moment. Therefore, if the user is training on a mobile device, the system will launch the corresponding mobile app, consisting of a game where the learner is asked to drag a series of numbers into slots, in ascending order. A level of difficulty for the materialization is also considered, depending on the competence level of the learner in the skill that they are training at the moment, discretized in three levels (easy, medium and hard). The lower the current score, the easier the materialization level. In the case of this example, given a weight of, for example, 0.5 for the “distinguish greater than from less than”, the chosen level of difficulty would be medium.

For MaTHiSiS to construct a robust collaboration strategy, a new method of adaptation is followed, to maximize the learning experience. In contrast to the “solo” learning experience, the method must consider not only the profile of both learners involved in the activity such as initial level of knowledge about the current learning activity but also their affective state and the performance from previous interactions. This strategy will adapt the level of difficulty of specific social learning actions to maintain both learners in the proper affective state and improve the learning experience. There are obviously several challenges: Given the lack of social skills in learners with severe learning disabilities and autistic characteristics in this project, true collaboration in the sense used by Kerawalla, Pearce, Yuill, Luckin, and Harris (2008) may not be possible. The ambition may be limited to encouraging any prosocial behaviour. Scaffolding is essential. Following the micro-script approach of Dillenbourg and Hong (2008) is one of the most appropriate because MaTHiSiS provides specific options for collaborative actions.

In summary, the collaborative (synchronous) experience has been implemented as follows, following the pedagogical directives and challenges described above:

1. The learners must clearly perceive that they are collaborating with other peers in order to reach positive objectives.
2. They must be able to help or to be helped by other peers.
3. The amount of help received and/or provided must be quantified.

A prototype implementation of the previously described system that exploits and combines the latest information and communication technologies is illustrated in the following figure (Fig. 2). It consists of two interacting sets of components: (a) a set implemented in user devices which we call platform agents (PA) and (b) another set residing in a cloud infrastructure which we call cloud-based learner space (CLS). The users (tutors, learners, caregivers) interact with the PAs which can be desktop/ laptop computers, mobile devices, interactive whiteboards or robots, thus providing a broad application potential of the proposed system and warranting efficient ubiquitous learning across a variety of educational contexts. In any given learning environment, a subset of these PAs is considered to exist. Through the platform agents, the users have access to (a) authoring tools to create new *learning graphs*, *smart learning atoms* and *learning action materializations*, (b) a platform configuration component to define the users and devices that will be involved in each learning experience, (c) a *learning experience* execution environment and of course to (d) a simple user interface for account creation and personal detail insertion.

The CLS is the core framework of the system executing processes for data acquisition and analysis (in the form of specialized learning models and educational rules) for predictive modelling and simulation (i.e. feedback analysis and response). These processes are described declaratively and stored in a process repository which executes educational rules and takes higher-level decisions that are streamed to the platform agents. The CLS consists of (a) the Experience Engine that materializes the learning experience by executing the learning graph and sending the relevant information and learning actions to connected agents and actuators. It is a

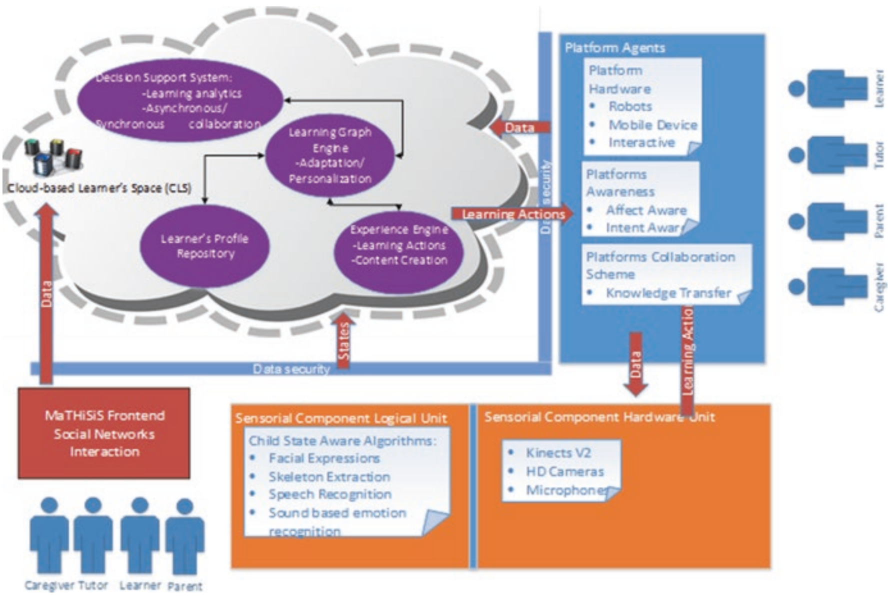

Fig. 2 The architecture of MaTHiSiS with its core technological elements

graph-based interactive storytelling engine that can generate transmedia interactive content, taking multiple forms (e.g. 3D, augmented reality, HTML based), according to the graph-based structure of the scenario. This generated content is then sent to the relevant platform agents that will execute/render it: (b) the Learning Graph Engine that is in charge of adapting the executed learning graph and learner's profile according to (i) her/his behaviour and interactions with the platform agents and (ii) the Decision Support System (DSS) recommendations. The Learning Graph Engine supervises the Experience Engine by adapting the executed learning graph to both the learner's behaviour and profile; and (c) the DSS that provides and collects learning analytics as well as any high-level information to/from the Learning Graph Engine to personalize the learning experience. The DSS controls the synchronous and asynchronous collaboration between different components. The Learner's Profile Repositories are required to store the collected data and the learning graphs for the user profiles. The PA include three major subparts: (1) interface and on-board modules, (2) interunit collaboration modules enabling affect detection and collaborative learning and (3) PA, CLS information and action communication. The so-called SC extracts information from the PA or static sensors. The SC extracts information concerning the learner cognitive and/or physical state to assist the learning analytics module within the CLS.

5 Affect Detection in Real-Life Settings

The sensorial component on the PAs and a subcomponent of the Learning Graph Engine component, in the back end, are the basis of the recognition of the learners' affect states. Their goal is to gather (physical) behavioural cues of the learner and apply machine learning techniques in order to interpret them into comprehensive affective cues that tell the story of the learner's uptake of the learning objective(s). This component can implement state-of-the-art technologies from various fields, spanning from computer vision to artificial intelligence, to extract and represent affect-related features stemming from the learner's face, gaze, body posture, speech and inertia sensors embedded into devices she/he uses. All sensor readings are captured from the user's interaction with devices. If the affect state is shown to tend to boredom, this is signalled to the logic component, and the challenge level is increased. In the case of frustration detection, the challenge is relaxed, so as to keep the learner in the flow state. In the MaTHiSiS system outlined above, a variety of algorithms for affect detection has been implemented and tested per modality. All adopted algorithms utilize machine learning techniques. Thus, appropriate training of the algorithms needs to take place prior to the normal operation of the system. Therefore, we opted for collecting data in the framework of our activities in schools engaging students without and with disabilities. In such cases, the teachers were asked to annotate the captured data with the affect state they believed that the student experienced. At the following, we shall refer to students without disabilities as "mainstream" students. The availability of sensing devices changes per real-life setting: when the user interacts with a mobile device, it is the gyroscope and inertia sensors that are used to detect the affect state; when the user interacts with an interactive whiteboard or a laptop or a robot, a camera is usually available and assists in affect detection through facial expression or gaze estimation.

The facial expressions are often considered as the strongest indicator of human emotions. They may expose people's feelings and mood state, from simple spontaneous emotions like happiness and disgust to time-dependent affective expressions states like anxiety, boredom and engagement during a current task and/or a situation. This allows the person's interaction counterpart to understand their affective state and adjust their behaviour according to the person's underlying feelings. Facial images are one of the data cues that will be captured through the sensorial component by means of different types of cameras across devices. Due to its high impact, facial images will play a central role along with other data channels to understand learner's affective states.

For the extraction of facial expressions, a graph-based method (D4.2 MaTHiSiS, 2017) has been adopted. More specifically, the face is represented as a graph, which is formed by points extracted from specific areas. The variation of muscle movements on the face during the expression of different emotions leads to different positions of points on the image and may generate different graphs. The input of the algorithm is an image. Then, facial landmarks are detected using the Supervised Descent Method (Xiong & De la Torre, 2013). For instance, such landmarks may be the nose, the eyes, the brows, the mouth, etc. These points are tracked, so that the movement of the facial muscles is followed over time. Assuming that all landmarks are connected, they may be considered as a graph. We then make the hypothesis that the density of the graph differs in each facial expression. More specifically, we use spectral graph analysis, through which a feature vector is extracted. This vector depicts areas of density in the graph by using the graph's Laplacian matrix and solving the eigendecomposition problem for the eigenvectors corresponding to the first and second greatest eigenvalues which capture information regarding different density areas of the initial graph. Such areas in the specific problem are those of the eyes, mouth and nose.

More specifically, the Laplacian matrix L of a graph G is defined as

$$L = D - A, \tag{1}$$

with D denoting the degree matrix and A the adjacency matrix of G. $A(i, j)$ is computed as

$$A(i,j) = 1 - e^{\frac{\left(-\left\|x_i - x_j\right\|\right)}{d}}, \tag{2}$$

where |•| denotes the Euclidean distance, x_i, x_j any two given landmark points and d a constant depicting the variance of the overall distance between the facial landmarks. In order to normalize between different image scales and sizes (i.e. for

Table 1 Experimental results of facial analysis

Emotion	Accuracy (%)
Anger	100.00
Disgust	86.37
Fear	60.00
Happiness	100.00
Sadness	75.00
Surprise	100.00

recognition "in the wild"), the symmetric Laplacian matrix is adopted as it is considered to be a more robust option:

$$L^{\mathrm{sym}} = D^{-1/2} L D^{-1/2} \tag{3}$$

Then, its eigendecomposition follows:

$$L^{\mathrm{sym}} v_i = \lambda_i v_i \tag{4}$$

For the classification, support vector machines (SVM) are used. The initial evaluation of the algorithm is done using images from the well-known public available Cohn-Kanade (CK) database (Lucey et al., 2010) leading to very satisfying results. Although this dataset involves expressions of the six basic Ekmanian emotions (Ekman & Friesen, 1978) which are, namely, anger, disgust, fear, happiness, sadness and surprise, a correlation of the aforementioned emotions with affective states was retrieved in Russell's Core Affect Framework (Baker, D'Mello, Rodrigo, & Graesser, 2010). A direct mapping of the spontaneous emotions to affect states conveys this correlation. Using this mapping, sadness corresponds to boredom, happiness to engagement and surprise and anger and fear to frustration. The performance of this algorithm using the CK dataset to predict affective stated reached a classification score that rounds up close to 100% accuracy. Results per emotion are depicted in Table 1.

6 Example Application in Real-Life Use Cases

The approach presented above was tested in real-life cases across Europe. In this section we present the case where the approach was applied to a high-school class and a course of computer science where the students were challenged to learn to use Publisher software. In this case a diverse body of students with a range of cognitive abilities and challenges was addressed. Inclusive mainstream education requires teachers to be competent in addressing particular challenges that some students might face and, at the same time, encourages the growth of already well-performing students. However, of course, some children are disrupted and can discharge this discontent with uneducated attitudes. Some of them are involved in other cultural or artistic activities like playing music, drawing, etc. and can show great aptitude to subjects such as art design and theatre which allow them to express their feelings. Through this, we realize that in order for them to flourish in their experiences, they must not be ignored but valued in order to meet their full potential. The main issue is they often lack a stable and continuous relation with their parents who are usually busy at work and miss an everyday reference. For this reason, they can feel that it is difficult to interact with their peers or adults, often hiding themselves behind video games or smartphones.

The challenge in this case is to recognize if their learning abilities are improving or if it is time to consider a new method. As these technologies are familiar to the 3–14-year-old age group, they are drawn to them. However, there is also the risk of boredom if the system does not compare well to the games with which they are familiar or if the games are not fast or engaging enough compared to familiar apps. Another purpose addressed in the trials was to make the children collaborate with special needs children to achieve the learning goal by using the same, or similar, learning materials and playing at the same time or collaborating with their peers.

In this scenario, it is the role of parent or caregiver to connect to the platform and start a learning experience for the learner, to select complementary resources from the provided list of resources and finally (optionally) to inspect the visualized performance of the learner. Two different types of learners are supported by the platform: (a) the supervised learner who will use the platform under supervision either because they will use the platform within the school educational path or they have special learning needs or they are minors without special needs and (b) independent learner for those who are advanced learners even when they use the platform within the school or educational path.

Once in action (e.g. in classroom), the tutor selects the graph (associated with a specific learning goal) and also defines the learners in the classroom and the devices each of them will use. The system automatically selects the learning action materialization that will be offered to each learner and adapts its difficulty level in real time depending on the affect state detected. Students in the same classroom may exercise with different learning action materializations. An individual learner may act both as a tutor (selecting the learning goal and the device they will interact with) and as a learner (interacting with the learning action materializations). Caregivers can assist the people they care for by accessing the system through any device available and prompting them to interact with the learning materials available for them. At school, two laptops with webcams and an interactive (web-enabled) whiteboard were available, all centrally maintained. Students were learning to use Publisher. Learning graphs were created prior to the lesson for the quiz section of each lesson. Ethics permission was gained from each student's parents prior to the lessons. One of the learning goals was "know about digital copyright", the Smart Learning Atom in the learning graph terminology was "digital copyright", and the "learning action" was "facts about digital copyright". The different learning materials that were prepared for the trials included three sets of multiple choice questions (with each set corresponding to different difficulty levels) and three sets of single-question quiz. For the students that interacted with the learning materials either through the laptop or the interactive whiteboard, the performance and the affect state were monitored and used to change the difficulty level whenever boredom or frustration was detected. When the students are at home, they can continue the learning experience through their tablet assuming a suitable learning material is available in the system. In any case, the system will decide which learning material and difficulty level to provide to the learner based on the personal competence registered in the system.

After interviews with the teachers (D8.8 MaTHiSis, 2017), the overall approach and solution were found promising, even though the tools to build the learning materials were not ready and they had to deliver the learning content to the technical team to produce them. The vision is for the system to support blended, adaptive and collaborative learning.

7 Conclusions

Pedagogy can become significantly smarter exploiting the technological evolution in multiple aspects of different values to the different user roles. It enables learning ubiquity in the sense that it can happen at school/university, at home or even on a train due to the multiplicity of agents that can be used for the learning material to reach us which expands from book to smartphones, tablets, robots, interactive whiteboards and any Internet-connected device. It even enables the creation of experiences through virtual or mixed reality to increase learning efficiency, so long as pedagogists advise developers on the specific design specifications for the augmented reality/virtual reality applications. It enables easy and fast development (using computer-based tools for easy development of materials from presentation to quizzes and games) and reuse of learning materials through learning management systems. It supports fast feedback acquisitions both performance and affect related based on data analytics components. It enables fast and easy learning experience personalization (taking into account the learner profile and the material personalization rules defined by the tutors) and adaptation to the real-time context (e.g. availability of devices) and affect status of the learner (employing sensors and artificial intelligence logic). For society at large to enjoy all these benefits, scientists and pedagogy and technology experts have to work closely together to establish mutual understanding and codesign learning tools whether they be systems, materials or applications.

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Gamification for Education: Review of Current Publications

Santa Dreimane

Abstract Educational practitioners are always looking for new and better ways to scaffold student learning; the latest approach that has become popular is called gamification.

The aim of this research is to explore the concept of gamification and to review current research and publications about gamification for education. To do so, the systematic analysis of publications was chosen as research method. During the research, 91 articles published since 2012, obtained via the “Scopus” and “SAGE Publications” databases, were reviewed. Articles were classified by publication year, research areas, longitude, research methodology and used keywords in the articles.

The study shows that there is little research that gives comprehensive insight into the concept of gamification for education, because the concept of gamification is relatively new. But gamification has a positive impact on student motivation and attitude changes.

Keywords Gamification · Serious games · Education · Game-based learning

1 Introduction

We are witnessing rapid changes in today’s world, including social and economic changes, globalisation and technological progress (Fadels, Bialika, & Trilings, 2017). This rapidly changing information society is characterised by the knowledgeable individual, who is able to use the latest technological advancements to increase their own and other’s well-being (Ēriksens, 2004).

It is essential to take into account the occurrence of generational replacement. A new generation has grown in a rapidly changing environment, in which mobile phones, computers, tablets and other platforms that provide both social and entertainment functions are an integral part of everyday life. This new generation has

S. Dreimane (✉)
University of Latvia, Riga, Latvia
e-mail: santa.dreimane@lu.lv

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grown in circumstances different to those of the previous generations, so it is natural that they have different world perception, values, needs and interests.

The society and our knowledge about it are changing more abruptly than ever before. The world for which the current educational system was designed no longer exists (Fadels et al., 2017; Garleja, 2006; Moritsugu, Vera, Jacobs, & Kennedy, 2017). There is an urgent need to adapt education to the modern generation in order to improve their quality of life (Chaudhary, 2010). In order to educate, engage and motivate the younger generation, we need to search for new approaches and methods.

Nowadays there is a new attitude towards entertainment in a knowledge society in which people want entertainment and leisure as well as personal enrichment (Chaudhary, 2010). A game always has been, and still is, a powerful tool that motivates and engages users in the learning process. Thus, languages, arts, mathematics, science and other subjects can be presented as a game (Karagiorgas & Niemann, 2017).

Educational practitioners are always looking for new and better ways to teach, and the latest method that appears is called gamification (Doherty, Palmer, & Strater, 2017).

The aim of this research is to explore the concept of gamification and to review current research and publications about gamification for education.

2 Theoretical Background

2.1 Gamification

The concept of gamification was created in 2002 by a computer game programmer Nick Pelling from the UK. He described the concept as a new way of using game elements in educational processes in any field (Karagiorgas & Niemann, 2017; Kim, 2015). Unfortunately, at that time, the concept did not gain the interest of the public. Only after 2010 did gamification became more widely known and used.

Since 2013 the concept of gamification has gained popularity among researchers, many of whom are trying to explain this new phenomenon. At the moment, many studies are being conducted in the attempt to interact gamification with different fields, including education (Doherty et al., 2017).

"Despite the increasing number of gamified applications, there is still no universally accepted scientific definition" (Sailer, Hanse, Mayr, & Mandl, 2017, p. 372). But this is what is agreed on thus far: gamification is a concept whereby game mechanisms and game design elements are used in non-game context (Deterding, Khaled, Nacke, & Dixon, 2011; Doherty et al., 2017; Woodcock & Johnson, 2017). Gamification refers to the use of distinct game building blocks embedded in real-world contexts (Sailer et al., 2017). Gamification involves the extraction and application of particular game elements or the meaningful combination of game elements within non-game processes (Landers, 2014). Gamification also strives to take the best parts of video games, such as awards, badges, points and levels, and apply them to pedagogy; however, the purpose of their use is not related to games or entertainment (Karagiorgas & Niemann, 2017).

It should be noted that gamification specifically relates to games, not play (Woodcock & Johnson, 2017). A game includes actions that provide challenge to a player, whereas play is associated with fun and entertainment.

Gamification is constructed of four components—game, elements, design and non-game context. *Game* is defined as "a system in which players engage in an artificial conflict, defined by rules, that results in a quantifiable outcome" (Salen & Zimmerman, 2004, p. 80). This means that gamification is rule-based and has goals. *Elements* distinguish the gamification of serious games, because serious games are associated with fully developed games (Sailer et al., 2017). *Design*, in the context of gamification, includes technological aspects and refers to the deliberate design process (Deterding et al., 2011). The term *non-game context* is a very abstract concept and doesn't specify the possible areas in which gamification could be applied (Sailer et al., 2017). So, the usage of gamification can be applied to any field, depending on the set goal.

The goal of gamification is to motivate users to engage in some specific, desirable behaviour (Doherty et al., 2017; Karagiorgas & Niemann, 2017). It is important to understand that gamification changes the participant's behaviour or attitude, which can affect learning outcomes (Landers, 2014). Motivation is among the important predictors of student academic achievements, which influences the effort and time a student spends engaging in learning (Linehan, Kirman, Lawson, & Chan, 2011). The keywords for gamification are motivation, engagement and behavioural change.

Gamification fosters more engagement in people by helping to create more robust experiences of everyday life events utilising game mechanics (Doherty et al., 2017; Karagiorgas & Niemann, 2017). The use of game elements in non-gaming systems improves user experience and user engagement (Landers, 2014). Learning with the elements of the game enables the player to identify obstacles and overcome challenges (Doherty et al., 2017). In a game, a person can make mistakes and try again; while in real life, we are not always given a second chance.

Some game design elements that are important for user's engagement with and experience of the gamification process are:

(1) Points, which serve as rewards for accomplishments (Werbach & Hunter, 2012)
(2) Badges, as visual representative of achievement (Werbach & Hunter, 2012)
(3) Leaderboards, where players can view their rank (Sailer et al., 2017)
(4) Performance graphs, offering player the chance to see information about their performance during the game and compare it with previous results (as often used in simulation games) (Sailer et al., 2017)
(5) Avatars, as visual representations of players (Werbach & Hunter, 2012)
(6) Teams and teammates (Sailer et al., 2017)

(7) Narratives about activities and characters in the game, which don't relate to the player (Sailer et al., 2017)

Gamification is based on the integration of different individual game elements, creating a meaningful aggregation of these elements (Landers, 2014), but elements that some people will like will not please others (Harviainen, 2014), for example, competition or interaction with other people. That is because gamification lacks the ability to adapt because the target audience is too broad and, thus, the game is incapable of meeting everyone's needs and desires (Harviainen, 2014; Vassileva, 2012).

Each game has elements that can be applied to gamification as well:

(1) A goal, an objective to achieve
(2) Game activity, which refers to the fact that the game is an activity, a process and an event that the player is doing something
(3) Game rules, which means that there are some rules that need to be followed, as a game is rule-based
(4) Outcome(s), which refers to a numerical score and particular game actions that result in gaining or losing, for example, points or virtual money
(5) Conflict or competition, which means that there is some kind of contest, either with the system or with other players, or even with game players themselves, in aiming to improve scores (Huizenga, ten Dam, Voogt, & Admiraal, 2017, p. 106)

2.2 Serious Games

There are two categories of games used to educate and to train. One is gamification, and the other, which is very similar to gamification, is called serious games, also known as learning games, games to learn, educational games, etc. Serious games have been known for a longer time than gamification and have been explored more.

The goal of both the serious games and the gamification is the learning outcomes, but the process is different. Participants of gamification are not directly affected by learning and knowledge. The purpose of gamification is to change the participant's behaviour or attitude and, thus, to affect their learning outcomes (Landers, 2014). But "the primary goal of a serious game is education (in its many forms), rather than entertainment" (Michael & Chen, 2006, p. 17). Game elements are used for serious purposes like education, health, etc., with instructions. Studies show that serious games are more effective in achieving goals, which might include developing cognitive abilities and knowledge (Huizenga et al., 2017).

Serious games incorporate all game elements, but to varying degrees. The term elements allows us to distinguish gamification from serious games (Deterding et al., 2011), because gamification uses only game elements, while serious games are associated with fully developed games serving a specific, non-entertainment purpose (Sailer et al., 2017). Serious games are designed to train, for stimulation, and to educate in virtual environments with previously defined learning objectives.

Serious games are used to practise, train and provide solutions (Karagiorgas & Niemann, 2017; Landers, 2014).

It should be noted that for gamification, game elements can be used in non-game contexts without the use of technologies. But, if taking into acount the latest technological advancements and the fact that an integral part of everyday life for new generation are mobile phones, computers, tablets and other platforms, gamification mostly is associated with technologies and digital game elements.

"A digital educational game is a game created for the purpose of teaching a subject in the form of software that runs on a computer" (Aslan & Balci, 2015, p. 307). Media and technologies that can be used in game-based learning, gamification and serious games are computers and video games, Internet links, multimedia networks, mobile phones, tablets, etc. In military training, medical training, as well as aviation industry, simulation technology is used in the training process (Chaudhary, 2010). Digital educational games are very versatile and are adaptable to the learning of almost any topic, information or skill (Prensky, 2007).

Using technologies is helping students develop the skills they need in today's digital age, supports individual and collective learning and provides easy access to various materials. Using multimedia brings interest and passion to the learning process. Such a learning process is mobile and also offers out-of-class learning (Shamir-Inbal & Blau, 2016).

3 Research Methodology

The aim of this research is to review current publications about gamification thus exploring the concept of gamification in the context of education. To see what has been done, what has been researched and in which areas research is being carried, the systematic analysis of publications was chosen as the research method. Scopus and SAGE Publications databases were chosen as the source of publications. To select the required articles, the keyword "gamification" was used. The language that was chosen for the publications was English.

Articles were arranged by publication year, research areas, longitude, research methodology and keywords used in the article.

During the research, 91 articles were selected for review.

4 Findings

As mentioned before, 91 articles were selected for review via a systematic analysis of articles published since 2012.

Many authors see the potential of gamification as an innovative approach that can be applied to variety of fields. According to reviewed publications, the contexts in

Table 1 Subject areas of publications about gamification

Subject area	Author
Education	Harviainen (2014), Huizenga et al. (2017), Karagiorgas and Niemann (2017), Kim and Lee (2015), Monterrat, Lavoué, & George, 2017, Barwick, Watkins, Kirk, & Law, (2016), Landers (2014), Landers and Armstrong (2017), Aslan & Balci, (2015), Doherty et al. (2017), etc.
Science	Tinati, Luczak-Roesch, Simperl, and Hall (2017), Tsai (2018)
Medicine and health care	Giuntia et al. (2018), Miller et al. (2016), Willoughby and Smith (2016), Orwoll and Diane (2017), etc.
Business	Surendro and Raflesia (2016), Veltsos (2017), Korn and Schmidt (2015), Dale (2014), Klabber (2018), etc.
Politics	Eränpalo (2014), Hassan (2017)
Social campaigns	Estacio et al. (2018), Willoughby and Smith (2016), De-Marcos, García-López, and García-Cabot (2017), etc.
Media and journalism	Viana and Pinto (2017), Sprinkle and Urick (2016), Larsen (2017), Ferrer-Conill (2017), etc.

which gamification has been implemented are education, science, medicine and health care, business, politics, social campaigns, media and journalism (see Table 1).

The study of the publications revealed that, in 2012, there were only two publications about gamification (see Chart 1). Both were theoretical articles about participants' motivation (Hwang, Wu, & Chen, 2012) and improving students learning performances (Vassileva, 2012).

But since 2013 the number of articles has increased progressively. As the Chart 2 shows, in 2017, there was the (as yet) largest number of publications and research about gamification published by the "Scopus" and "SAGE Publications" databases.

All 91 articles retrieved from the databases were arranged by subject areas (see Chart 2). Since 2012, 36% of the published articles were theoretical, trying to understand and explain this new phenomenon, as well as reviewing other articles

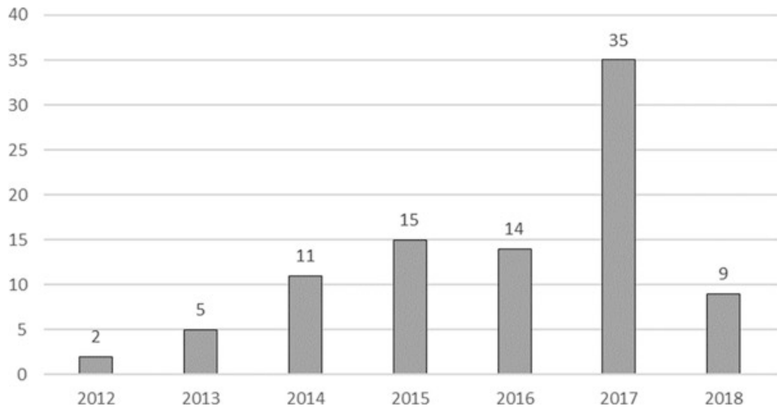

Chart 1 Publications about gamification since 2012

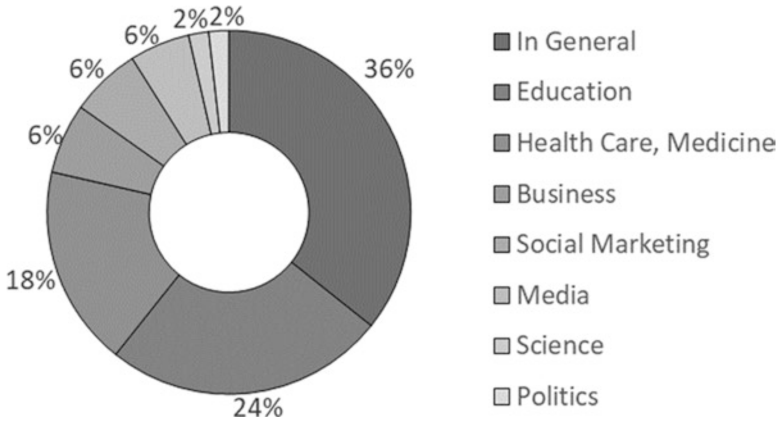

Chart 2 Publications since 2012: subject areas

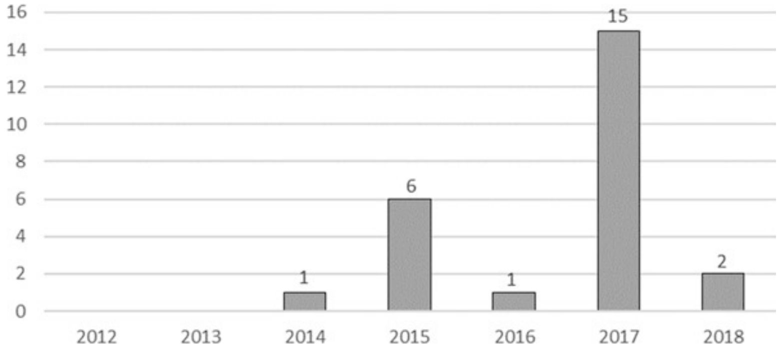

Chart 3 Publications about gamification in education since 2012

and research. Twenty-four percent of the reviewed articles were about gamification in the context of education and 18% about health care and medicine. Six percent were about business and about social marketing and 6% related to media. Two percent referred to science and gamification in the context of politics.

The publication analysis revealed that educational researchers began to explore the new concept of gamification in 2014 (see Chart 3). The first article was called “Critical Challenges to Gamifying Education: A Review of Central Concepts” by J. T Harviainen. In 2015 there was an acceleration of publications about gamification in education. But research data shows that the largest number occurred in 2017, with 15 publications about gamification in education being obtained for that year from the “Scopus” and “SAGE Publications” databases (see Chart 3).

In the context of education, there have been 25 publications about gamification since 2014.

From these 25 publications about education, 9 articles were theoretical, reviewing other articles about current research and the application of gamification in the learning process (Barneva, Kanev, Kapralos, Jenkins, & Brimkov, 2017; Dichev & Dichev, 2017; Doherty et al., 2017; Harviainen, 2014; Karagiorgas and Niemann, 2017; Kim, 2015; Markopoulos, Fragkou, Kasidiaris, & Davim, 2015), offering datasets from research about experiments implementing gamification in online learning (Tenório et al., 2017) and on the learning performance of digital skill (De-Marcos et al., 2017).

The other 16 articles were research into the implementation of gamification in the learning process. From all the publications about gamification in the education context, eight articles could be described as longitudinal.

In 2015, the research about gamification in education was as follows: (1) an article about testing of the game platform for music gestural skills development in order to engage teachers, learners and expert performers (Volioti et al., 2015); (2) an experiment using the Microsoft Kinect sensor to develop and evaluate a game-based learning system (Tsai, 2018); (3) a survey of Japanese students' perception of digital game use for English learning in higher education (Bolliger, Mills, White, & Kohyama, 2015); and (4) an observation that showed the promise of technologies in terms of students' engagement in the classroom and technological skills development in school in South Africa (Conger, Krauss, & Simuja, 2015).

Only one article was published in 2016, and it was about the use of a specially designed game as a data-collecting tool, where the game, developed using participatory design techniques, was used as a means to investigate children's perceptions in their everyday lives. The participant children played this particular game in the classroom for 1 year (Barwick, Watkins, Kirk, & Law, 2016). It must be noted that the purpose of this research was not connected with learning outcomes; however, it is an example of how students can be engaged and motivated to participate in the classroom (or, as in this case, in particular activity) by game design elements without knowing the real goal set by the researchers.

In 2017, the research about gamification in education was as follows: (1) a study of the gaming features that can be adapted to learning environments and the player model that could be used for the adaptation process (Monterrat, Lavoué, & George, 2017); (2) a study, based on a theoretical framework, of a gamified training module with game fiction designed in order to improve outcomes over the original training (Landers & Armstrong, 2017); (3) a study to develop a game-based learning judgement system of online educational environments (Jo, Yu, Koh, & Lim, 2017); (4) a research about the application of gamification within the learning process of children with dyslexia (Vasalou, Khaled, Holmes, & Gooch, 2017); (5) an article about social gamification and microlearning for the engagement of nurses (Orwoll & Diane, 2017); (6) an article about the use of game design elements to increase student engagement, motivation and autonomy in a business communication course (Veltsos, 2017); (7) a research aiming to examine the ability of gamified modules in a statistics course to have positive impacts on both learning and attitudes towards statistics (Smith, 2017); (8) a research trying to prove that a learning environment created with meaningful gamification elements can improve student perceptions of learning (Stansburty & Earnest, 2017); and (9) a study about teachers' perceptions of the usefulness of application of digital games in education (Huizenga et al., 2017).

Two articles were published in 2018: (1) a case study about game-based learning in mechanical engineering education (Mavromihales, Holmes, & Racasan, 2018) and (2) a research about gameful learning environments to support student autonomy and promote engagement (Aguilar, Holman, & Fishman, 2018).

5 Conclusions

Taking into account that the concept of gamification is relatively new and that studies only began about 4 years ago, it is not yet possible to fully understand the concept's effect on the educational process. Many researches are trying to answer questions like what is gamification? Does it have positive impact on the learning process? Does it motivate or engage students? Does it change attitudes? And so on. There are still many questions about gamification and too little in the way of researches that gives comprehensive insight.

Previous studies conclude that "attitudes are an important factor related to learning statistics that were changed positively after having the gamified instruction and long-term knowledge gains resulted" (Smith, 2017, p. 850) and that "the gamified modules were successful in shifting students' attitudes in a positive direction and subsequently increasing performance" (Smith, 2017, p. 832).

Results showed that "increasing the number of gaming features of an environment also increases its perceived complexity, so only a few features should be proposed to the learners" (Monterrat et al., 2017, p. 651).

Also, a study revealed the function of gamification in enhancing a child's self-esteem, where the game becomes a forum for rehearsing game-state failures and successes (Vasalou et al., 2017).

There was also a case when gamification "did not improve learners' engagement as expected" (Monterrat et al., 2017, p. 265), but it must be noted that the previous research shows a path for future study towards the implementation of gamification as an approach to the learning process.

This new, innovative platform and learning methodology have the potential to maximise learning not only for children but also for adults in various fields (Chaudhary, 2010).

The theory of learning via a digital educational game is suitable for modern, high-tech children and young people living in global world (Aslan & Balci, 2015). Digital education-based learning and gamification meet the needs and learning styles of today's generation, as well as those of the future, and are very effective if used wisely. Games are motivating because they are fun (Prensky, 2007).

As mentioned, gamification provides new possibilities of learning for children and adults. But, to implement the approach of gamification, teachers need to develop digital competence and master the principles of gamification.

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